Maxwell
of
Kirkconnell

SUPPLEMENT

TO THE THIRD EDITION OF THE

ENCYCLOPÆDIA BRITANNICA,

OR, A

DICTIONARY

OF

ARTS, SCIENCES,

AND

MISCELLANEOUS LITERATURE.

IN TWO VOLUMES.

Illuſtrated with Fifty Copperplates.

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

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

VOL. I.

THE SECOND EDITION, WITH IMPROVEMENTS.

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TO THE KING.

SIR,

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

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

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

SIR,

YOUR MAJESTY'S

Most faithful Subject,

And most devoted Servant,

STIRLING,
Dec. 10. 1800.

GEORGE GLEIG.

SUPPLEMENT

TO THE

ENCYCLOPÆDIA BRITANNICA.

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

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

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

ABERRATION, in optics (in Encycl.), refers the reader to the article Optics, nº 17, 136, 173. It ſhould have referred him to Optics, nº 17, and 251—256.

Aberration of the Viſual Ray, is a phenomenon, of which, though ſome account of it has been given in the Encyclopædia (ſee Aberration, in aſtronomy; and the article Astronomy, nº 337.), one of the moſt candid of our correſpondents requires a fuller explanation. If ſuch an explanation be requiſite to him, it muſt be much more ſo to many others; and we know not where to find, or how to deviſe, one which would be more ſatisfactory, or more familiar, than the following by Dr Hutton.

"This effect (ſays he) may be explained and familiarized by the motion of a line parallel to itſelf, much after the manner that the compoſition and reſolution of forces are explained. If light have a progreſſive motion, let the proportion of its velocity to that of the earth in her orbit be as the line BC to the line AC; then, by the compoſition of theſe two motions, the particle of light will ſeem to deſcribe the line BA or DC, inſtead of its real courſe BC; and will appear in the direction AB or CD, inſtead of its true direction CB. So that if AB repreſent a tube, carried with a parallel motion by an obſerver along the line AC, in the time that a particle of light would move over the ſpace BC, the different places of the tube being AB, *ab*, *cd*, CD; and when the eye, or end of the tube, is at A, let a particle of light enter the other end at B; then when the tube is at *ab*, the particle of light will be at *e* exactly in the axis of the tube; and when the tube is at *cd*, the particle of light will arrive at *f*, ſtill in the axis of the tube; and, laſtly, when the tube arrives at CD, the particle of light will arrive at the eye or point C, and conſequently will appear to come in the direction DC of the tube, inſtead of the true direction BC: and ſo on, one particle ſucceeding another, and forming a continued ſtream or ray of light in the apparent direction DC. So that the apparent angle made by the ray of light with the line AE is the angle DCE, inſtead of the true angle BCE; and the difference BCD, or ABC, is the quantity of the aberration."

Plate II. fig. 1.

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

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

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

Plate II.

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

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

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

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

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

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

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

It is the opinion of Dr Reid, and we have adopted it (ſee METAPHYSICS, nº 109, &c. Encycl.), that no being can be an *agent*, or perform an *action*, in the proper ſenſe of the word, which does not poſſeſs, in ſome degree, the powers of will and underſtanding. If this opinion be juſt, it is obvious, that what are called the powers of nature, ſuch as *impulſe*, *attraction*, *repulſion*, *elaſticity*, &c. are not, ſtrictly ſpeaking, *powers* or *cauſes*, but the effects of the agency of ſome active and intelligent being; and that *phyſical cauſes*, to make uſe of common language, are nothing more than *laws* or *rules*, according to which the *agent* produces the effect.

This doctrine has been controverted by a writer whoſe acuteneſs is equalled only by his virtues; and we ſhall conſider ſome of his objections to it in another place (ſee CAUSE): but a queſtion of a different kind falls under our preſent conſideration; and perhaps the anſwer which we muſt give to it, may go far to remove the objections to which we allude.

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

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

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

What thoſe agents are, we pretend not to ſay. If the Supreme Being himſelf be the immediate author of every change which takes place in the corporeal world, it is obvious that he acts by fixed rules, of which many are apparent to the moſt heedleſs obſerver, whilſt the diſcovery of others is reſerved for the reward of the judicious application of the faculties which he has given us. If he employs inferior agents to carry on the great operations of nature, it is ſurely not difficult to conceive that the powers of thoſe agents which were derived from him, may by him be reſtrained within certain limits, and their exerciſe regulated by determined laws, in ſuch a manner as to make them produce the greateſt benefit to the whole creation. Nor let it be thought an objection to this theory, that the changes which take place among bodies at great diſtances from each other, vary both in degree and in kind according to the diſtances; for this variation, which we acknowledge to be a fact, appears to us wholly unaccountable upon any other hypotheſis than that which attributes the different changes to agents diſtinct from the bodies themſelves. Did we perceive all the particles of matter, at all diſtances, tending towards each other by a fixed law, we might be led to conſider mutual attraction as an *eſſential* property of that ſubſtance, and think no more of inquiring into its cauſe, than we think of inquiring into the cauſe of extenſion. But when we find that the ſame particles, which at one diſtance ſeem to attract each other, are at a different diſtance kept aſunder by a power of repulſion, which no force, with which we are acquainted, is able to overcome, we cannot attribute the *principle* or *cauſe* of theſe changes to brute matter, but muſt refer it to ſome other agent exerting power according to a fixed law.

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

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

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

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

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

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

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

The hiſtory, from which this abſtract is taken, gives a long and unintereſting detail of the exploits of the Afghans, and of their zeal in overthrowing the temples of idols. It boaſts of the following monarchs of their race who have ſat upon the throne of *Dehli*: Sultan BEHLOLE, *Afghan* LODI, Sultan SECANDER, Sultan IRBAHIM, SHIR SHAH, ISLAM SHAH, ADIL SHAH SUR. It alſo numbers the following kings of *Gaur* deſcended of the Afghan chiefs: SOLAIMAN *Shah Gurzani*, BEYAZID *Shah*, and KUTB *Shah*; beſides whom, their nation, we are told, has produced many conquerors of provinces. The Afghans are ſometimes called *Solaimani*, either becauſe they were formerly the ſubjects of SOLOMON king of Iſrael, or becauſe they inhabit the mountains of Solomon. They are likewiſe called PATANS, a name derived from the *Hindi* verb *Paitna* "to ruſh," which was given to them by one of the Sultans whom they ſerved, in conſequence of the alacrity with which they had attacked and conquered his enemies. The province which they occupy at preſent was formerly called *Roh*; and hence is derived the name of the *Rohillas*. The city which was eſtabliſhed in it by the *Afghans* was called by them *Paiſhwer* or *Paiſher*, and is now the name of the whole diſtrict. The ſects of the Afghans are very numerous; of which the principal are, *Lodi*, *Lohouni*, *Sur*, *Serwani*, *Yuſufzihi*, *Bangiſh*, *Dilazaui*, *Khetti*, *Yaſin*, *Kail*, and *Beloje*. They are *Muſulmans*, partly of the *Sunni*, and partly of the *Shiek* perſuaſion.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Under the auſpices of Almamon alſo a degree of the meridian was meaſured on the plains of Sinjar or Sindgiar (or, according to ſome, Fingar), upon the borders of the Red Sea; by which the degree was found to contain 56⅔ miles, of 4000 coudees each, the coudee being a foot and a half: but it is not known what foot is here meant, whether the Roman, the Alexandrian, or ſome other. Riccioli makes this meaſure of the degree amount to 81 ancient Roman miles, which value anſwers to 62,046 French toiſes; a quantity more than the true value of the degree by almoſt one-third. Finally, Almamon revived the ſciences in the Eaſt to ſuch a degree, that many learned men were found, not only in his own time, but after him, in a country where the ſtudy of the ſciences had been long forgotten. This learned king died near Tarſus in Cilicia, by having eaten too freely of ſome dates, on his return from a military expedition, in the year 833.

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

ſufficient

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

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

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

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

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

ALTERNATE ANGLES. See GEOMETRY (*Encycl.*), Part I. 35.

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

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

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

ltitude,
Alum.

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

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

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

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

Alum.

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

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

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

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

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

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

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

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

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

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

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

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

There is likewiſe a pure ſulphat of alumine, very aſtringent, very difficult of cryſtallization, in the form of brilliant pearl-coloured plates without conſiſtence, and which cannot be rendered inſoluble by the addition of a new quantity of its baſe. This laſt ſalt may with the greateſt propriety be called the ſulphat of alumine.

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

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

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

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

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

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

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

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

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

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

Dr Gillan, who was appointed phyſician to the embaſſy, as well for his knowledge of chemiſtry as for his medical ſkill, is confident that the iſland of Amſterdam is the product of ſubterraneous fire, as it bears in every part of it evident marks of volcanic eruption. "On the weſt and ſouth-weſt ſides (ſays he) there are four ſmall cones regularly formed, with craters in their centres, in which the lava and other volcanic ſubſtances have every appearance of recent formation. The heat continues ſtill ſo great, and ſuch a quantity of elaſtic vapours iſſues through numberleſs crevices, that there can be no doubt of their having been very lately in a ſtate of eruption. In a thermometer placed upon the ſurface, the quickſilver roſe conſtantly to 180 degrees, and when ſunk a little into the aſhes, it advanced to 212 degrees. It certainly would have riſen ſtill higher; but the ſcale being graduated only to the point of boiling water, and the length of the tube proportioned to that extent, the thermometer was immediately withdrawn, leſt the increaſing expanſion of the quickſilver ſhould burſt the glaſs. The ground was felt tremulous under the feet; a ſtone thrown violently upon it returned a hollow ſound; and the heat was ſo intenſe for a conſiderable diſtance around, that the foot could not be kept for a quarter of a minute in the ſame poſition without being ſcorched. But the great crater on the eaſtern ſide, now full of water, is by far the largeſt here, or perhaps elſewhere, and is of an aſtoniſhing ſize, conſiderably exceeding in diameter thoſe of Etna or Veſuvius. The quantity of matter to be thrown up, which required ſo wide an orifice for its paſſage, and the force with which ſuch matter was impelled, in order to overcome the reſiſtance of the ſuperincumbent earth and ſea, muſt have been indeed prodigious.

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

"The ſoil everywhere being light and ſpongy, and full of holes, formed in it by ſea-birds for neſts, is very troubleſome to walk upon; the foot breaks through the ſurface, and ſinks deep at every ſtep; a circumſtance which renders the journey acroſs the iſland uncommonly fatiguing, although it be ſcarcely three miles from the edge of the great crater to the oppoſite weſt ſide. There is one place near the centre of the iſland, extending about 200 yards in length, and ſomewhat leſs in breadth, where particular caution is neceſſary in walking over it. From this ſpot a hot freſh ſpring is ſuppoſed to derive its ſource, finding its way through the interſtices of the lava to the great crater, and burſting out a little above the water covering its bottom. The heat in this upper ſpot is too great to admit of vegetation. The ſurface is covered with a kind of mud or paſte formed from the aſhes, moiſtened by ſteam conſtantly riſing from below. When the mud is removed, the vapour iſſues forth with violence, and in ſome parts copiouſly. This mud is ſo hot, that a gentleman who inadvertently ſtepped into it had his foot ſeverely ſcalded by it. The ſame cauſes which have prevented vegetation on this ſpot, have had the ſame effect on the four cones recently thrown up. Their ſurfaces are covered with aſhes only; nor is there the leaſt appearance even of moſs on the ſurrounding lava, for the production of which there does not appear to have elapſed a ſufficient length of time ſince the cones were formed: but this is not the caſe with the lava of the great primary crater; for in thoſe parts of it where the edges are more perpendicular, and where conſequently the mouldering decompoſed earth, having no baſis to ſupport it, ſlides down the ſides of the rock, pretty long moſs was generally found growing upon it. All the ſprings or reſervoirs of hot water, except one only, were brackiſh. One ſpring derives its ſource from the high ground and ridges of the crater. The water in it, inſtead of boiling upwards through the ſtones and mud, as in the other ſprings, flows downward with a conſiderable velocity, in a ſmall collected ſtream. Its temperature has been found not to exceed 112 degrees. The hand could be eaſily kept in it for a conſiderable time. It is a pretty ſtrong chalybeate. The ſides of the rock whence it iſſues, and of the cavity into which it falls, are incruſted with ochre depoſited from it.

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

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

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

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

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

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

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

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

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

ANACLASTIC curves, a name given by M. de Mairan to certain apparent curves formed at the bottom of a veſſel full of water, to an eye placed in the air; or the vault of the heavens, ſeen by refraction through the atmoſphere.

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

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

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

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

ANDERSON (Alexander), an eminent mathematician, was born at Aberdeen towards the end of the 16th century. Where he was educated, or under what maſters, we have not learned; probably he ſtudied the belles lettres and philoſophy in the univerſity of his native city, and, as was the practice in that age of all who could afford it, went afterwards abroad for the cultivation of other branches of ſcience. But wherever he may have ſtudied, his progreſs in ſcience muſt have been rapid; for, early in the 17th century, we find him profeſſor of mathematics in the univerſity of Paris, where he publiſhed ſeveral ingenious works; and among others, 1. *Supplementum Apollonii Redivivi; ſive analyſis problematis hactenus deſiderati ad Apollonii Pergæi doctrinam* ϖερι νευϛιων, *a Marino Ghetaldo Patritio Raguſino hujuſque, non ita pridem reſtitutam. In qua exhibetur mechanice æqualitatum tertii gradus ſive ſolidarum, in quibus magnitudo omnino data, æquatur homogeneæ ſub altero tantum coefficiente ignoto. Huic ſubnexa eſt variorum problematum practice,* Paris, 1612, in 4to.—2. Αιτιολογια: *Pro Zetetico Apolloniani problematis a ſe jam pridem edito in* *ſupplemento Apollonii Redivivi. Ad clariſſimum et ornatiſſimum virum Marinum Ghetaldum Patritium Raguſinum. In qua ad ea quæ obiter mihi perſtrinxit Ghetaldus reſpondetur, et analytices clarius detegitur.* Paris, 1615, in 4to.—3. *Franciſci Vietæ Fontenacenſis de Æquationum Recognitione et Emendatione Tractatus duo*, with a dedication, preface, and appendix, by himſelf. Paris, 1615, in 4to.—4. Vieta's *Angulares Sectiones;* to which he added demonſtrations of his own. Our profeſſor was couſin-german to Mr David Anderſon of Finſhaugh, a gentleman who alſo poſſeſſed a ſingular turn for mathematical knowledge. This mathematical genius was hereditary in the family of the Anderſons; and from them it ſeems to have been tranſmitted to their deſcendants of the name of Gregory, who have for ſo many generations been eminent in Scotland as profeſſors either of mathematics, or, more lately, of the theory and practice of phyſic. The daughter of the David Anderſon juſt mentioned, was the mother of the celebrated James Gregory, inventor of the reflecting teleſcope; and obſerving in her ſon, while yet a child, a ſtrong propenſity to mathematical ſtudies, ſhe inſtructed him in the elements of that ſcience herſelf. From the ſame lady deſcended the late Dr Reid of Glaſgow, who was not leſs eminent for his knowledge of mathematics than for his writings as a metaphyſician.

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

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

Plate III.

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

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

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

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

ANTECEDENTAL CALCULUS. See CALCULUS in this Supplement.

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

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

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

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

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

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

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

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

The firſt thing to be attended to is, to ſet the horizon-glaſs perpendicular to the plane of the inſtrument, which is performed as follows: Hold the inſtrument with its plane perpendicular to the horizon, and look over backwards into the glaſs and beyond it. If the limb of the inſtrument appears in a right line with its reflection, the glaſs is upright; but if it does not appear ſo, looſen or tighten the little ſcrew on the foot of the glaſs until it be adjuſted: Then with the inſtrument, as in taking an altitude, look through the ſight vane or teleſcope at ſome diſtant object, with the index fixed in any intended ſituation; the two ſcrews at the upper centre being looſe, turn the glaſs about till the ſame object appears nearly in the ſame part of the horizon-glaſs: Next hold it in a horizontal poſition, and adjuſt the object-glaſs or large ſpeculum with the ſcrews which are behind and before, on the foot of it, till the object and its reflection are ſeen in the ſame horizontal line. Laſtly, with the inſtrument upright, turn the tangent-ſcrew belonging to the horizon-glaſs at the back of the inſtrument, until there be a perfect coincidence of the object and its reflection that way, and the adjuſtments are complete.

ANTIPARALLELS, in geometry, are thoſe lines which make equal angles with two other lines, but contrariwiſe; that is, calling the former pair the firſt and ſecond lines, and the latter pair the third and fourth lines, if the angle made by the firſt and third lines be equal to the angle made by the ſecond and fourth, and contrariwiſe the angle made by the firſt and fourth equal to the angle made by the ſecond and third; then each pair of lines are antiparallels with reſpect to each other, viz. the firſt and ſecond, and the third and fourth. So, if AB and AC be any two lines, Plate II. fig. 5. and FC and FE be two others, cutting them ſo,

that the angle B is equal to the angle E,
and the angle C is equal to the angle D;

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

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

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

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

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

the irregularity of its refractions. Hence, in viewing Venus through a teleſcope, a much leſs aperture is to be uſed than for the moon, or Jupiter, or Saturn, becauſe her light is ſo bright and glaring. And this circumſtance ſomewhat invalidates and diſturbs Azout's proportion, as is ſhown by Dr Hook, Phil. Tranſ. N° 4."

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

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

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

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

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

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

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

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

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

1 Arch defined.

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

2 Hiſtory of architecture connected with arches.

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

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

3 Origin of Greek architecture

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

4 Egyptian

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

5 Arabian, and

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

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

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

Plate I. 7 Origin of he arch. The pediment of the Greeks ſeems to have ſuggeſted the greateſt improvement in the art of building. In erecting their ſmall houſes, they could hardly fail to obſerve occaſionally, that when two rafters were laid together, from the oppoſite walls, they would, by leaning on each other, give mutual ſupport, as in fig. 1. Nor is it unlikely that ſuch a ſituation of ſtones as is repreſented in fig. 2. would not unfrequently occur by accident to maſons. This could hardly fail of exciting a little attention and reflection. It was a pretty obvious reflection, that the ſtones A and C, by overhanging, leaned againſt the intermediate ſtone B, and gave it ſome ſupport, and that B cannot get down without thruſting aſide A and C, or the piers which ſupport them. This was an approach to the theory of an arch; and if this be combined with the obſervation of fig. 1. we get the diſpoſition repreſented in fig. 3. having a perpendicular joint in the middle, and the *principle of the arch* is completed. Obſerve that this is quite different from the principle of the arrangement in fig. 2. In that figure the ſtones act as wedges, and one cannot get down without thruſting the reſt aſide; the ſame principle obtains in fig. 4. conſiſting of five arch ſtones; but in fig. 3. the ſtones B and C ſupport each other by their mutual preſſure (independent of their own weight), ariſing from the tendency of each lateral pair to fall outwards from the pier. This is the principle of the arch, and would ſupport the key-ſtone of fig. 4. although each of its joints were perpendicular, by reaſon of the great friction ariſing from the horizontal thruſt exerted by the adjoining ſtones.

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

8 recian. We are diſpoſed to give the Greeks the merit of this diſcovery; for we obſerve arches in the moſt ancient buildings of Greece, ſuch as the temple of the ſun at Athens, and of Apollo at Didymos; not indeed as roofs to any apartment, nor as parts of the ornamental deſign, but concealed in the walls, covering drains or other neceſſary openings; and we have not found any *real* arches in any monuments of ancient Perſia or Egypt. Sir John Chardin ſpeaks of numerous and extenſive ſubterranean paſſages at Tchilminar, built of the moſt exquiſite maſonry, the joints ſo exact, and the ſtones ſo beautifully dreſſed, that they look like one continued piece of poliſhed marble: but he nowhere ſays that they are arched; a circumſtance which we think he would not have omitted—no arched door or window is to be ſeen. Indeed one of the tombs is ſaid to be arch-roofed, but it is all of one ſolid rock. No trace of an arch is to be ſeen in the ruins of ancient Egypt; even a wide room is covered with a ſingle block of ſtone. In the pyramids, indeed, there are two galleries, whoſe roofs conſiſt of many pieces; but their conſtruction puts it beyond doubt that the builder did not know what an arch was: for it is covered in the manner repreſented in fig. 5. where every projecting piece is more than balanced behind, ſo that the whole awkward maſs could have ſtood on two pillars. The Greeks therefore ſeem entitled to the honour of the invention. The arched dome, however, ſeems to have ariſen in Etruria, and originated in all probability from the employment of the augurs, whoſe buſineſs it was to obſerve the flight of birds. Their ſtations for this purpoſe were *templa*, ſo called *a templando*, "on the ſummits of hills." To ſhelter ſuch a perſon from the weather, and at the ſame time allow him a full proſpect of the country around him, no building was ſo proper as a dome ſet on columns; which accordingly is the figure of a temple in the moſt ancient monuments of that country. We do not recollect a building of this kind in Greece except that called the *Lanthern of Demoſthenes*, which is of very late date, whereas they abounded in Italy. In the later monuments and coins of Italy or of Rome, we commonly find the Etruſcan dome and the Grecian temple combined; and the famous pantheon was of this form, even in its moſt ancient ſtate.

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

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

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

11
Skill and myſteries of the Dionyſiacs.

12
The art of building arches underſtood in the middle ages

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

13
Better than by the Greeks and Romans.

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

14
Defects of the church of St Sophia at Conſtantinople.

Anthemius and Iſidorus, whom the Emperor Juſtinian had ſelected as the moſt eminent architects of Greece for building the celebrated church of St Sophia at Conſtantinople, ſeem to have known very little of this matter. Anthemius had boaſted to Juſtinian, that he would outdo the magnificence of the Roman pantheon, for he would hang a greater dome than it aloft in the air. Accordingly he attempted to raiſe it on the heads of four piers, diſtant from each other about 115 feet, and about the ſame height. He had probably ſeen the magnificent vaultings of the temple of Mars the Avenger, and the temple of Peace at Rome, the thruſts of which are withſtood by two maſſes of ſolid wall, which join the ſide walls of the temple at right angles, and extend ſidewiſe to a great diſtance. It was evident that the walls of the temple could not yield to the preſſure of the vaulting without puſhing theſe immenſe buttreſſes along their foundations. He therefore placed four buttreſſes to aid his piers. They are almoſt ſolid maſſes of ſtone, extending at leaſt 90 feet from the piers to the north and to the ſouth, forming as it were the ſide walls of the croſs. They effectually ſecured them from the thruſts of the two great arches of the nave which ſupport the dome; but there was no ſuch proviſion againſt the puſh of the great north and ſouth arches. Anthemius truſted for this to the half dome, which covered the ſemicircular eaſt end of the church, and occupied the whole eaſtern arch of the great dome. But when the dome was finiſhed, and had ſtood a few months, it puſhed the two eaſtern piers with their buttreſſes from the perpendicular, making them lean to the eaſtward, and the dome and half dome fell in. Iſidorus, who ſucceeded to the charge on the death of Anthemius, ſtrengthened the piers on the eaſt ſide, by filling up ſome hollows, and again raiſed the dome. But things gave way before it was cloſed; and while they were building in one part it was falling in in another. The pillars and walls of the eaſtern ſemicircular end were much ſhattered by this time. Iſidorus ſeeing that they could give no reſiſtance to the puſh which was ſo evidently directed that way, erected ſome clumſy buttreſſes on the eaſt wall of the ſquare which ſurrounded the whole Greek croſs, and was roofed in with it, forming a ſort of cloiſter round the whole. Theſe buttreſſes, ſpanning over this cloiſter, leaned againſt the piers of the dome, and thus oppoſed the thruſts of the great north and ſouth arches. The dome was now turned for the third time, and many contrivances were adopted for making it extremely light. It was made offenſively flat; and, except the ribs, it was roofed with pumice ſtone; but, notwithſtanding theſe precautions, the arches ſettled ſo as to alarm the architects, and they made all ſure by filling up the whole from top to bottom with arcades in three ſtories. The loweſt arcade was very lofty, ſupported by four noble marble columns, and thus preſerved, in ſome meaſure, the church in the form of a Greek croſs. The ſtory above formed a gallery for the women, and had ſix columns in front, ſo that they did not bear fair on thoſe below. The third ſtory was a dead wall filling up the arch, and pierced with three rows of ſmall ill-ſhaped windows. In this unworkmanlike ſhape it has ſtood till now, and is the oldeſt church in the world; but it is an ugly miſhapen maſs, more reſembling an overgrown potter's kiln, ſurrounded with furnaces pieced and patched, than a magnificent temple. We have been thus particular in our account of it, becauſe this hiſtory of the building ſhows that the ancient architects had acquired no diſtinct notions of the action of arches. Almoſt any maſon of our time would know, that as the ſouth arch would puſh the pier to the eaſtward, while the eaſt arch puſhed it to the ſouthward, the buttreſs which was to withſtand theſe thruſts muſt not be placed on the ſouth ſide of the pier, but on the ſouth-eaſt ſide, or that there muſt be an eaſtern as well as a ſouthern buttreſs. No ſuch blunders are to be ſeen

15
Such as ar
never foun
in a Gothi
church.

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

16 Dr Hooke's principle of arches

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

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

17 Explained,

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

But if we ſuppoſe planes de, fg, hi, &c. drawn, that the points of mutual contact a, b, c, each biſecting the angle formed by the lines that unite the adjoining contacts (fg, for example, biſecting the angle formed by ab, bc), and if we ſuppoſe that the pieces are changed for others of the ſame weights, but having flat ſides, which meet in the planes de, fg, hi, &c. it is evident that we ſhall have an arch of equilibration, and that the arch will have ſome ſtability, or will bear a little change of form without tumbling down: for it is plain that the equilibrium of the original feſtoon obtained only in the points a, b, c, of contact, where the preſſures were perpendicular to the touching ſurfaces; therefore if the curve a, b, c, ſtill paſſes through the touching ſurfaces perpendicularly, the conditions that are required for equilibrium ſtill obtain. The caſe is quite ſimilar to that of the ſtability of a body reſting on a horizontal plane. If the perpendicular through the centre of gravity falls within the baſe of the body, it will not only ſtand, but will require ſome force to puſh it over. In the original feſtoon, if a ſmall weight be added in any part, it will change the form of the curve of equilibration a little, by changing the points of mutual contact. This new curve will gradually ſeparate from the former curve as it recedes from A or C. In like manner, when the feſtoon is ſet up as an arch, if a ſmall weight be laid on any part of it, it will bring the whole to the ground, becauſe the ſhifting of the points of contact will be juſt the contrary to what it ſhould be to ſuit the new curve of equilibration. But if the ſame weight be laid on the ſame part of the arch now conſtructed with flat joints, it will be ſuſtained, if the new curve of equilibration ſtill paſſes through the touching ſurfaces.

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

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

18 And applied.

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

It is plain that this proceſs will produce an arch of perfect equilibration; but ſome farther conſiderations are neceſſary for making it exactly ſuit our purpoſe. It is an arch of equilibration for a bridge, that is ſo loaded that the weight of the arch-ſtones is to the weight of the matter with which the haunches and crown are loaded, as the weight of the chain AfB is to the ſum of the weights of all the little bits of chain very nearly. But this proportion is not known beforehand; we muſt therefore proceed in the following manner: Adapt to the curve produced in this way a thickneſs of the arch-ſtones as great as are thought ſufficient to enſure ſtability ; then compute the weight of the arch ſtones, and the weight of the gravel or rubbiſh with which the haunches are to be filled up to the road-way. If the proportion of theſe two weights be the ſame with the proportion of the weights of chain, we may reſt ſatisfied with the curve now found ; but if different, we can eaſily calculate how much muſt be added equal to, or taken from, each appended bit of chain, in order to make the two proportions equal. Having altered the appended pieces accordingly, we ſhall get a new curve, which may perhaps require a very ſmall trimming of the bits of chain to make them fit the road-way. This curve will be infinitely near to the curve wanted.

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

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

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

20
Theory founded on this principle.

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

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

21
Accommodated to the conſtruction of an arch vault,

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

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

C *b*

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

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

22 And demonſtrated. Becauſe *b*CL, NCF, are right angles, and FCL is common to both, the angles *b*CF and MCL are equal. Therefore the right angled triangles *b*CF and MCL are ſimilar. And ſince CF is equal to CL, *cb* is equal to CM. It is evident that the triangles GCM and *d*CN are ſimilar. Therefore CG : C*d* = CM : CN, = C*b* : CN. Therefore we have $\mathrm{CN} = \frac{\mathrm{C}b \times \mathrm{C}d}{\mathrm{CG}}$. But becauſe CDP and CLG are right angles, and therefore equal, and the angle GCP is common to the two triangles GCL, PCD, and CD is equal to CL, we have CG equal to CP. Therefore $\mathrm{CN} = \frac{\mathrm{C}b \times \mathrm{C}d}{\mathrm{CP}}$. Alſo, ſince CDP is a right angle, DP meets the diameter in Q, the oppoſite point of the circumference, and the angle DQC is equal to DC*d*, or DC*b* (becauſe *b*C*d* is biſected by the tangent), that is, to PCQ (becauſe the right angles *b*CP, *c*DO are equal, and *c*DP is common). Therefore PQ is equal to PC; and if PO be drawn perpendicular to CQ, it will biſect it, and O is the centre of the circle BCDQB.

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

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

This load on every elementary arch of the wall is commonly a quantity of ſolid matter incumbent on that element of the curve, and preſſing it vertically; and it may be conceived as made up of a number of heavy lines ſtanding vertically on it. Thus, if the element E*e* of the curve were lying horizontally, a little parallelogram RE*er* ſtanding perpendicularly on it, would repreſent its load. But as this element E*e* has a ſloping poſition, it is plain that, in order to have the ſame quantity of heavy matter preſſing it vertically, the height of the parallelogram muſt be increaſed till it meets in *ep*, the line R*e* drawn parallel to the tangent EG. It is evident that the angle RE*p* is equal to the angle AEG. Therefore we have ER : E*p* = Rad. : Sec. Elev. Arch,

If therefore the arch is kept in equilibrio by the vertical preſſure of a wall, we muſt have the height of the wall above any point proportional to $\frac{\text{Sec.}^3\ \text{Elev.}}{\text{Rad. of Curv.}}$

Cor. I. If OS be drawn perpendicular to the vertical CS, CS will be half the vertical cord of the equicurve circle. The angle OCS is equal to *c*CF, that is, to the angle of elevation. Therefore 1 : Sec. Elev. = CS : CO, and the ſecant of elevation may be expreſſed by $\frac{\mathrm{CO}}{\mathrm{CS}}$, and its cube by $\frac{\mathrm{CO}^3}{\mathrm{CS}^3}$. Therefore the height of wall is proportional to $\frac{\mathrm{CO}^3}{\mathrm{CS}^3 \times \mathrm{CO}}$, or to $\frac{\mathrm{CO}^2}{\mathrm{CS}^3}$, or $\frac{\mathrm{CO}^2}{\mathrm{CS}^2 \times \mathrm{CS}}$, or to $\frac{\text{Sec.}^2\ \text{of Elev.}}{\text{Vert. Cord of Curv.}}$ 23 Corollaries.

Cor. II. If we make the arch VC = *z*, the abſciſſa VH = *x*, the ordinate HC = *y*, the radius oſculi CO = *r*, and the ½ vertical cord CS = *s*, the height of wall preſſing on any point is proportional to $\frac{\dot{z}^3}{\dot{y}^3 r}$; or to $\frac{\dot{z}^2}{\dot{y}^2 s}$, or $\frac{\dot{x}^2 + \dot{y}^2}{\dot{y}^2 s}$. Therefore, when the equation of the curve is given, and the height of wall on any one point of it is alſo given, we can determine it for any other point: for the equation of the curve will always give us the relation of $\dot{z}$, $\dot{x}$, and $\dot{y}$, and the value of *r* or *s*. This may be illuſtrated by an example or two. For this purpoſe it will generally be moſt convenient to aſſume the height above the vertex V for the unit of computation. The thickneſs of the arch at the crown is commonly determined by other circumſtances. At the vertex the tangent to the arch is horizontal, and therefore the cube of the ſecant is unity or 1. Call the height of wall, at the crown, H, and let the radius of curvature in that point be R, and its half cord R (it being then coincident with the radius), and the height on any other point *h*. We have $\frac{1}{\mathrm{R}} : \frac{\dot{z}^3}{\dot{y}^3 r} = \mathrm{H} : h$, and $h = \mathrm{H} \times \frac{\dot{z}^3}{\dot{y}^3} \times \frac{\mathrm{R}}{r}$. The other formula gives $h = \mathrm{H} \times \frac{\dot{z}^2}{\dot{y}^2} \times \frac{\mathrm{R}}{s}$.

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

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

It gives alſo a very ſimple conſtruction. Draw the vertical CS, cutting the horizontal diameter in S. Draw ST, cutting the radius OC perpendicularly in T. Draw the horizontal line T*z*, cutting the vertical in *z*. Join *zo*. Make C*u* = V*v*, and draw *ux* parallel to *zo*. C*c* muſt be made = C*x*. The demonſtration is evident.

It is very eaſy to ſee that if CV is an arch of 60°, and V*v* is $\frac{1}{14}$th of VC, the points *v* and *c* will be on a level; for the ſecant of CV is twice CO, and therefore C*c* is 8 times V*v*, which is $\frac{1}{7}$th of VH.

Arch.

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

It is plain that if vV be greater, all the other ordinates of the curve $v g c f$, reſting on the circumference AVE, will be greater in the ſame proportion, and the curve will cut the horizontal line drawn through v in ſome point nearer to v than c is. Hence it appears that a circular arch cannot be put in equilibrio by building on it up to a horizontal line, whatever be its ſpan, or whatever be the thickneſs at the crown. We have ſeen that when this thickneſs is only $\frac{1}{14}$th of the radius, an arch of 120 degrees will be too much loaded at the flanks. This thickneſs is much too ſmall for a bridge, being only $\frac{1}{23}$th of the ſpan CM, whereas it ſhould have been almoſt double of this, to bear the inequalities of weight that may occaſionally be on it. When the crown is made ſtill thinner, the outline is ſtill more depreſſed before it riſes again. There is therefore a certain ſpan, with a correſponding thickneſs at the crown, which will deviate leaſt of all from a horizontal line. This is an arch of about 54 degrees, the thickneſs at the crown being about one-fourth of the ſpan, which is extravagantly great. It appears in general, therefore, that the circle is not a curve ſuited to the purpoſes of a bridge or an arcade, which requires an outline nearly horizontal.

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

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

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

Arch.

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

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

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

Then, by the general theorem, $c\mathrm{C} = \frac{\dot{z}^3}{r\dot{y}^3}$, r being the radius of curvature. This, by the common rules, is $= \frac{\dot{z}^3}{\dot{y}\ddot{x} - \dot{x}\ddot{y}}$. This gives us $c\,\mathrm{C} = \frac{\dot{y}\ddot{x} - \dot{x}\ddot{y}}{\dot{y}^3}$, or $= \frac{\dot{y}\ddot{x} - \dot{x}\ddot{y}}{\dot{y}^3} \times \mathrm{C}$; where C is a conſtant quantity, found by taking the real value of cC in V, the vertex of the curve. But it is evident that it is alſo $= a + x - u$. Therefore $a + x - u = \frac{\dot{y}\ddot{x} - \dot{x}\ddot{y}}{\dot{y}^3} \times \mathrm{C}, = \frac{\mathrm{C}}{\dot{y}} \times$ fluxion of $\frac{\dot{x}}{\dot{y}}$.

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

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

Example. To find the form of the balanced arch AVE (fig. 13.), having the horizontal line $c v$ for its extrados.

Plate II.

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

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

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

It only remains to find the conſtant quantity C. This we readily obtain by ſelecting ſome point of the extrados where the values of x and y are given by particular circumſtances of the caſe. Thus, when the ſpan $2s$ and height h of the arch are given, we have $s = \sqrt{C} \times L\left(\frac{a + h + \sqrt{2ah + h^2}}{a}\right)$, and conſequently $\sqrt{C} = \frac{s}{L\left(\frac{a + h + \sqrt{2ah + h^2}}{a}\right)}$. Therefore

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

$$= \frac{s}{L\,\frac{a+h+\sqrt{2ah+h^2}}{a}} \times L\,\frac{a + x + \sqrt{2ax + x^2}}{a}.$$

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

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

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

26
efects of
e Caten
an curve.

The reader will perhaps be ſurpriſed that we have made no mention of the celebrated Catenarian curve, which is commonly ſaid to be the beſt form for an arch; but a little reflection will convince him, that although it is the only form for an arch conſiſting of ſtones of equal weight, and touching each other only in ſingle points, it cannot ſuit an arch which muſt be filled up in the haunches, in order to form a road-way. He will be more ſurpriſed to hear, after this, that there is a certain thickneſs at the crown, which will put the Catenaria in equilibrio, even with a horizontal road-way; but this thickneſs is ſo great as to make it unfit for a bridge, being ſuch that the preſſure at the vertex is equal to the horizontal thruſt. This would have been about 37 feet in the middle arch of Blackfriars Bridge. The only ſituation, therefore, in which the Catenarian form would be proper, is an arcade carrying a height of dead wall; but in this ſituation it would be very ungraceful. Without troubling the reader with the inveſtigation, it is ſufficient to inform him that in a Catenarian arch of equilibration the abſciſſa VH is to the abſciſſa $v\,h$ in the conſtant ratio of the horizontal thruſt to its exceſs above the preſſure on the vertex.

27
Inutility of
the common theory
of equilibration.

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

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

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

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

But this is by no means the caſe. The forms which the uſes for which arches are erected oblige us to adopt, and the loads laid on the different points of the arch, frequently deviate conſiderably from what are neceſſary for the equilibrium of vertical preſſures. The varying load on a bridge, when a great wagon paſſes along it, ſometimes bears a very ſenſible proportion to the weight of that point of the arch on which it reſts. It is even very doubtful whether the preſſures which are occaſioned by the weight of the ſtuff employed for filling up the flanks really act in a vertical direction, and in the proportion which is ſuppoſed. We are pretty certain that this is not the caſe with ſand, gravel, fat mould, and many ſubſtances in very general uſe for this purpoſe. When this is the caſe, the preſſures ſuſtained by the different parts of the arch are often very inconſiſtent with the theory—a part of the arch is overloaded, and tends to fall in, but is prevented by the cement. This part of the arch therefore acts on the remoter parts by the intervention of the parts between, employing thoſe intermediate parts as a kind of levers to break the arch in a remote part, juſt as a lintel would be broken. We apprehend that a mathematician would be puzzled how to explain the ſtability of an arch cut out of a ſolid and uniform maſs of rock. His theory conſiders the mutual thruſts of the arch ſtones as in the direction of the tangents to the arch. Why ſo? becauſe he ſuppoſes that all his poliſhed joints are perpendicular to thoſe tangents. But in the preſent caſe he has no exiſting joints; and there ſeems to be nothing to direct his imagination in the aſſumption of joints, which, however, are abſolutely neceſſary for employing his theory, becauſe, without a ſuppoſition of this kind, there ſeems no conceiving any mutual abutment of the arch ſtones. Aſk a common, but intelligent, maſon what notion he forms of ſuch an arch? We apprehend that he will conſider it as no arch, but as a lintel, which may be broken like a wooden lintel, and which reſiſts entirely by its coheſion. He will not readily conceive that, by cutting the under ſide of a ſtone lintel into an arched form, and thus taking away more than half of its ſubſtance, he has changed its nature of a lintel, or given it any additional ſtrength. Nor would there be any change made in the way in which ſuch a maſs of ſtone would reſiſt being broken down, if nothing were done but forming the under ſide into an arch. If the lintel be ſo laid on the piers that it can be broken without its parts puſhing the piers aſide (which will be the caſe if it lies on the piers with horizontal joints), it will break like any other lintel; but if the joints are directed downwards, and converging to a point within the arch, the broken ſtone (ſuppoſe it broken at the crown by an overload in that part) cannot be preſſed down without forcing the piers outwards. Now, in this mode of acting, the mind cannot trace any thing of the ſtatical equilibrium that we have proceeded on in the foregoing theory. The two parts of the broken lintel ſeem to puſh the piers aſide in the ſame manner that two rafters puſh outwards the walls of a houſe, when their feet are not held together by a tie-beam. If the piers cannot be puſhed aſide (as when the arch abuts on two ſolid rocks), nothing can preſs down the crown which does not cruſh the ſtone.

This concluſion will be ſtrictly true if the arch is of ſuch a form that a ſtraight line drawn from the crown to the pier lies wholly within the ſolid maſonry. Thus if the vault conſiſt of two ſtraight ſtones, as in fig. 1. or if it conſiſt of ſeveral ſtones, as in fig. 14. diſpoſed in two ſtraight lines, no weight laid on the crown can deſtroy it in any other way but by cruſhing it to powder.

29 When it i to be calle into the ai of the bui der. But when ſtraight lines cannot be drawn from the overloaded part to the firm abutments through the ſolid maſonry, and when the coheſion of the parts is not able to withſtand the tranſverſe ſtrains, we muſt call the principles of equilibrium to our aid; and in order to employ them with ſafety, we muſt conſider how they are modified by the excitement of the cohering forces.

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

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

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adequate to all the effects we have been ſpeaking of.

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

We apprehend that the procedure of nature was ſomewhat in this manner. Straight lines can be drawn within the arch-ſtones from A (fig. 15.) to B and D, and from thoſe points to C and E. Each of the portions ED, DA, AB, BC, reſiſt as if they were of one ſtone, compoſing a polygonal vault EDABC. When this is overloaded at A, A can deſcend in no other way than by puſhing the angles B and D outwards, cauſing the portions BC, DE, to turn round C and E. This motion muſt raiſe the points B and D, and cauſe the arch-ſtones to preſs on each other at their *inner* joints *b* and *d*. This produced the copious ſplintering at thoſe joints immediately preceding the total downfal. The ſplintering which happened a fortnight before aroſe from this circumſtance, that the lines AB and AD, along which the preſſure of the overload was propagated, were tangents to the ſoffit of the arch in the points F, H, and G, and therefore the ſtrain lay all on thoſe corners of the arch-ſtones, and ſplintered a little from off them till the whole took a firmer bed. The ſubſequent phenomena are evident conſequences of this diſtribution and modification of preſſure, and can hardly be explained in any other way; at leaſt not on the theoretical principles already ſet forth: for in this bridge the loads at B and D were very conſiderably greater than what the equilibrium required; and we think that the firſt obſerved ſplintering at H, F, and G, was moſt inſtructive, ſhowing that there was an extraordinary preſſure at the inner joints in thoſe places, which cannot be explained by the uſual theory.

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

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

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

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

31 Conſtruction of Blackfriars Bridge. Plate III.

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

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

The portion *a* Y of the arch is joggled like the upper part. The interior part is filled up with large blocks of Kentiſh rag, forming a kind of courſed rubble-work, the courſes tending to the centres of the arch. The under corner of each arch-ſtone projects over the one below it. By this form it takes faſt hold of the rubble-work behind it. Above this rubble there is conſtructed the inverted arch I *e* G of Portland ſtone. This arch ſhares the preſſure of the two adjoining arches, along with the arch-ſtones in Y *a* and in G *b*. Thus all tend together to compreſs and keep down the rubble-work in the heart of this part of the pier. This is a very uſeful precaution; for it often happens, that when the centres of the arches are ſtruck, before the piers are built up to their intended height, the thruſt of the arches ſqueezes the rubble-work horizontally, after the mortar has ſet, but before it has dried and acquired its utmoſt hardneſs. Its bond is broken by this motion, and it is ſqueezed up, and never acquires its former firmneſs. This is effectually prevented by the preſſure exerted by the back of the inverted arch.

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

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

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

32 Origin o the Goth arches.

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

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

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

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

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Dome or
cupola

There is another ſpecies of arch which muſt not be overlooked, namely, the Dome or Cupola, with all its varieties, which include even the pyramidal ſteeple or ſpire.

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

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

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Proper conſtruction of
octagonal
pyramids.

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

38
Examples of ſuch conſtruction.

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

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

Plate II.

39
Stability of a dome depends on principles

It is now time to attend to the principle of equilibrium, as it operates in a ſimple circular dome, and to determine the thickneſs of the vaulting when the curve is given, or the curve when the thickneſs is given. Therefore, let B b A (fig. 17.) be the curve which produces the dome by revolving round the vertical axis AD. We ſhall ſuppoſe this curve to be drawn through the middle of all the arch-ſtones, and that the courſing or horizontal joints are every where perpendicular to the curve. We ſhall ſuppoſe (as is always the caſe) that the thickneſs KL, HI, &c. of the arch-ſtones is very ſmall in compariſon with the dimenſions of the arch. If we conſider any portion HA b of the dome, it is plain that it preſſes on the courſe, of which HL is an arch-ſtone, in a direction b C perpendicular to the joint HI, or in the direction of the next ſuperior element βb of the curve. As we proceed downwards, courſe after courſe, we ſee plainly that this direction muſt change, becauſe the weight of each courſe is ſuperadded to that of the portion above it, to complete the preſſure on the courſe below. Through B draw the vertical line BCG, meeting βb, produced in C. We may take $b c$ to preſs the preſſure of all that is above it, propagated in this direction to the joint KL. We may alſo ſuppoſe the weight of the courſe HL united in b, and acting on the vertical. Let it be repreſented by b F. If we form the parallelogram b FGC, the diagonal b G will repreſent the direction and intenſity of the whole preſſure on the joint KL. Thus it appears that this preſſure is continually changing its direction, and that the line, which will always coincide with it, muſt be a curve concave downward. If this be preciſely the curve of the dome, it will be an equilibrated vaulting; but ſo far from being the ſtrongeſt form, it is the weakeſt, and it is the limit to an infinity of others, which are all ſtronger than it. This will appear evident, if we ſuppoſe that b G does not coincide with the curve A b B, but paſſes without it. As we ſuppoſe the arch-ſtones to be exceedingly thin from inſide to outſide, it is plain that this dome cannot ſtand, and that the weight of the upper part will preſs it down, and ſpring the vaulting outwards at the joint KL. But let us ſuppoſe, on the other hand, that b G falls within the curvilineal element b B. This evidently tends to puſh the arch-ſtone inward, towards the axis, and would cauſe it to ſlide in, ſince the joints are ſuppoſed perfectly ſmooth and ſlipping. But ſince this takes place equally in every ſtone of this courſe, they muſt all abut on each other in the vertical joints, ſqueezing them firmly together. Therefore, reſolving the thruſt b G into two, one of which is perpendicular to the joint KL, and the other parallel to it, we ſee that this laſt thruſt is withſtood by the vertical joints all around, and there remains only the thruſt in the direction of the curve. Such a dome muſt therefore be firmer than an equilibrated dome, and cannot be ſo eaſily broken by overloading the upper part. When the curve is concave upwards, as in the lower part of the figure, the line b' C always falls below b B, and the point C below B. When the curve is concave downwards, as in the upper part of the figure, $'b$ C′ paſſes above, or without b B. The curvature may be ſo abrupt, that even b' G′ ſhall paſs without $'b$ B, and the point G′ is above B′. It is alſo evident that the force which thus binds the ſtones of a horizontal courſe together, by puſhing them towards the axis, will be greater in flat domes than in thoſe that are more convex; that it will be ſtill greater in a cone; and greater ſtill in a curve whoſe convexity is turned inwards: for in this laſt caſe the line b G will deviate moſt remarkably from the curve. Such a dome will ſtand (having poliſhed joints) if the curve ſprings from the baſe with any elevation, however ſmall; nay, ſince the friction of two pieces of ſtone is not leſs than half of their mutual preſſure, ſuch a dome will ſtand, although the tangent to the curve at the bottom ſhould be horizontal, provided that the horizontal thruſt be double the weight of the dome, which may eaſily be the caſe if it do not riſe high.

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

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

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The weight of the latter conſiderably exceeds 3000 tons, and they occaſion a horizontal thruſt which is nearly half this quantity, the elevation of the cone being about 60°. This being diſtributed round the circumference, occaſions a ſtrain on the hoop $= \frac{7}{2 \times 22}$ of the thruſt, or nearly 238 tons. A ſquare inch of the worſt iron, if well forged, will carry 25 tons with perfect ſafety; therefore a hoop of 7 inches broad and $1\frac{1}{2}$ inches thick will completely ſecure this circle from burſting outwards. It is, however, much more completely ſecured; for beſides a hoop at the baſe of very nearly theſe dimenſions, there are hoops in different courſes of the cone which bind it into one maſs, and cauſe it to preſs on the piers in a direction exactly vertical. The only thruſts which the piers ſuſtain are thoſe from the arches of the body of the church and the tranſepts. Theſe are moſt judiciouſly directed to the entering angles of the building, and are there reſiſted with inſuperable force by the whole lengths of the walls, and by four ſolid maſſes of maſonry in the corners. Whoever conſiders with attention and judgment the plan of this cathedral, will ſee that the thruſts of theſe arches, and of the dome, are incomparably better balanced than in St Peter's church at Rome. But to return from this ſort of digreſſion.

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We have ſeen that if *b* G, the thruſt compounded of the thruſt *b* C, exerted by all the courſes above HILK, and if the force *b* F, or the weight of that courſe, be everywhere coincident with *b* B, the element of the curve, we ſhall have an equilibrated dome; if it falls within it, we have a dome which will bear a greater load; and if it falls without it, the dome will break at the joint. We muſt endeavour to get analytical expreſſions of theſe conditions. Therefore draw the ordinates *b* δ *b*″, BDB″, C *d* C″. Let the tangents at *b* and *b*″ meet the axis in M, and make MO, MP, each equal to *b c*, and complete the parallelogram MONP, and draw OQ perpendicular to the axis, and produce *b* F, cutting the ordinates in E and *e*. It is plain that MN is to MO as the weight of the arch HA*b* to the thruſt *b c* which it exerts on the joint KL (this thruſt being propagated through the courſe HILK); and that MQ, or its equal *b e*, or δ *d*, may repreſent the weight of the half AH.

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

If the curvature of the dome be preciſely ſuch as puts it in equilibrium, but without any mutual preſſure in the vertical joints, this value of OG muſt be equal to CB, or to $\ddot{x}$, the point G coinciding with B. This condition will be expreſſed by the equation $\frac{dy\dot{x}\sqrt{\dot{x}^2 + \dot{y}^2}}{\int dy\sqrt{\dot{x}^2 + \dot{y}^2}} = \ddot{x}$, or, more conveniently, by $\frac{dy\sqrt{\dot{x}^2 + \dot{y}^2}}{\int dy\sqrt{\dot{x}^2 + \dot{y}^2}} = \frac{\ddot{x}}{\dot{x}}$. But this form gives only a tottering equilibrium, independent of the friction of the joints and the coheſion of the cement. An equilibrium, accompanied by ſome firm ſtability, produced by the mutual preſſure of the vertical joints, may be expreſſed by the formula $\frac{dy\sqrt{\dot{x}^2 + \dot{y}^2}}{\int dy\sqrt{\dot{x}^2 + \dot{y}^2}} > \frac{\ddot{x}}{\dot{x}}$, or by $\frac{dy\sqrt{\dot{x}^2 + \dot{y}^2}}{\int dy\sqrt{\dot{x}^2 + \dot{y}^2}} = \frac{\ddot{x}}{\dot{x}} + \frac{\dot{t}}{t}$, where t is ſome variable poſitive quantity, which increaſes when x increaſes. This laſt equation will alſo expreſs the equilibrated dome, if t be a conſtant quantity, becauſe in this caſe $\frac{\dot{t}}{t}$ is $= o$.

Since a firm ſtability requires that $\frac{dy\dot{x}\sqrt{\dot{x}^2 + \dot{y}^2}}{\int dy\sqrt{\dot{x}^2 + \dot{y}^2}}$ ſhall be greater than $\ddot{x}$, and CG muſt be greater than CB: Hence we learn, that figures of too great curvature, whoſe ſides deſcend too rapidly, are improper. Alſo, ſince ſtability requires that we have $\frac{dy\,\dot{x}\sqrt{\dot{x}^2+\dot{y}^2}}{\ddot{x}}$ greater than $\int dy\sqrt{\dot{x}^2+\dot{y}^2}$, we learn that the upper part of the dome muſt not be made very heavy. This, by diminiſhing the proportion of b F to b C, diminiſhes the angle $c\,b$ G, and may ſet the point G above B, which will infallibly ſpring the dome in that place. We ſee here alſo, that the algebraic analyſis expreſſes that peculiarity of dome-vaulting, that the weight of the upper part may even be ſuppreſſed.

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

This laſt equation will eaſily give us the depth of vaulting, or thickneſs d of the arch, when the curve is given. For its fluxion is $\frac{dy\sqrt{\dot{x}^2+\dot{y}^2}}{a}=\frac{\dot{t}\dot{x}+t\ddot{x}}{\dot{y}}$, and $d=\frac{a\dot{t}\dot{x}+at\ddot{x}}{y\dot{y}\sqrt{\dot{x}^2+\dot{y}^2}}$, which is all expreſſed in known quantities; for we may put in place of t any power or function of x or of y, and thus convert the expreſſion into another, which will ſtill be applicable to all ſorts of curves.

Inſtead of the ſecond member $\frac{\ddot{x}}{\dot{x}}+\frac{\dot{t}}{t}$, we might employ $\frac{p\ddot{x}}{\dot{x}}$, where p is ſome number greater than unity. This will evidently give a dome having ſtability; becauſe the original formula $\frac{dy\,\dot{x}\sqrt{\dot{x}^2+\dot{y}^2}}{\int dy\sqrt{\dot{x}^2+\dot{y}^2}}$ will then be greater than $\ddot{x}$. This will give $d=\frac{pa\dot{x}^{p-1}\ddot{x}}{y\dot{y}^p\sqrt{\dot{x}^2+\dot{y}^2}}$. Each of theſe forms has its advantages when applied to particular caſes. Each of them alſo gives $d=\frac{a\ddot{x}}{y\dot{y}\sqrt{\dot{x}^2+\dot{y}^2}}$ when the curvature is ſuch as is in preciſe equilibrium. And, laſtly, if d be conſtant, that is, if the vaulting be of uniform thickneſs, we obtain the form of the curve, becauſe then the relation of $\ddot{x}$ to $\dot{x}$ and to y is given.

The chief uſe of this analyſis is to diſcover what curves are improper for domes, or what portions of given curves may be employed with ſafety. Domes are generally built for ornament; and we ſee that there is great room for indulging our fancy in the choice. All curves which are concave outwards will give domes of great firmneſs: They are alſo beautiful. The Gothic dome, whoſe outline is an undulated curve, may be made abundantly firm, eſpecially if the upper part be convex and the lower concave outwards.

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

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

In order to diſcover what portion of a hemiſphere may be employed (for it is evident that we cannot employ the whole) when the thickneſs of the vaulting is uniform, we may recur to the equation or formula $\frac{dy\,\dot{x}\sqrt{\dot{x}^2-\dot{y}^2}}{\ddot{x}}=\int dy\sqrt{\dot{x}^2+\dot{y}^2}$. Let a be the radius of the hemiſphere. We have $\dot{x}=\frac{ay\dot{y}}{\sqrt{a^2-y^2}}$, and $\ddot{x}=\frac{a^2\dot{y}^2}{\overline{a^2-y^2}|^{\frac{3}{2}}}$. Subſtituting theſe values in the formula, we obtain the equation $y^2\sqrt{a^2-y^2}=\int\frac{a^2 y\dot{y}}{\sqrt{a^2-y^2}}$. We eaſily obtain the fluent of the ſecond member $=a^3-a^2\sqrt{a^2-y^2}$, and $y=a\sqrt{-\frac{1}{2}+\sqrt{\frac{5}{4}}}$. Therefore if the radius of the ſphere be one, the half breadth of the dome muſt not exceed $\sqrt{-\frac{1}{2}+\sqrt{\frac{5}{4}}}$, or 0,786, and the height will be 618. The arch from the vertex is about 51° 49′. Much more of the hemiſphere cannot ſtand, even though aided by the cement, and by the friction of the courſing joints. This laſt circumſtance, by giving connection to the upper parts, cauſes the whole to preſs more vertically on the courſe below, and thus diminiſhes the outward thruſt; but it at the ſame time diminiſhes the mutual abutment of the vertical joints, which is a great cauſe of firmneſs in the vaulting. A Gothic dome, of which the upper part is a portion of a ſphere not exceeding 45° from the vertex, and the lower part is concave outwards, will be very ſtrong, and not ungraceful.

43 Dome of St Peter's at Rome.

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

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

Plate II.

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

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

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

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

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It is not a ſmall advantage of dome-vaulting that it is lighter than any that can cover the ſame area. If, moreover, it be ſpherical, it will admit conſiderable varieties of figure, by combining different ſpheres. Thus, a dome may begin from its baſe as a portion of a large hemiſphere, and may be broken off at any horizontal courſe, and then a ſimilar or a greater portion of a ſmaller ſphere may ſpring from this courſe as a baſe. It alſo bears being interſected by cylindrical vaultings in every direction, and the interſections are exact circles, and always have a pleaſing effect. It alſo ſprings moſt gracefully from the heads of ſmall piers, or from the corners of rooms of any polygonal ſhape; and the arches formed by its interſections with the walls are always circular and graceful, forming very handſome ſpandrels in every poſition. For theſe reaſons Sir Chriſtopher Wren employed it in all his vaultings, and he has exhibited many beautiful varieties in the tranſepts and the aiſles of St Paul's, which are highly worthy of the obſervation of architects. Nothing can be more graceful than the vaultings at the ends of the north and ſouth tranſepts, eſpecially as finiſhed off in the fine inſide view publiſhed by Gwynn and Wale.

46
Effects of cement and friction in dome vaulting.

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

47
The iron bridge at Sunderland deſcribed.

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

This arch is a ſegment of a circle whoſe diameter is about 444 feet. The ſpan or cord of the arch is 236 feet, and its verſed ſine or ſpring is 34 feet. It ſprings at the elevation of 60 feet from the ſurface of the river at low water, ſo that veſſels of 200 or perhaps 300 tons burden may paſs under it in the middle of the ſtream, and even 50 feet on each ſide of it.

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

Plate IV.

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

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

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

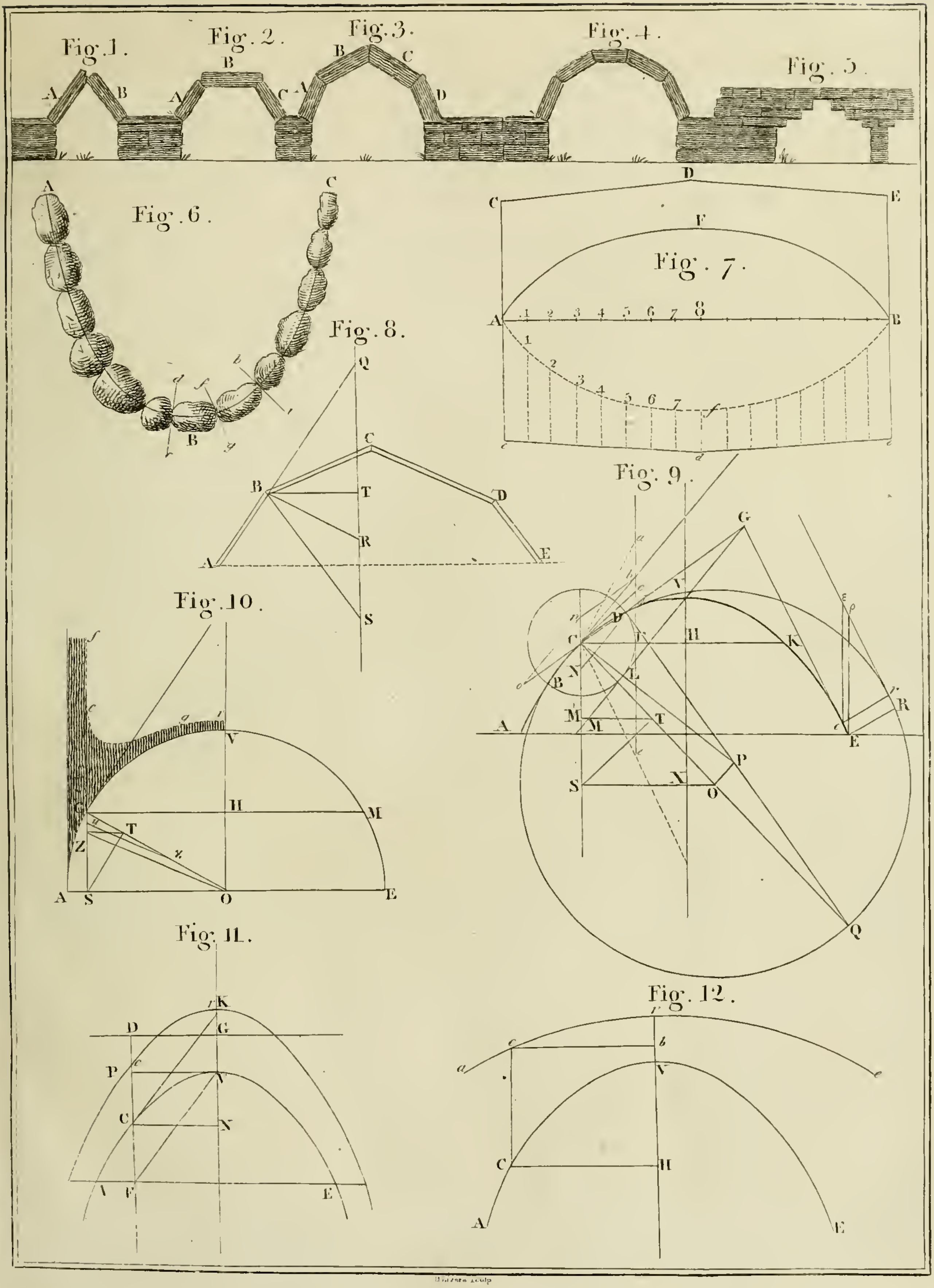
48 Its con- ſtructio ſimple a judiciou

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

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

49 Though one par cular cr- ble, per haps, of provem

PLATE I.



[illegible] sculp

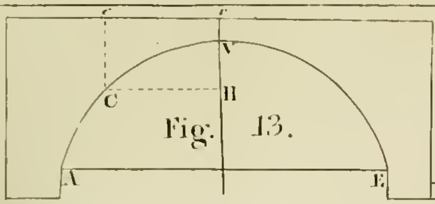


Fig. 13.

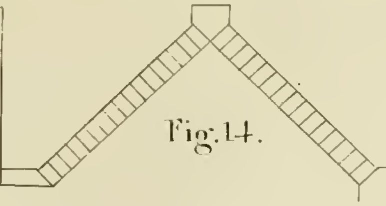


Fig. 14.

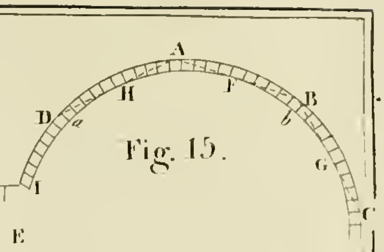


Fig. 15.

Fig. 18. No. 2.

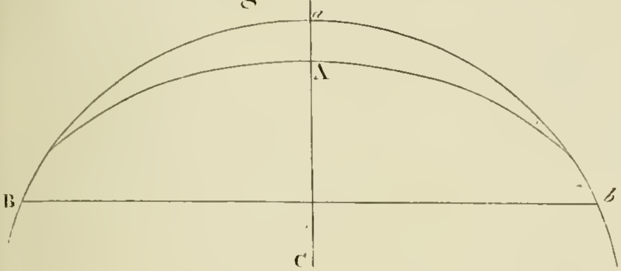


Fig. 19.

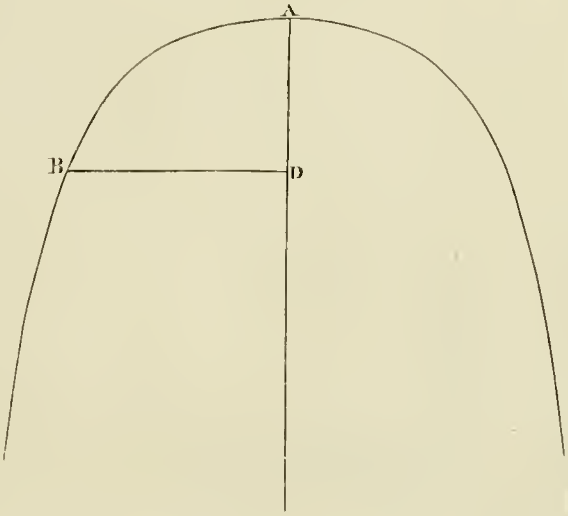


Fig. 18. No. 1.

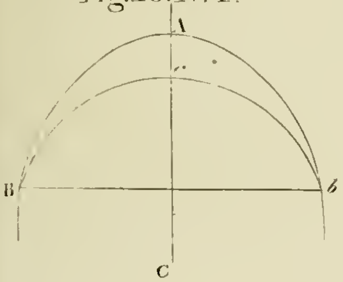


Fig. 17.

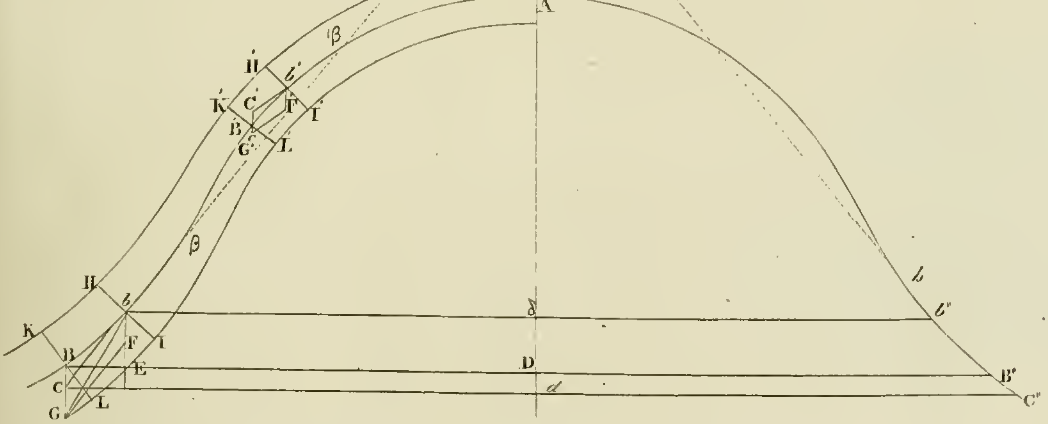


Fig. 2.

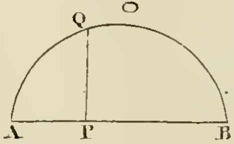


Fig. 3.

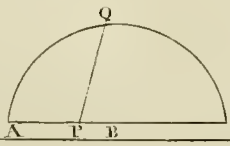


Fig. 4.

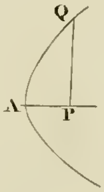


Fig. 5.

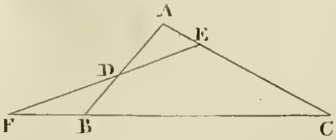
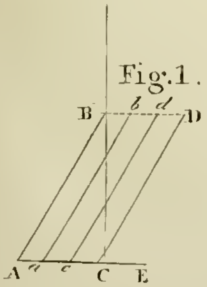


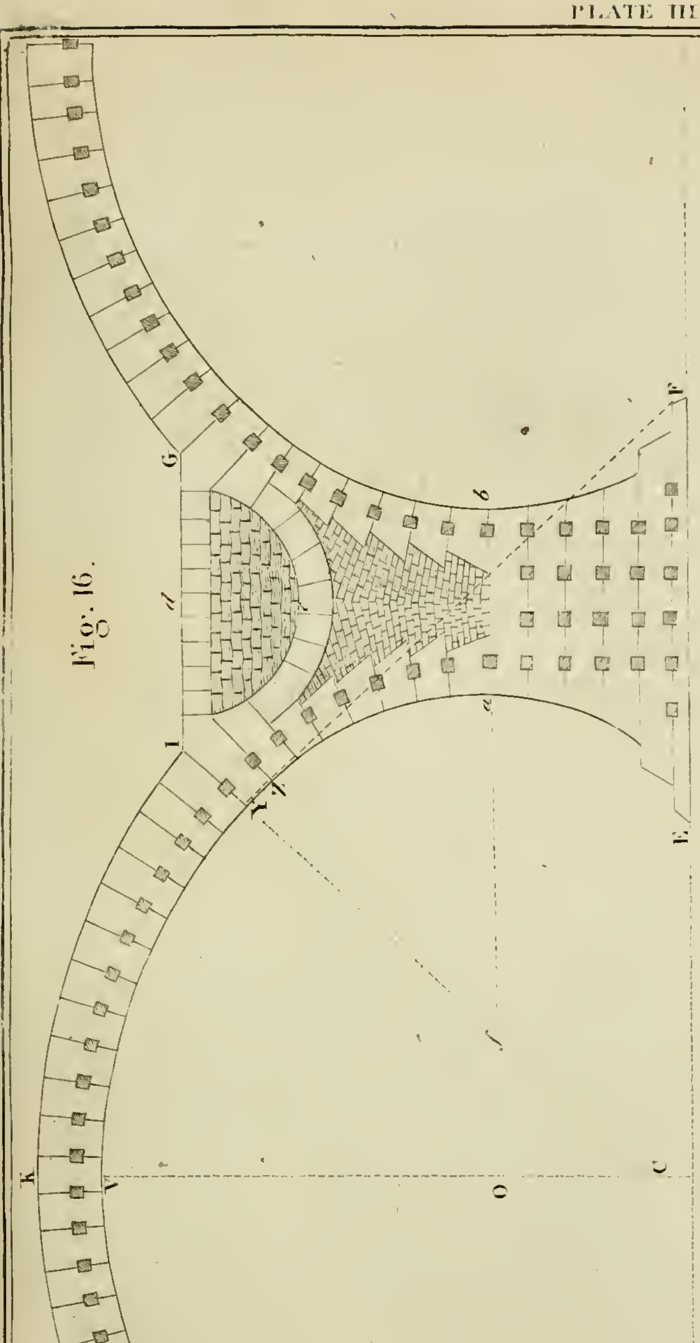
Fig. 1.



D.Lizars sculpt

PLATE III.

Fig. 16.



MALE ANHINGA

PLATE IV.

IRON BRIDGE

Fig. 1.

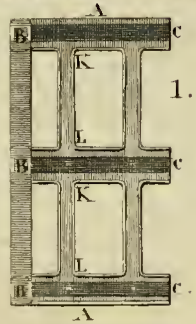


Fig. 2.

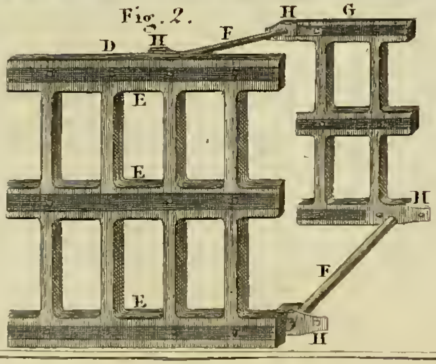


Fig. 3.

D. Lizars Sculpt

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

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

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

Gothic Architecture. It is that which is to be viewed in all our ancient cathedrals, and in other large buildings which have been erected from the middle of the 12th to the beginning of the 16th century. That ſuch edifices have been conſtructed on principles of ſcience, has been ſhewn elſewhere (ſee Roof, *Encycl.* and Arch, in this *Suppl.*): but a queſtion ſtill preſents itſelf to the inquiſitive mind, " How came ſuch ſtructures to be thought of by a people whom we are accuſtomed to call ignorant and barbarous?" This queſtion has occupied the attention of many ingenious men, who have attributed the Gothic ſtyle of building, ſome to neceſſity, and others to an imitation of the works of nature. That, where materials are bad, larger edifices can be erected in the Gothic than in the Grecian ſtyle, has been made ſufficiently evident in the articles to which we have referred; and that neceſſity is the parent of invention, is an adage which has been too long received to be now called in queſtion. But whence came the peculiarities of the Gothic ornaments in building, the pointed arch, and the double row of cluſtered pillars compoſed of ſlender ſhafts, which, reaching from the ground almoſt to the roof of the building, are there ſpread out in all directions, forming the ribs or *groins* of a vaulted roof?

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

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

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

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

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

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

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

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

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

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

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

As the ſtone edifices of ancient Greece were conſtructed in imitation of a wooden fabric, compoſed of ſquare beams laid at right angles on round poſts or ſtems of trees, Sir James conceives that the Gothic fabrics with pointed arches have been executed in imitation of a ruſtic dwelling, conſtructed in the following manner: Suppoſe a ſet of round poſts driven firmly into the ground in two oppoſite rows, the interval between the neighbouring poſts in the ſame row being equal to that between the rows, and each poſt being raiſed above the ground to a height equal to three of thoſe intervals; then a ſet of long and flexible rods of willow being applied to each poſt, let them be thruſt into the ground at its baſe, and bound to it by two tyings, one near the ground, and another at two-thirds of its height; the rods being left looſe from this laſt point upwards, and free to be moved in any direction. Let three rods be connected with each outſide corner poſt, and five with each of the others, and let their poſition be ſuch as to cover the inſide of the poſt, ſo that when ſeen from between the rows the lower part of each poſt ſhall be concealed from the view, and preſent the appearance of a bundle of rods (fig 1.)

Plate V.

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

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

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

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

GOTHIC ARCHITECTURE PLATE V.

Fig 1

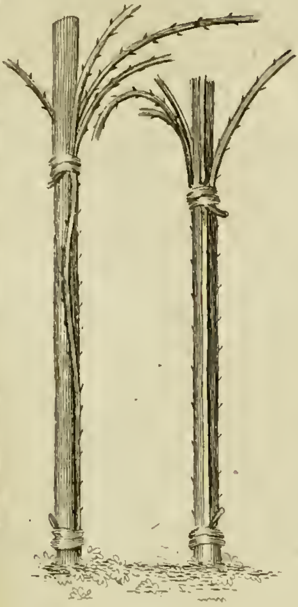


Fig. 2.

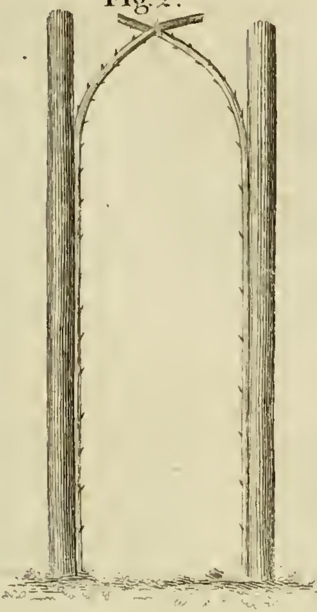


Fig 3

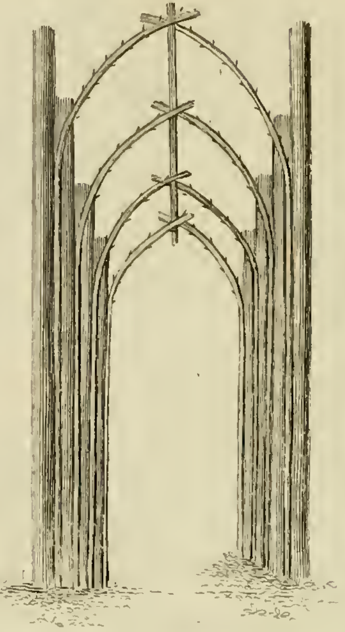


Fig 4.

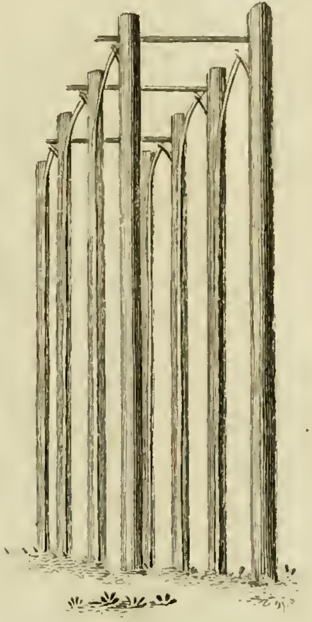


Fig. 6.

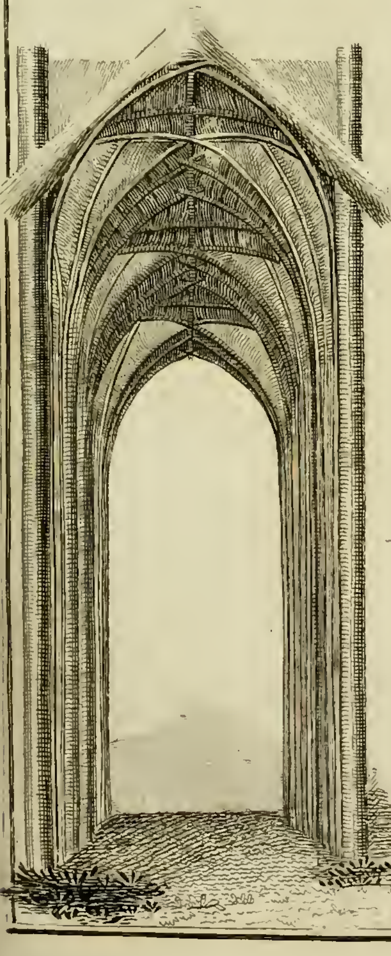


Fig. 5.

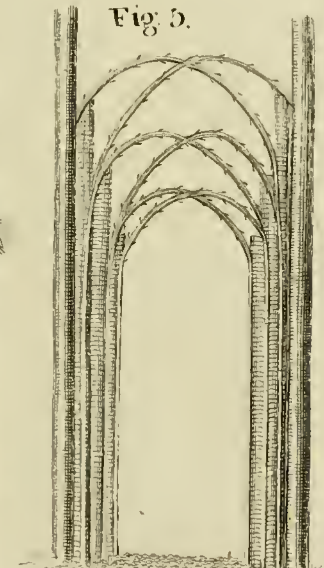
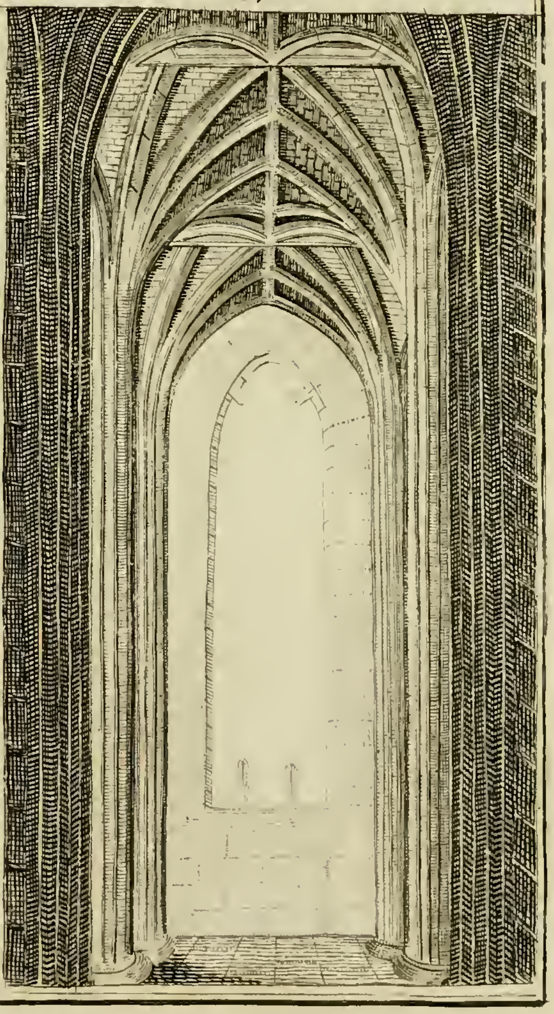


Fig 7



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

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

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

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

Binary ARITHMETIC. See *Binary Arithmetic*, Encycl.

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

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

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

Logiſtical Arithmetic, a name ſometimes employed for the arithmetic of ſexageſimal fractions, uſed in aſtronomical computations. Shakerly, in his *Tabulæ Britannicæ*, has a table of logarithms adapted to ſexageſimal fractions, which he calls *logiſtical logarithms*: and the expeditious arithmetic, obtained by means of them, he calls *logiſtical arithmetic*. The term *logiſtical arithmetic*, however, or *logiſtic*, has been uſed by Vieta and others for the rules of computations in algebra.

Political Arithmetic. See *Political Arithmetic*, Encycl.

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

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

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

ARITHMETICAL complement, of a logarithm, is what the logarithm wants of 10·00000, &c. and the eaſieſt way to find it is, beginning at the left hand, to ſubtract every figure from 9, and the laſt from 10.

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

"In 1728 (ſays Linnæus) I came from Lund to Upſal. I wiſhed to devote myſelf to medicine. I inquired who, at that univerſity, excelled moſt for his knowledge: every one named Artedi. I was impatient to ſee him. I found him pale, and in great diſtreſs for the loſs of his father, with his thin hair neglected. He reſembled the portrait of Ray the naturaliſt. His judgment was ripe, his thoughts profound, his manners ſimple, his virtues antique. The converſation turned upon ſtones, plants, animals. I was enchanted with his obſervations, equally ingenious and new; for at the very firſt he was not afraid to communicate them to me with the utmoſt frankneſs. I deſired his friendſhip, he aſked mine. From that moment we formed a friendſhip; which we cultivated with the greateſt ardour for ſeven months at Upſal. I was his beſt friend, and I never had any who was more dear to me. How ſweet was that intimacy! With what pleaſure did we ſee it increaſe from day to day! The difference, even of our characters, was uſeful to us. His mind was more ſevere, more attentive; he obſerved more ſlowly, and with greater care. A noble emulation animated us. As I deſpaired of ever becoming as well inſtructed in chemiſtry as he, I abandoned it; he alſo ceaſed to ſtudy botany with the ſame ardour, to which I had devoted myſelf in a particular manner. We continued thus to ſtudy different branches of ſcience; and when one of us excelled the other, he acknowledged him for his maſter. We diſputed the palm in ichthyology; but ſoon I was forced to yield, and I abandoned that part of natural hiſtory to him, as well as the amphibia. I ſucceeded better than he in the knowledge of birds and inſects, and he no longer tried to excel in theſe branches. We marched together as equals in lithology, and the hiſtory of quadrupeds. When one of us made an obſervation, he communicated it to the other: ſcarce a day paſſed in which one did not learn from the other ſome new and intereſting particular. Thus emulation excited our induſtry, and mutual aſſiſtance aided our efforts. In ſpite of the diſtance of our lodgings, we ſaw each other every day. At laſt I ſet out for Lapland; he went to London. He bequeathed to me his manuſcripts and his books.

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

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

"Some days after, as he returned to ſup with Seba, the night being dark, he fell into the canal. Nobody perceived it, and he periſhed. Thus died, by water, this great ichthyologiſt, who had ever delighted in that element."

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

ASTRONOMY

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

1
Object of this article.

The cauſes of all phenomena are not only inferred from the phenomena, but are characteriſed by them; and we can form no notion of their nature but what we conceive as competent to the phenomena themſelves. The aſtronomical phenomena are aſſumed to be the motions of the *bodies*, which we call the *ſun*, the *planets*, the *comets*, &c. The notion which we expreſs by the word *body* in the preſent caſe, is ſuppoſed to be the ſame with that which we form of other objects around us, to which we give the ſame name; ſuch as ſtones, ſticks, the bodies of animals, &c. Therefore the notion which we have of the cauſes of the celeſtial motions muſt be the ſame with that which we have of the cauſes of motion in thoſe more familiar bodies. All men ſeem to have agreed in giving the name FORCES, or MOVING FORCES, to the cauſes of thoſe familiar motions. This is a figurative or metaphorical term. The true and original meaning of it is, the exertion which we are conſcious of making when we ourſelves put other bodies in motion. Force, when uſed without figure, always ſignifies the exertion of a living and acting thing. We are more intereſted in thoſe productions of motion than in any other, and our recollections of them are more numerous. Hence it has happened that we uſe the ſame term to expreſs the cauſe of bodily motion in general, and ſay that a magnet has force, that a ſpring has force, that a moving body has force.

2
Metaphorical uſe of the term *force*.

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

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

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

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

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

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

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

3
Our notion of a moving power.

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

4
Meaſure of moving forces.

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

5
Accelerated motion the mark of unvaried action;

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

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

6
And gives a meaſure of the acquired velocity.

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

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

Becauſe halves have the ſame proportions with the units of which they are the halves, it is plain that we may take the ſpaces, deſcribed in equal times with motions uniformly accelerated, as meaſures of the forces which have produced thoſe motions. The velocities generated are, however, the beſt meaſures.

7
Meaſure of the velocity produced by action not uniform.

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

Plate VI.

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

8
Intenſity and direction of deflecting forces.

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

9
Meaſure of theſe forces obtained.

Let two bodies A and a (fig. 2.) deſcribe in the ſame time the arches AC, $a\,c$ of two circles. They are deflected from the tangents AB, $a\,b$. Let us ſuppoſe that the direction of the deflecting forces is known to be that of the chords AE, $a\,e$ of theſe circles. Let theſe be called the DEFLECTIVE CHORDS. Draw CB, $c\,b$ parallel to AE, $a\,e$, and CD, $c\,d$ parallel to AB, $a\,b$. Join AC, $a\,c$, CE, and $c\,e$. It is plain that the angle BAC is equal to the angle CEA in the alternate ſegment. Therefore ACD is alſo equal to it; and, becauſe the angle CAD is common to the two triangles CAD and EAC, theſe two triangles are ſimilar, and $\mathrm{AD} : \mathrm{AC} = \mathrm{AC} : \mathrm{AE}$, and $\mathrm{AD} = \frac{\mathrm{AC}^2}{\mathrm{AE}}$. For ſimilar reaſons $a\,d = \frac{a\,c^2}{a\,e}$. But AD and $a\,d$ are reſpectively equal to BC and $b\,c$. Therefore $\mathrm{BC} = \frac{\mathrm{AC}^2}{\mathrm{AE}}$, and $b\,c = \frac{a\,c^2}{a\,e}$. Therefore $\mathrm{BC} : b\,c = \frac{\mathrm{AC}^2}{\mathrm{AE}} : \frac{a\,c^2}{a\,e}$, or $\mathrm{BC} : b\,c = \mathrm{AC}^2 \times a\,e : a\,c^2 \times \mathrm{AE}$. But BC and $b\,c$ being reſpectively equal to AD and $a\,d$, are equal to the ſpaces through which the deflecting forces would have impelled the bodies from a ſtate of reſt in the time of deſcribing the arches AC, $a\,c$. Therefore, when theſe times are diminiſhed without end, the *ultimate* ratio of AD and $a\,d$ is the ratio of the forces which deflect the bodies in the points A and a. But it is evident that the ultimate ratio of AC to $a\,c$ is the ratio of the velocity in the point A to the velocity in the point a; becauſe theſe arches are ſuppoſed to be deſcribed in the ſame or equal times. Therefore the deflecting forces, by which bodies are made to deſcribe arches of circles, are to each other as the ſquares of the velocities directly, and as the deflective cords of thoſe circles inverſely. This ratio may be expreſſed ſymbolically thus, $\mathrm{F} : f = \frac{\mathrm{V}^2}{\mathrm{C}} : \frac{v^2}{c}$; or thus, in a proportional equation, $f \doteqdot \frac{v^2}{c}$.

It is eaſy to ſee that in this laſt formula f expreſſes directly the line $b\,c$, or the ſpace through which the body is actually made to deviate from rectilineal motion in the time of deſcribing the arch $a\,c$. It is a third proportional to $a\,e$ the deflective chord, and $a\,c$ the arch of the circumference deſcribed in a ſmall moment of time. This is the meaſure afforded immediately by obſervation. We have obſerved the arch AC that is deſcribed, and know the direction and the length of AE from ſome circumſtances of the caſe. The formula which comes to us, when treating this queſtion by the help of fluxions, is $f = \frac{2\,v^2}{c}$. This is perhaps a more proper expreſſion of the phyſical fact; for it expreſſes twice the line $b\,c$, or the meaſure of the velocity which the deflecting force would have generated in the body by acting on it during the time of its deſcribing the arch $a\,c$. But it is indifferent which meaſure we take, provided we always take the ſame meaſure. The firſt mathematicians, however, have committed miſtakes by mixing them.

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

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

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

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

10
Two uſeful affections of curvilineal motions.

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

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

11
Phyſical ſcience of aſtronomy

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

12
Completed by Newton and

13
His followers.

This has accordingly been done by Sir Iſaac Newton and his followers. Sir Iſaac Newton has diſcovered the general laws which regulate the exertions of thoſe forces which produce the planetary motions, by reaſoning from general phenomena which had been obſerved with a certain preciſion before his time; and has alſo ſhown that certain conſiderable deviations from the generality which he ſuppoſed to be perfect were neceſſary conſequences of the very univerſality of the phyſical law, although the phenomenon was not ſo general as was at firſt imagined. He has gone farther, and has pointed out ſome other minute deviations which muſt reſult from the phyſical law, but which the art of obſervation was not then ſufficiently advanced to diſcover in the phenomena. This excited the efforts of men of ſcience to improve the art of aſtronomical obſervation; and not only have the intimations of Newton been verified by modern obſervation, but other deviations have been diſcovered, and, in proceſs of time, have alſo been ſhown to be conſequences of the ſame general law of agency: And, at this preſent day, there is not a ſingle anomaly of the planetary motions which has not been ſhown to be a modification of one general law which regulates the action; and therefore characteriſes the nature of that ſingle force which actuates the whole ſyſtem of the ſun, and his attending planets and comets.

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

We ſhall follow in order the ſteps of this inveſtigation.

14
The ſteps by which they proceeded.

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

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

15 Centripetal forces.

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

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

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

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

17 Law of action of the centripetal force,

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

Kepler's ſecond law or obſervation of the planetary motions was, that *each primary planet deſcribed an ellipſe, having the ſun in one focus.* It is eaſy to ſhow, even without any knowledge of the geometrical properties of the ellipſe, what is the proportion of the intenſities of the deflecting force at the aphelion and perihelion (ſee fig. 4.) At thoſe two points of the orbit, the motion of the planet is at right angles to the line joining it with the ſun. Therefore, ſince the areas deſcribed in equal times are equal, the arches deſcribed in equal times muſt be inverſely at the diſtances from the ſun; or the velocities muſt be inverſely as the diſtances from the ſun. But the curvature in the aphelion and perihelion is the ſame; and therefore the diameters of the equicurve circles in thoſe points are equal. But thoſe diameters are, in this particular caſe, what we called the deflective chords. Therefore, calling the aphelion and perihelion diſtances D and d, the velocities in the aphelion and perihelion V and v, let the common deflective chord be C. Then we have $F : f = V^2 \times C : v^2 \times C, = V^2 : v^2, = d^2 : D^2$. That is, the forces which deflect the planet in the aphelion and perihelion are inverſely as the ſquares of the diſtances from the ſun. A perſon almoſt ignorant of mathematics may ſee the truth of this by looking into a table of natural verſed ſines. He will obſerve, that the verſed ſine of one degree is quadruple the verſed ſine of half a degree, and ſixteen times the verſed ſine of a quarter of a degree; in ſhort, that the verſed ſines of ſmall arches are in the proportion of the ſquares of the arches. Now ſince the arches deſcribed in equal times are inverſely as the diſtances, their verſed ſines are inverſely as the ſquares of the diſtances. But theſe verſed ſines are the ſpaces through which the centripetal forces at the aphelion and perihelion deflect the planet from the tangent. Therefore, &c.

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

18 Demonſtrated with reſpect to the earth,

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

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

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

Thus

19
Obſerved in the motion of the moon &c.

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

It was therefore very natural for Sir Iſaac Newton to examine whether the like diminution of force obtained in the action of this force on different planets; that is, whether the deflection of the earth from the tangent of its orbit was to the ſimultaneous deflection of Jupiter as the ſquare of Jupiter's diſtance from the ſun to the ſquare of the earth's diſtance. This was very probable, but by no means certain. Its probability is very great indeed, when we know that a comet moves ſo in its orbit that its deflections in equal times are inverſely as the ſquares of its diſtances from the ſun, and that the comet paſſes through the orbits of all the planets; and when at the ſame diſtance from the ſun as any one of them, it ſuffers the ſame deflection with it. Newton therefore calculated the actual ſimultaneous deflections of the different planets, and found them agreeable to this law. But it was deſirable to obtain a demonſtration of this important propoſition in general terms. This was ſupplied by Kepler's third general obſervation of the motions, viz. that *the ſquares of the periodic times of the different planets were proportional to the cubes of their mean diſtances from the ſun.* The orbits of the planets are ſo nearly circular, that we may ſuppoſe them exactly ſo in the preſent queſtion, without any remarkable error. In this caſe, then, the deflective chords are the diameters of the orbits (for DS is equal to AC), and are proportional to the diſtances, which are their halves. The centripetal forces, being proportional to $\frac{v^2}{c}$, are proportional to $\frac{v^2}{d}$, when d is the radius of the orbit, or the mean diſtance from the ſun. But the velocity in a circular orbit is as the circumference directly, and as the time of a revolution inverſely. Therefore, inſtead of v^2, we may write $\frac{d^2}{t^2}$, and then the forces will be proportional to $\frac{d^2}{t^2 d}$, or to $\frac{d}{t^2}$; that is, directly as the diſtances, and inverſely as the ſquares of the times of revolution. But, by Kepler's obſervation, t^2 is proportional to d^3. Therefore the centripetal forces are proportional to $\frac{d}{d^3}$, or to $\frac{1}{d^2}$; that is, inverſely as the ſquares of the mean diſtances from the ſun.

20
And demonſtrated in general terms.

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

Therefore draw SD (fig. 4.) to the extremity of the conjugate axis, and biſect it in t. About S, with the radius SD, deſcribe the circle DFG. Let D d, D δ be equal ſmall arches of the ellipſe and the circle. Join d S, δ S. It is well known that DS is half of the chord of the equicurve circle at D, and therefore D t is one fourth part of it. It has been demonſtrated, that the velocity in any point D of a curve, deſcribed by means of a deflecting force, is that which the force in that point would communicate to it by uniformly impelling it along the fourth part of the deflective chord, that is, along D t. But if a body revolved round S in a circle DFG, its velocity in that circle would be that which the deflecting force would communicate to it by uniformly impelling it along one-fourth of the diameter, that is, along D t. Therefore the planet, if projected in the direction D δ, with the velocity which it has in the point D of the ellipſe, would deſcribe the circle DFG by the action of the centripetal force. Farther, it would deſcribe it in the ſame time that it deſcribes the ellipſe; for becauſe the velocities are equal, the areas DS d, DS δ are deſcibed in the ſame time. But the baſes D d, D δ being equal, theſe areas are as their heights S n (or CD), and SD (or CA). But becauſe the diameter of the circle is equal to AB, the area of the whole ellipſe is to the area of the circle as CD is to CA; that is, as the area DS d to the area DS δ deſcribed in the ſame time. Therefore the elliptical and circular areas are ſimilar portions of the ellipſe and circle; and therefore the times of deſcribing them are ſimilar portions of the whole revolutions in the ellipſe and in the circle. Therefore theſe revolutions are performed in equal times.

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

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

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

The 3d Keplerean law is alſo obſerved in the revolutions of the ſatellites of Jupiter, Saturn, and the lately diſcovered planet; and we muſt infer from it, that they are retained in their orbits round their reſpective primary planets, by forces whoſe intenſity decreaſes according to the ſame law of the diſtances. Alſo the elliptical motion of the moon round the earth, ſhews that the force by which ſhe is retained in her orbit varies in the ſame proportion of the diſtances. But when we compare the motion of a ſatellite of Jupiter with that of one of the ſatellites of the other two planets, we find that the proportion does not hold. We ſhall find that, at equal diſtances from Jupiter and Saturn, the force toward Jupiter is almoſt thrice as great as the force toward Saturn. We ſhall alſo find that the force toward Jupiter is three hundred times greater than the force which retains the moon in its elliptical orbit round the earth, when acting at the ſame diſtance.

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

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

But a force inverſely proportional to the ſquare of the earth's diſtance from the ſun is not what the univerſality of the law requires: It muſt be inverſely as the ſquare of the moon's diſtance from the ſun; and it muſt not be parallel to the earth's diſtance from the ſun, but muſt be directed toward the ſun; and therefore, in the quadratures, it muſt converge to the earth's *radius vector*. Therefore, ſince a force having the above mentioned conditions will allow the deſcription of areas round the earth exactly proportional to the times, a force acting on the moon, inverſely proportional to the ſquare of her diſtance from the ſun, and directed exactly to the ſun, is incompatible with the accurate elliptical motion round the earth. At new moon, her tendency to the ſun exceeds the earth's tendency to him, and this exceſs will diminiſh her tendency to the earth, and her motion will be leſs incurvated, ſo that ſhe will retire a little from the earth. At full moon, the earth's tendency to the ſun exceeds the moon's tendency to him, and the earth will ſeparate a little from the moon, ſo that the relative orbit will again be leſs incurvated. In the quadratures, the impulſe on the moon is indeed equal to that on the earth, but not parallel, and tends to make the moon approach the earth, and increaſe the curvature of her orbit. In other ſituations of the moon, this want of equality and paralleliſm of the forces acting on the earth and moon, muſt produce other diſturbances of the regular elliptical motion.

23
How the irregularity of the moon's motion

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

24
May be calculated with preciſion.

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

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

25 The ſecular equation of the moon's mean diſtance

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

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

26 Deduced from the Newtonian law of planetary deflection.

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

During the 18th century, the ſquare of the earth's eccentricity has diminiſhed 0,0000015325, the mean diſtance from the ſun being = 1. This has increaſed the angular motion of the moon in that time 0,00000001285. As this augmentation is gradual, we muſt multiply the angular motion during the century by the half of this quantity, in order to obtain its accumulated effect. This will be found to be 9″ very nearly, which exceeds that deduced, from a moſt careful compariſon of the motion of the laſt two centuries, only by a fraction of a ſecond!

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

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

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

27 Certainty and utility of this law.

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

28 Reciprocal deflection of the earth and moon, and of the ſun and planets,

It is diſcovered by obſervation, that the deflection of the moon to the earth, and of the planets to the ſun, are accompanied by an equal and oppoſite deflection of the earth to the moon, and of the ſun to the planets.

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

29 Proved by the ebbing and flowing of the ſea,

30 And by di ferent con putations of the ſun place in th heavens.

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

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

Appearances perfectly ſimilar to theſe oblige us to affirm

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

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

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Confirmed
by obſerva-
tion.

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

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

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

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

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

34
Deflection of the planets towards each other.

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

Plate VI.

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

35
General reſult of ſuch mutual action.

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

The earth's tendency to the ſun is diminiſhed while Jupiter is in the neighbourhood of his oppoſition or conjunction, and increaſed while he is in the neighbourhood of his ſtationary poſitions. Jupiter being about 1000 times leſs than the ſun, and 5 times more remote, IS muſt be conſidered as repreſenting $\frac{1}{25000}$th of the earth's deflection to the ſun, and the forces ED and EG are to be meaſured on this ſcale.

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

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

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

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

36
A peculiarity explained in the motions of Jupiter and Saturn.

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

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

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

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

37
Oſcillation of the planetary ſyſtem.

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

38 Authenticity of the Indian aſtronomy.

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

39 Origin of the aſtrological diviſion of the heavens.

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

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

40 Action of the comets.

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

41 They are affected by the planets

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

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

42 Conſequence of a comet and planet meeting.

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

43 Tendency of ſpherical bodies towards each other directly as the quantity of matter, and inverſely as the ſquare of the diſtance of their centres.

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

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

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

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

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

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

Thus we ſee that the ſun is incomparably bigger than any planet, having more than a thouſand times as much matter as Jupiter, the moſt maſſy of them all. There is a conſiderable uncertainty, however, in the proportion to the ſun, becauſe we do not know his diſtance nearer than within $\frac{1}{500}$th part. The proportions of the reſt to each other are more accurate. The quantities of matter in Mercury and Mars can only be gueſſed at: the quantity in Mercury may be called 0,1, and Mars may be called 0,12. Venus is ſuppoſed nearly equal to the Earth. This is concluded from the effect which ſhe produces on the preceſſion of the equinoxes and the equation of the ſun's motion. The moon is ſuppoſed to be about $\frac{1}{60}$th of the earth, from the effect ſhe produces on the tides and the preceſſion of the equinoxes, compared with thoſe produced by the ſun.

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

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

> *Jam dubios nulla caligine prægravat error;*
> *Queis ſuperum penetrare domos atque ardua cæli*
> *Scandere ſublimis genii conceſſit acumen.*
>
> HALLEY.

46 Progreſs of Newton's diſcovery of

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

deflect as much from the tangent in a ſecond. Having the dimenſions, as he thought, of the moon's orbit, he immediately computed the moon's deflection in a ſecond; but he found it conſiderably different from what he wiſhed it to be. He therefore concluded that the planetary force was not the weight of the planet. For ſome years he thought no more of it: but one day, in the Royal Society, he heard an account read of meaſurements of a degree of the meridian, which ſhewed him that the radius of the earth and the diſtance of the moon were very different from what he had believed them to be. When he went home he repeated his computation, and found, that the deflection of a ſtone was to the ſimultaneous deflection of the moon as the ſquare of the moon's diſtance from the centre of the earth to the ſquare of the ſtone's diſtance. Therefore the moon is deflected by its weight; and the fall of a ſtone is juſt a particular inſtance of the exertion of the univerſal planetary force. This computation was but roughly made at firſt; but it was this coincidence that excited the philoſopher to a more attentive review of the whole ſubject. When every circumſtance which can affect the reſult is taken into account, the coincidence is found to be moſt accurate. The fall of the ſtone is not the full effect of its weight; for it is diminiſhed by the rotation of the earth round its axis: It is alſo diminiſhed by the weight of the air which it diſplaces: It is alſo diminiſhed by its tendency to the moon. On the other hand, the moon does not revolve round the earth, but round a common centre of the earth and moon, and its period is about $\frac{1}{170}$th ſhorter than if it revolved round the earth; and the moon's deflection is affected by the ſun's diſturbing force. But all theſe corrections can be accurately made, and the ratio of the full weight of the ſtone to the full deflection of the moon aſcertained. This has been done.

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

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

47 The univerſal law of gravitation,

But we do not think that this inference is abſolutely certain. We acknowledge that the experiments on pendulums, conſiſting of a vaſt variety of terreſtrial matter, all of which performed their oſcillations in equal times, demonſtrate that the acceleration of gravity on thoſe pendulums was proportional to their quantities of matter, and that equal gravitation may be affirmed of all terreſtrial matter.

The elliptical motion of a planet is full proof that the accelerating power of its gravity varies in the inverſe duplicate ratio of the diſtance; and the proportionality of the ſquares of the periods to the cubes of the diſtances, ſhews that the whole gravitations of the planets vary by the ſame law. But this third obſervation of Kepler might have been the ſame, although the gravitation of a particle of matter in Jupiter had been equal to that of a particle of terreſtrial matter, provided that all the matter in Jupiter did not gravitate. If $\frac{1}{25}$th of Jupiter had been ſuch gravitating matter, his deflection from the tangent of his orbit would have been the ſame as at preſent, and the time of his revolution would have been what we obſerve. In order that the third law of Kepler may hold true of the planetary motions, no more is required than that the accumulated gravitation of the planet be proportional to its quantity of matter, and thus the matter which does not gravitate will be compenſated by the ſuperior gravitation of the reſt.

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

48 Which is the ultimatum of his philoſophy.

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

49 Objections to the law of gravitation ill-founded.

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

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

50 Our knowledge of that law ſatisfactory.

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

51 Vain attempts to account for it.

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

But Newton is equally anxious with other philoſophers not to aſcribe gravity to matter as an innate inherent property. In a letter to Dr Bently, he earneſtly requeſts him not to charge him with ſuch an abſurd opinion. It is an avowed principle, that nothing can *act* on any thing that is at a diſtance; and this is conſidered as an intuitive axiom. But it is ſurely very obſcure; for we cannot obtain, or at leaſt convey, clear notions of the terms in which it is expreſſed. The word *act* is entirely figurative, borrowed from animal exertions; it is therefore unlike the expreſſion of any thing intitled to the appellation of *intuitive*. If we try to expreſs it without figure, we find our confidence in its certainty greatly diminiſhed. Should we ſay that the condition of a body A cannot depend on another body B that is at diſtance from it, we believe that no perſon will ſay that he makes this aſſertion from perceiving the abſurdity of the contrary propoſition. In the demonſtration, as it is called, of the perſeverance of a body in a ſtate of reſt, the only argument that is offered is, that no cauſe can be aſſigned why it ſhould move in one direction rather than in another: but ſhould any one ſay that another body is near it, to the right hand, and that this is a ſufficient reaſon for its moving that way, we know no method by which this aſſertion can be ſhewn to be falſe.

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

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

52 Inconſiſten cy of ſome of theſe ac counts wit the phenomena.

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

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

53 Vortices of Deſcartes. It is aſtoniſhing that ſo crude a conception ever obtained any partiſans; yet it long maintained its authority, and ſtill has zealous defenders. Till Sir Iſaac Newton ſaw the indiſpenſable neceſſity of mathematical inveſtigation in every queſtion of matter in motion, no perſon had taken the trouble of giving any thing like a diſtinct deſcription of thoſe vortices, the circumſtances of their motion, and the manner of their action; all determined with that preciſion that is required in the explanation: for this muſt always be kept in mind, that we want an explanation of the preciſe motions *which have been obſerved*, and which will enable us to predict thoſe which are yet to happen. Men were contented with ſome vague notion of a *ſort* of ſimilarity between the effects of ſuch vortices and the planetary motions in a few general circumſtances; and were neither at the trouble to conſider how theſe motions were produced, nor how far they tallied with the phenomena. Their account of things was only fit for careleſs chat, but unworthy of the attention of a naturaliſt. But ſince this explanation came from a perſon deſervedly very eminent, it was reſpected by Newton, and he honoured it with a ſerious examination.

54 Examined by Newton. It is to this examination alone that we are indebted for all the knowledge that we have of the conſtitution of a fluid vortex, of the motions of which it is ſuſceptible, of the manner in which it can be produced, the laws of its circulation, and the effects which it can produce. We have this account in Sir Iſaac Newton's Principles of Natural Philoſophy; and it contains many very curious and intereſting particulars, which have been found of great ſervice in other branches of mechanical philoſophy. But the reſult of the examination was fatal to the hypotheſis; ſhewing that the motions which were poſſible in the vortices, and the effects which they muſt produce, are quite incompatible with the appearances in the heavens. We do not know one perſon who has acquired any reputation as a mechanician that now attempts to defend it; nor do we know of any other perſon beſides Newton who has attempted to explain mathematically how the circulation of a fluid can produce the revolution of a planet, if we except Mr Leibnitz, the celebrated rival of the Britiſh philoſopher.

55 Hypotheſis of Leibnitz. This gentleman publiſhed in the Leipſic Review in 1689, three years after the publication of the *Principia*, an attempt to explain the elliptical motion of the planets, and the deſcription of areas proportional to the times, by the impulſe of a vortex. It muſt not be paſſed over in this place, becauſe it acquired great authority in Germany, and many of that country ſtill affirm that Leibnitz is the diſcoverer of the law of planetary gravitation, and of the mechanical conſtitution of the ſolar ſyſtem. We cannot help thinking this explanation the moſt faulty of any, and a moſt diſingenuous plagiariſm from the writings of Newton.

Mr Leibnitz ſuppoſes a fluid, circulating round the ſun in ſuch a manner that the velocity of circulation in every part is inverſely as its diſtance from the ſun. (*N. B.* Newton had ſhewn that ſuch a circulation was poſſible, and that it was the only one which could be generated in a fluid by an action proceeding from the centre). Leibnitz calls this *harmonical circulation*. He ſuppoſes that the planet adopts this circulation in every part of its elliptical orbit, obeying without any reſiſtance the motion of this fluid. He does not aſcribe this to the impulſe of the fluid, ſaying *expreſsly* that the planet follows its motion, *non abrepta tamen, ſed tranquilliter quaſi natante*. The planet therefore has no tendency to perſevere in its former ſtate of motion. Why therefore does it not follow this harmonic motion exactly, and deſcribe a circle *tranquilliter natans?* This is owing, ſays Leibnitz, to its centrifugal force, by which it perſeveres in a ſtate of rectilineal motion. It has no tendency to preſerve its former velocity, but it perſeveres in its former direction. The planet therefore is not like common matter, and has laws of motion peculiar to itſelf; it was needleſs therefore to employ any impulſe to explain its motions. But to proceed: This centrifugal force muſt be counteracted in every point of the orbit. Leibnitz therefore ſuppoſes that it is alſo urged toward the centre by a ſolicitation like gravity or attraction. He calls it the *paracentric force*. He computes what muſt be its intenſity in different parts of the orbit, in order to produce an elliptical motion, and he finds that it muſt be inverſely as the ſquare of the diſtance from the centre (for this reaſon he is frequently quoted by Bernoulli, Wolff, and others, as the diſcoverer of the law of gravitation). But Leibnitz arrives at this reſult by means of ſeveral mathematical blunders, either ariſing from his ignorance at that time of fluxionary geometry, or from his perceiving that an accurate procedure would lead him to a concluſion which he did not wiſh: for we have ſeen (and the demonſtration is adopted by Leibnitz in all his poſterior writings of this kind), that if the ordinary laws of motion are obſerved, a body, actuated by this paracentric force alone, will deſcribe an ellipſe, performing both its motion of harmonic circulation, and its motion of approach to and receſs from the centre, without farther help. Therefore, if the harmonic circulation is produced by a vortex, a force inverſely as the ſquare of the diſtance from the centre, combined with the harmonic circulation, will produce a motion entirely different from the elliptical. It is demonſtrated, that the force which is neceſſary for deſcribing circles at different diſtances, with the angular velocity of the different parts of the orbit, is not in the inverſe duplicate, but in the inverſe triplicate, ratio of the diſtances. This muſt have been the nature of his paracentric force, in order to counteract the centrifugal force ariſing from the harmonic circulation.

56 Diſingenuity of the author. Therefore Leibnitz has not arrived at his concluſion by juſt reaſoning, nor can be ſaid to have diſcovered it. He ſays, *Video hanc propoſitionem innotuiſſe viro celiberrimo Iſaaco Newtono, licet non poſſim judicare quomodo ad eam pervenerit*. This is really ſomewhat like impudence. The *Principia* were publiſhed in 1686. They were reviewed at Leipſic, and the Review publiſhed in 1687. Leibnitz was at that time the principal manager of that Review. When Newton publiſhed, Leibnitz was living at Hanover, and a copy was ſent him within two months of its publication, by Nicholas Facio, long before the Review. The language of the Review has ſeveral ſingularities, which are frequent in Leibnitz's own compoſition; and few doubt of its being his writing. Beſides, this propoſition in the *Principia* had been given to the Royal Society ſeveral years before, and was in the records before 1684. Theſe were all ſeen by Leibnitz when in England, being lent him by his friend Collins.

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

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

57
Hypotheſis of Le Sage.

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

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

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Ether of Newton ſolves no difficulties.

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

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

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

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

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

60 mpulſe arely obſerved.

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

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

61 Intervening fluids multiply difficulties.

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

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

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

62
Eternal durability of the ſolar ſyſtem

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

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

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

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

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

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

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This permanency of the ſyſtem, within very narrow limits of deviation from its preſent ſtate, depends entirely on the law of planetary deflection. Had it been directly or inverſely as the diſtance, the deviations would have been ſuch as to have quickly rendered it wholly unfit for its preſent purpoſes. They would have been very great, had the planetary orbits differed much from circles; nay, had ſome of them moved in the oppoſite direction. The ſelection of this law, and this form of the orbits, ſtrikes the mind of a Newton, and indeed any heart poſſeſſed of ſenſibility to moral or intellectual excellence, as a mark of wiſdom prompted by benevolence. But De la Place and others, infected with the *Theophobia Gallica* engendered by our licentious deſires, are eager to point it out as a mark of fataliſm. They ſay that it is eſſential to all qualities that are diffuſed from a centre to diminiſh in the inverſe duplicate ratio of the diſtance. But this is falſe, and *very falſe*: it is a mere geometrical conception. We indeed ſay, that the denſity of illumination decreaſes in this proportion; but who ſays that this is a quality? Whether it be conſidered as the emiſſion of luminous corpuſcles, or an undulation of an elaſtic fluid, it is not a quality emanating from a centre: and even in this eſtimation, it ſeems gratuitous, whether we ſhall conſider the baſe of the luminous pyramid, or its whole contents, as the expreſſion of the quantity. Nay, if all qualities muſt diminiſh at this rate, all action *e diſtanti* muſt do the ſame; for when the diſtances bear any great proportion to the diameters of the particles, their action deviates inſenſibly from this law, and is perceived only by the accumulation of its effects after a long time. It is only thus that the effects of the oblate figure of Jupiter are perceived in the motion of his ſatellites. The boaſted ſound philoſophy, which ſees fatal neceſſity where the *moſt ſucceſsful ſtudents of nature* ſaw moral excellence, has derived very little credit or title to the name of *wiſdom*, by letting looſe all thoſe propenſities of the human heart which are eſſentially deſtructive of ſocial happineſs. Theſe propenſities were always known to lurk in the heart of man; and thoſe ſurely were the wiſeſt who laboured to keep them in check by the influence of moral principles, and particularly by cheriſhing that diſpoſition of the human heart which prompts us to ſee contrivance wherever we ſee nice and refined adjuſtment of means to ends; and, from the admirable beauty of the ſolar ſyſtem, to cry out,

> " Theſe are thy glorious works, Parent of good!
> " Almighty, thine this univerſal frame,
> " Thus wond'rous fair; thyſelf how wond'rous then!
> " Unſpeakable, who ſitt'ſt above theſe heavens,
> " To us inviſible, or dimly ſeen
> " In theſe thy loweſt works; yet theſe declare
> " Thy goodneſs beyond thought, and power divine."
> *Par. Loſt*, b. v.
>
> " But wandering oft, with brute unconſcious gaze,
> " Man marks not THEE, marks not the mighty hand
> " That, ever buſy, wheels the ſilent ſpheres."
> THOMSON.

64
And evince the wiſdom of the Creator.

65
Saturn's ring.

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

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

66
Diſcovery of Dr Herſchel relating to it.

Dr Herſchel's diſcovery of brighter ſpots on its ſurface, and that thoſe ſpots were permanent during the whole time of his obſervation, ſeems to make it more probable that the parts of the ring have a ſolid connection. Mr Herſchel has diſcovered, by the help of thoſe ſpots, that the ring turns round its axis, and that this axis is alſo the axis of Saturn's rotation. The time of rotation is 10h. 32¼'. But the other circumſtances are not narrated with the preciſion ſufficient for an accurate compariſon with the theory of gravity. He informs us, that the radii of the four edges of the ring are 590, 751, 774, 830, of a certain ſcale, and that the angle

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

We can tell the figure which a fluid ring muſt have, ſo that it may maintain its form by the mutual gravitation of its particles to each other, and their gravitation to the planet. Suppoſe it cut by a meridian. It may be in equilibrio if the ſection is an ellipſe, of which the longer axis is directed to the centre of the planet, and very ſmall in compariſon with its diſtance from the centre of the planet, and having the revolution of its middle round Saturn, ſuch as agrees with the Keplerean law. Theſe circumſtances are not very conſiſtent with the dimenſions of Saturn's inner ring. The diſtance between the middle of its breadth and the centre of Saturn is 670, and its breadth is 161′, nearly one-fourth of the diſtance from the centre of Saturn. De la Place ſays, that the revolution of the inner ring obſerved by Herſchel is very nearly that required by Kepler's law: but we cannot ſee the grounds of this aſſertion. The above compariſons with the ſecond Caſſinian ſatellite ſhows the contrary. The elongation of that ſatellite is taken from Bradley's obſervations, as is alſo its periodic time. A ring of detached particles revolving in 10h. $32\frac{1}{2}'$ muſt be of much ſmaller diameter than even the inner edge of Saturn's ring. Indeed the quantity of matter in it might be ſuch as to increaſe the gravitation conſiderably; but this would be ſeen by its diſturbing the ſeventh and ſixth ſatellites, which are exceedingly near it. We cannot help thinking therefore that it conſiſts of matter which has very conſiderable tenacity. An equatorial zone of matter, tenacious like melted glaſs, and whirled briſkly round, might be thrown off, and, retaining its great velocity, would ſtretch out while whirling, enlarging in diameter and diminiſhing in thickneſs or breadth, or both, till the centrifugal force was balanced by the united force of gravity and tenacity. We find that the equilibrium will not be ſenſibly diſturbed by conſiderable deviations, ſuch as unequal breadth, or even want of flatneſs. Such inequalities appear on this ring at the time of its diſparition, when its edge is turned to the ſun or to us. The appearances of its different ſides are then conſiderably different.

67
Its probable conſiſtency

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

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

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

68
And origi

We think that the rotation of Saturn's ring affords ſome hopes of deciding a very important queſtion about the nature of light. If light be the propagation of elaſtic undulations, its velocity depends entirely on the elaſticity and denſity of the fluid: but if it be the emiſſion of corpuſcles, their velocity may be affected by other cauſes. The velocity of Saturn's ring is $\frac{50}{63}$ of that of the earth in its orbit, and therefore about $\frac{1}{100000}$ of the velocity of light. The weſtern extremity (to us in the northern regions) is moving from us, and the eaſtern is moving toward us. If light, by which we ſee it, be reflected like an elaſtic ball from an elaſtic body, there will be an exceſs in the velocity of the light by which we ſee the eaſtern limb above the velocity of the light by which we ſee the weſtern limb. This exceſs will be $\frac{1}{2500}$ of the mean velocity of light. This ſhould be diſcovered by a difference in the refraction of the two lights. If an acromatic priſm could be made to refract fourteen degrees, and if Saturn be viewed through a teleſcope with this priſm placed before it, there ſhould be

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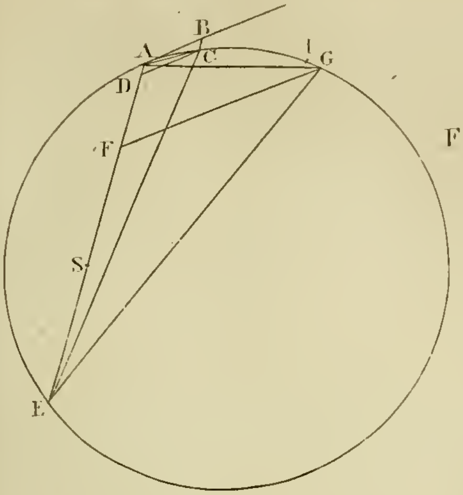
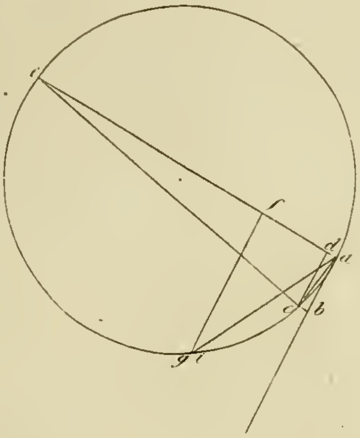


Fig. 2.



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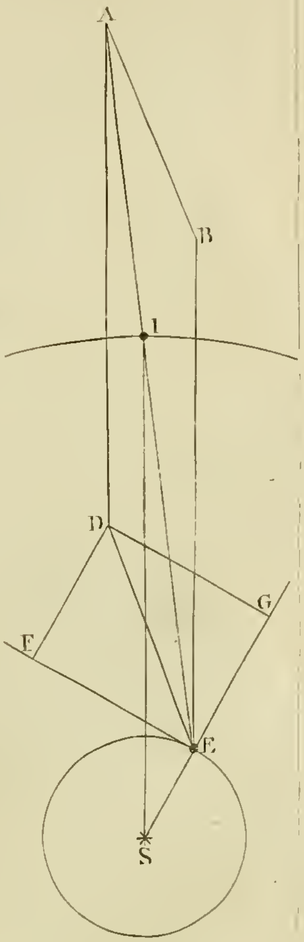

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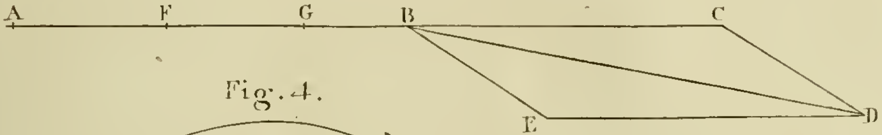

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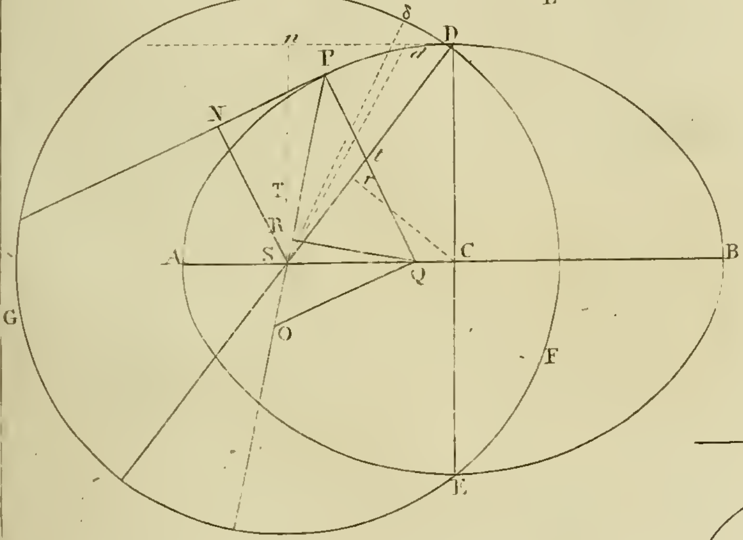


Fig. 3.

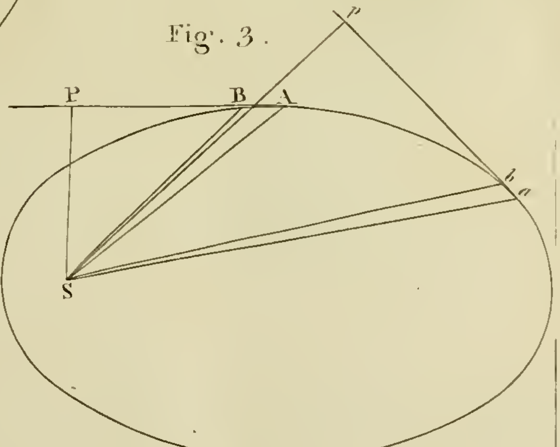
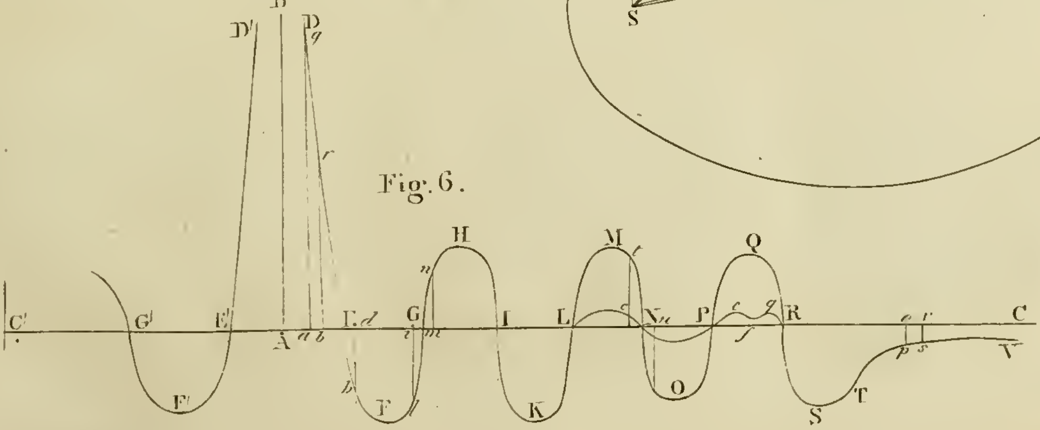


Fig. 6.



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

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

Our expectation is founded on this unqueſtionable principle in dynamics, that when a particle of light paſſes through the active ſtratum of a tranſparent body which refracts light toward the perpendicular, the addition made to the ſquare of its velocity by the refracting forces is equal to the ſquare of the velocity which thoſe forces would communicate to a particle at reſt on the ſurface of this refracting ſtratum of the tranſparent body. Therefore if the velocity of the incident light be increaſed, the ratio of the ſine of incidence to the ſine of refraction will be diminiſhed. It is conſonant to common ſenſe, that when the incident light has a greater velocity, it paſſes more rapidly through the attracting ſtratum, and a ſmaller addition is made to the velocity. When the velocity of the incident light is 10000 times greater than that of the earth's annual motion, the ſine of incidence is to the ſine of refraction in glaſs as 20 to 31, or as 10000 to 15500. If this be increaſed $\frac{1}{2500}$, making it 10004, the ratio will be that of 10004 to 15502,62, or of 10000 to 15496,4. The difference between the refractions of the light from the eaſtern and weſtern extremities of the ring will be, to all ſenſe, the ſame, if the velocity of the one be diminiſhed to 9998, and the other increaſed to 10002.

70 bable ſon why ſee no noſphere out the on.

We may juſt add here, by the way, that the action of another body may conſiderably change the conſtitution of this atmoſphere. Thus, ſuppoſing that the moon had originally an atmoſphere, the limit will be that diſtance from the moon where the centrifugal force, ariſing from the moon's rotation, added to the gravitation to the earth, balances the gravitation to the moon. If the moon be $\frac{1}{59}$th of the earth, this limit will be about $\frac{1}{9}$th of the moon's diſtance from the earth. If at this diſtance the elaſticity of the atmoſphere is not annihilated by its rarefaction, it will be all taken off by the earth, and accumulate round it. This may be the reaſon why we ſee no atmoſphere about the moon.

What has been ſaid in the article Tide *(Encycl.)*, will explain the trade-winds on the earth and in Jupiter and Saturn. On the earth they are increaſed by the expanſion of the air by heat. This cauſes it to riſe in the parts warmed by the ſun, and flow off toward the poles, where it is again cooled and condenſed. The under ſtratum of colder and denſer air is continually flowing in from the poles. This having leſs velocity of circulation than the equatorial parts of the earth, muſt have a relative motion contrary to that of the earth, or from eaſt to weſt, and this muſt augment the current produced by gravitation.

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

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

Quæ toties animos veterum torſêre ſophorum,
Quæque ſcholas hodie rauco certamine vexant,
Obvia conſpicimus, nubem pellente Matheſi.
Surgite mortales, terrenas mittite curas,
Atque hinc cœligenæ vires dignoſcite mentis,
A pecudum vitâ longe lateque remotæ.

ſtrothemata

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

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

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

ymmetry.

ASYMMETRY, the want of proportion, otherwiſe

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

Aſymptotes.

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

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

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

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

AUBIGNE. See STUART in this Supplement.

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

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

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

The whole of Auteniqua, from the chain of mountains which divides it from the country of that race of Hottentots called *Gonaquas* to the ſea, is inhabited by ſeveral planters, who rear a number of cattle, make butter, cut down timber, and collect honey; all of which they tranſport to the Cape: but it appears that they make not the moſt of their ſituation. "Can it be believed (ſays M. Vaillant), that the directors of the Company, for their own uſe, ſhould order ſhips to be ſent every year from Amſterdam, loaded with planks and boards of every kind, whilſt in this country there are immenſe foreſts, and the moſt beautiful trees in the world? This abſurdity, however, is not at all aſtoniſhing. The Company gratuitouſly furniſhes the governor and all the officers with whatever wood they have occaſion for; and it is delivered to them at their houſes without any expence. The governor therefore has no *perſonal* intereſt to extend his views to this part of the adminiſtration, and to aboliſh an abuſe ſo prejudicial to the colony."

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

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

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

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

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

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

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

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

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

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

Automaton.

a prey to the paſſion of jealouſy (as other travellers have repreſented the Hottentots in general), are ſo obliging, as to lend their wives to travellers who viſit them, and that they actually accommodated his Hottentots in this way. Auteniqua, as laid down in M. Vaillant's map, lies between 33° 30′ and 34° 50′ of ſouth latitude, and between 20° and 23° 40′ of eaſt longitude; and his rout through the country was from ſouth-weſt to north-eaſt, or nearly ſo.

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

In the deſcription of this figure (*Encycl.* Vol. I. p. 787.), "it is ſaid that the automaton could not play unleſs M. de Kempel or his ſubſtitute was near it to direct its moves. A ſmall box during the game was frequently conſulted by the exhibiter; and herein conſiſted the ſecret, which he ſaid he could in a moment communicate." The ſecret was indeed ſimple: "A well taught boy, very thin and ſmall of his age, was concealed in this box almoſt immediately under the cheſs-board, and agitated the whole machine." This we learn from Thomas Collinſon, Eſq; who was let into the ſecret at Dreſden by a gentleman of rank and talents, named *Joſeph Freidrick Freyhere*, by whom the *vitality* and *ſoul* of the cheſs-playing figure had ſome time before been completely diſcovered. Mr Collinſon, finding that Dr Hutton had given the ſame credit with us to the reality of mechanical cheſs-playing, undeceived his friend, by communicating the diſcovery of Freyhere in a letter, which the Doctor has with great propriety publiſhed in the *Addenda* to his Mathematical Dictionary. Mr Collinſon adds, and we doubt not with truth, that, "even after this abatement of its being ſtrictly an automaton, much ingenuity remains to the contriver." This was in ſome degree true of the mechaniſm of the writing figure, of which the compiler of this article detected the bungling impoſture of the two exhibiters. The figure itſelf, with all the principles of its motion, were very ingeniouſly conſtructed; but the two men who exhibited it were ignorant and awkward, and could not conceal from a ſcrutinizing eye, that the automaton wrote ſometimes well and ſometimes ill, and never wrote at all when they were both preſent to the company. It was by inſiſting upon ſeeing them both together, and threatening to expoſe the cheat to the whole town, that the preſent writer prevailed upon him who appeared to be the principal exhibiter, to confeſs in private that his companion was concealed behind a ſcreen, and to ſhow how, from thence, he directed the movements of the figure.

Automaton, Axis.

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

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

B.

Bahrdt.

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

Carl Friedirich Bahrdt was, in 1741, born at Leipſig, where his father, then a pariſh miniſter, and afterwards profeſſor of theology, died in 1775. It is natural to ſuppoſe that ſuch a parent would be at due pains to inſtil into the mind of his ſon the principles of piety, virtue, and patriotiſm, which is indeed a branch of virtue; but if ſo, he lived to ſee that his labour had been in vain. While yet at college, where the courſe of his ſtudies was calculated to fit him for the important office of preaching the goſpel, the young man enliſted as a huſſar in the Pruſſian ſervice; but being bought off, he returned to the univerſity, where, in 1761, he was admitted to the degree of M. A. Soon afterwards he became catechiſt in his father's church, was a popular preacher, and in 1765 publiſhed ſermons, and ſome controverſial writings, which evinced that he poſſeſſed both learning and genius. Neither learning nor genius, however, nor both united, could attach him to the cauſe of virtue, or make him obſerve even the common rules of decorum; for immediately after this publication he began to indulge in conviviality, and to give ſcope to his reſentments in anonymous paſquinades, in the higheſt degree bitter and offenſive. From the ſhafts of his malice no perſon was ſafe. Profeſſors, magiſtrates,

Bahrdt.

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

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

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

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

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

Bahrdt, from whoſe memoirs of himſelf this ſtory is taken, admits that there was a great ſquabble on the occaſion ; but he went home, comforting himſelf with the belief that he ſhould now have no farther trouble from Madam Godſchuſky or her girl. He chanced, however, to be miſtaken. The magiſtrate Bel had ſome how been made acquainted with this nefarious tranſaction, and brought it into court on the day that our hero was to make ſome very reverend appearance at church. The caſe of Bahrdt was now hopeleſs ; for after ſome unſucceſsful attempts of his poor father to ſave him, he was obliged to give in his gown and band, and to quit Leipſig.

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

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

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

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

To Marſchlins he went about the year 1776, and began his new career by forming the ſeminary after the model of an academy which had ſome time before been ſet up in the principality of Anhalt Deſſau by one Baſedow, a man of talents and learning, who gave to it the appellation of PHILANTHROPINE. The plan of this academy was very different from thoſe of the univerſities ; for its author profeſſed to conſider languages, ſciences, and the ornamental exerciſes, as mere acceſſories, his aim being to form the young mind to the love of mankind and of virtue, by a courſe of moral education certainly ſpecious, and apparently unexceptionable. To make this novel inſtitution the more extenſively uſeful, the rules by which the education was to be conducted were framed in ſuch a manner as, it was thought, would remove from the minds of Catholics, Lutherans, and Calviniſts, all uneaſineſs reſpecting the faith of their children, as it related to thoſe particular tenets which ſeparated them into different communions. It was even propoſed to baniſh from the philanthropine all *poſitive* religion whatever, and to inſtruct the youth educated there in the principles only of natural, or, as it was called, *philoſophical religion*.

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

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

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

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

For ſo much kindneſs the reader doubtleſs ſuppoſes that the heart of Bahrdt overflowed with gratitude; but if ſuch be his opinion, he is a ſtranger to the principles of thoſe who have on the continent of Europe aſſociated for the purpoſe of enlightening the world. This amiable man, whoſe character is here ſo juſtly drawn, was afterwards depicted by the monſter whom he had ſaved from periſhing by hunger, as a wretch loſt to all ſenſe of ſhame and decency, as an apoſtate from the Chriſtian faith, and as a notorious frequenter of the London brothels! Fortunately he was able to vindicate his character completely from this ſlanderous abuſe, and to convict Bahrdt of having publiſhed what *could not poſſibly be true*.

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

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

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

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

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

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

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

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

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

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

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

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

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

So much for the purity of his morals and his religion, as he appears in the character of a father and of a clergyman. His *decency* as a huſband, and his gratitude to his friend, we have already ſeen; and we ſhall now ſee his kindneſs and fidelity. After waſting the greateſt part of his wife's little fortune, he was ſo provoked becauſe her brother would not give him up the remainder, amounting to about L. 110, that he ever afterwards treated her with the greateſt cruelty, and exhibited her to contempt and ridicule in two infamous novels. At Halle he brought a miſtreſs into the houſe, and committed to her the care of his family, confining his wife and daughter to their own apartment; and the laſt thing which he did was to ſend for a bookſeller, who had publiſhed ſome of his vileſt pieces, and, without a thought of his injured wife, recommend his ſtrumpet and her children to his protection.

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

BAILLY (Jean-Sylvian), who made ſuch a figure during the firſt years of the French revolution, was born at Paris on the 15th of September 1736, of a family which had been diſtinguiſhed painters during four ſucceſſive generations. He was bred to the ſame profeſſion, but ſhowed an early taſte for poetry and the belles lettres. Chancing, however, to become acquainted with the geometer La Caille, this circumſtance decided his genius, and he thenceforth devoted himſelf to the cultivation of ſcience. He calculated the orbit of the comet of 1759; and on the 29th of January 1763 was received into the Academy of Sciences. In that year he publiſhed an uſeful and laborious compilation, being the reduction of the obſervations made by La Caille in 1760 and 1761, on the zodiacal ſtars. He likewiſe began to conſider the theory of Jupiter's ſatellites, and, in the competition for this prize queſtion of 1764, had a formidable rival in La Grange, who already promiſed to become the firſt mathematician in Europe. The reſults of his inveſtigations were collected into a treatiſe publiſhed in 1766, containing alſo the hiſtory of that part of aſtronomy. In 1771 he gave a moſt curious and important memoir on the light of the ſatellites, and introduced a degree of accuracy till then unknown in the obſervations of their eclipſes.

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

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

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

We now approach the eventful period which ſummoned Bailly from his retirement, to enter on a political career, that was full of difficulty and danger, and for which his habits and ſtudies appear not to have fitted him. He had ſeen, as others ſaw, the defects of the old government of France. His heart panted for civil and eccleſiaſtical liberty; but unfortunately, like many other philoſophers both in his own country and in this, he had formed notions of that bleſſing which experience ſhould have taught him can never be realiſed among beings ſo imperfect as the bulk of mankind. When the ſtates-general were ſummoned to meet, he was on the 26th of April 1789 nominated ſecretary by the electors of Paris, and then appointed one of the deputies. He was choſen preſident of the *Tiers Etat;* and when that chamber was conſtituted the National Aſſembly, he continued in the chair, and concurred in all the levelling decrees which laid the foundation of the preſent miſery of his country, as well of moſt other countries of Europe.

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

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

Such is the encomium paſſed upon this philoſopher and ſtateſman by no leſs a man than the celebrated aſtronomer M. DE LA LANDE; but to thoſe who are not infected with the *mania* of freedom, it will doubtleſs appear greatly exaggerated. That M. Bailly was a man of eminence in the republic of letters, is known to all the learned of Europe; that in his political conduct he meant to promote the good of his country, it would certainly be preſumptuous in us to deny; and that he ſuffered unjuſtly, is incontrovertible: But let it be remembered that he ſuffered in a ſtorm, which he exerted all his abilities to raiſe; and that he ſet an example of injuſtice, when he concurred in the degradation of the privileged orders, and in the violent confiſcation of the property of the church.

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

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

Hutton's Dictionary.

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

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

BANYAN-TREE. See FICUS, *Encycl.*

BRITISH BARILLA, is the name given by Mr James King of Newcaſtle upon Tyne, to a material invented by him to ſupply the place of Spaniſh barilla in the making of crown window-glaſs, broad window-glaſs, and glaſs-bottles, as alſo in the manufacturing of ſoap and alum. For theſe purpoſes he affirmed that it anſwered much better than any other material then in uſe ; and in conſequence of that affirmation he obtained a patent for his invention, dated March 4. 1787.

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

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

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

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

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

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

The intimate acquaintance which he had cultivated with claſſical antiquity, enabled him, in the cloſe of a long life, to compoſe that *chef-d'œuvre*, the "Travels of the Younger Anacharſis into Greece" in the middle of the fourth century before the vulgar era. In repreſenting the curioſity of a Scythian ſavage (for we cannot conſider in any other light the man who put muſic and the exceſſes of the table on the ſame level), he takes occaſion to interweave very curious and inſtructive details on the laws, religion, manners, cuſtoms, and general ſpirit, of a great nation, as well as its progreſs in arts and ſciences. The epoch which he has choſen is that of letters and arts, combining the age of Pericles with that of Alexander, the revolution which changed the appearance of Greece, and ſoon after overturned the empire of Perſia. The introduction comprehends the 1250 years elapſed from the age of Cecrops to the ſuppoſed era of Anacharſis, in two intervals; the firſt reaching to the commencement of the Olympiads, the ſecond to the capture of Athens by the Lacedemonians. The hiſtory of the Athenians commences about 150 years after the firſt Olympiad, including the age of Solon, or that of legiſlation; that of Themiſtocles and Ariſtides, or that of glory, of luxury, and arts. In the ſecond, ſpeaking of war, his obſervation, that "the example of one nation, that prefers death to ſlavery, is too important and too inſtructive to be paſſed in ſilence," ſhould have preſerved him from the horrors of a long confinement in an advanced age, from which he was delivered only to die. But arts, ſciences, and literature, are alike forgotten and overwhelmed in France. In the third interval, ſpeaking of the corruption of manners introduced by Pericles to ſupport his power, he has this obſervation, applicable to every ſtate: "Corrupted morals are not reſtored but by the loſs of liberty, which brings that poverty inconſiſtent with ſoftneſs, and inſeparable from abſtemiouſneſs, if not that rigid principle of a healthy mind, which is properly called *virtue*." In this period, though the arts were encouraged, philoſophy was neglected.

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

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

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

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

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

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

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

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

BAT, an animal which has been deſcribed under its generic name VESPERTILIO in the *Encycl.* but ſince that article was written, we have met with an account of a new ſpecies, ſo very ſingular, that, if the veracity of our author can be depended on, it is well intitled to a place here. This ſpecies was diſcovered in the country of the Nimiquas, in the interior of Africa, by *M. Vaillant*, during the courſe of his ſecond travels, and is by him called the *oreillar* bat. To this title it has indeed a very good claim; for it has, he ſays, four ears, or at leaſt the external part of four ears, each ear being double; the outer fold, which ſerves as a covering to the inner, is very ample, being two inches eight lines high, and nearly as broad when ſtretched out. On the noſe alſo a membrane ſtands erect, one inch four lines in height, which might be taken for another ear, as it has exactly the ſhape of one. This membrane, as well as the ears and wings of the animal, are of a ruſty red, paler below than above. The body is only three inches long, and is covered with very fine greyiſh hair. Its width, from the tip of one wing to that of the other, is eight inches. The reader will pardon me, ſays our author, for inſerting theſe trifling details of meaſurement, of which I am not more fond than himſelf; but they appeared to me neceſſary here, to convey an accurate idea of the extraordinary length of the ears of this animal, which are certainly larger in proportion than thoſe of any other we are acquainted with, ſince they are only four lines, or the third part of an inch, ſhorter than the body itſelf.

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

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

The fortifications of Batavia, though a place of ſo much importance, were not, when Sir George ſaw them, ſuch as would be deemed formidable in Europe; but when the difficulties were conſidered of forcing the paſſage of the river, or of landing troops on other parts of the iſland, it might perhaps be thought of greater ſtrength than it would at the firſt view have credit for. The defences of the river were the water fort, ſituated at its entrance, having mounted or diſmounted fourteen guns and two howitzers. It conſiſted of a parapet, originally well conſtructed, retained by by a wall; but the parapet was much neglected, and the wall nearly deſtroyed by the conſtant working of the ſea. This fort was protected on the land ſide by a noxious ſwamp, and towards the ſea, on the north-weſt, by extenſive flats, over which even boats could not paſs. The only good approach was that by the channel, which it ſees and defends. The next work upon the river was on the weſt ſhore, about a quarter of a mile from the water fort. It is a battery mounting ſeven guns, bearing down the river. Oppoſite to this was a battery of ſix guns, facing the river, and two to the eaſtward. This formed one flank of a line that occupied the low land to the north-eaſt of the town. The line was a low breaſt-work of earth, that was ſcarcely diſcoverable. The canals which interſect the town joined the great canal or river, at the diſtance of half a mile from the entrance. Below the junction a boom was laid of wood, armed with iron ſpikes. A little above was the caſtle, a regular ſquare fort, but without ravelins or other outworks. It had two guns mounted on each flank, and two, or ſometimes three, on each face: they were not *en barbette*, nor properly *en embraſure*, but in a ſituation between both, having both their diſadvantages without the advantage of either. The wall was of maſonry, about 24 feet high. It had no ditch, but a canal ſurrounded it at ſome diſtance. It had no cordon. The length of the exterior ſide of the work was about 700 feet. The town is rectangular, three quarters of a mile long, and half a mile broad, incloſed by a wall of about 20 feet in height. Small projections were conſtructed, of various forms, at intervals of about 350 feet. Theſe generally mounted three guns each. It was alſo ſurrounded by a canal, having ſeveral ſluices. At ſhort diſtances from the town, three or four ſmall ſtar forts of earth were erected in particular paſſes, perhaps for defence againſt the inhabitants of the iſland.

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

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

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

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

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

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

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

Few of theſe are natives of Europe, but many are deſcended from Dutch ſettlers here, and are educated with ſome care. The features and outlines of their faces are European; but the complexion, character, and mode of life, approach more to thoſe of the native inhabitants of Java. A pale languor overſpreads the countenance, and not the leaſt tint of roſe is ſeen in any cheek. While in their own houſes they dreſs like their ſlaves, with a long red checkered cotton gown deſcending to the ankles, with large wide ſleeves. They wear no head-dreſs, but plait their hair, and faſten it with a ſilver bodkin on the top of the head, like the country girls in ſeveral cantons of Switzerland. The colour of their hair is almoſt univerſally black; they anoint it with the oil of the cocoa nut, and adorn it with chaplets of flowers. When they go abroad to pay viſits, or to take an airing in their carriages, and particularly when they go to their evening parties, they dreſs magnificently, in gold and ſilver ſpangled muſlin robs, with a profuſion of jewels in their hair, which, however, is worn without powder. They never attempt to mould or regulate the ſhape by any fancied idea of elegance, or any ſtandard of faſhion; and conſequently formed a ſtriking contraſt with ſuch few ladies as were lately arrived from Holland, who had powdered hair and fair complexions, had contracted their waiſts with ſtays, wore large head-dreſſes and hoops, and perſevered in the early care of forcing back the elbows, chin, and ſhoulders. Every native lady is conſtantly attended by a female ſlave handſomely habited, who, as ſoon as her miſtreſs is ſeated, ſits at her feet before her, on the floor, holding in her hands her miſtreſs's gold or ſilver box, divided into compartments, to contain areca nut, cardamom ſeeds, pepper, tobacco, and ſlacked lime; all which, mixed together in due proportions, and rolled within a leaf of betel, conſtitute a maſticatory of a very pungent taſte, and in general uſe. When in the public aſſemblies the ladies find the heat diſagreeable, they retire to free themſelves from their coſtly but inconvenient habits, and return without ceremony in a more light and looſe attire, when they are ſcarcely recognizable by ſtrangers. The gentlemen follow the example; and throwing off their heavy and formal dreſſes, appear in white jackets, ſometimes indeed adorned with diamond buttons. The elderly gentlemen quit their periwigs for nightcaps. Except in theſe moments the members of this government have always combined their perſonal gratification with the eaſtern Policy of ſtriking awe into vulgar minds, by the aſſumption of exterior and excluſive diſtinctions. They alone, for inſtance, appear abroad in crimſon velvet. Their carriages are diſtinguiſhed by peculiar ornaments. When met by others, the latter muſt ſtop and pay homage to the former. One of the gates of the city is opened only to let them paſs. They certainly ſucceed in ſupporting abſolute ſway over a vaſt ſuperiority in number of the deſcendants of the original inhabitants of the country, as well as of the ſlaves imported into it, and of the Chineſe attracted to it by the hope of gain; thoſe claſſes, though healthy, active, and as if quite at home, readily obeying a few emaciated Europeans. Such is the conſequence of dominion once acquired; the prevalence of the mind over mere bodily exertions, and the effect of the combination of power againſt divided ſtrength.

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

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

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

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

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

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

It would have been very extraordinary, and very culpable, in Sir George Staunton, and Dr Gillan phyſician to the embaſſy, if they had not, when on the ſpot, inquired into the truth of Foerſch's account of the *upas* or poiſon tree of Java (ſee *Poison Tree of Java*, Encycl.) But the moſt minute inquiries were made reſpecting it; and the reſult of them was, that no ſuch tree is known at Batavia, and certainly does not exiſt where Foerſch has planted it. It is indeed a common opinion at Batavia, that there exiſts in that country a vegetable poiſon, which, rubbed on the daggers of the Javaneſe, renders the ſlighteſt wounds incurable; though ſome European practitioners have of late aſſerted that they had cured perſons ſtabbed by thoſe weapons, but not without having taken the precaution of keeping the wound long open, and procuring a ſuppuration. One of the keepers of the medical garden at Batavia aſſured Dr Gillan, that a tree diſtilling a poiſonous juice was in that collection, but that its qualities were kept ſecret from moſt people in the ſettlement, leſt the knowledge of them ſhould find its way to the ſlaves, who might be tempted to make an ill uſe of it. In the ſame medical garden, containing it ſeems hurtful as well as grateful ſubſtances, is found alſo the plant from whence is made the celebrated gout remedy, or moxa of Japan, mentioned in the works of Sir William Temple, and deſcribed in the Encyclopædia under the titles of Artemisia and Moxa.

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

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

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

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

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

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

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

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

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

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

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

After

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

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

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

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

Beſides this evidence of the firſt diſcovery of America having been made by Behem, we find the following particulars in the remarks made by Petrus Mateus on the canon law, two years before the expedition of Columbus: "*Primæ navigationes*, &c. The firſt Chriſtian voyages to the newly diſcovered iſlands became frequent under the reign of Henry, ſon of John, king of Luſitania. After his death Alphonſus V. proſecuted the deſign; and John, who ſucceeded him, followed the plan of Alphonſus, by the aſſiſtance of Martin Behem, a very ſkilful navigator; ſo that in a ſhort time the name of Luſitania became famous over the whole world." Cellarius, one of the moſt learned men of his age, ſays expreſsly, "*Behaimeus non modo*, &c. Bœhm did not think it enough to ſurvey the iſland of Fayal, which he firſt diſcovered, or the other adjacent iſlands which the Luſitanians call *Azores*, and we, after the example of Bœhm's companions, call *Flemiſh* iſlands, but advanced ſtill farther and farther ſouth, until he arrived at the remoteſt ſtrait, through which Ferdinand Magellan, following his track, afterwards ſailed, and called it after his own name."

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

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

Theſe marks of diſtinction, conferred on a ſtranger, could

Behem.

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

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

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

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

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

Behem.

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

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

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

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

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

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

Doctrines.

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

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

2. With regard to faith in Chriſt, and aſſurance of ſalvation through his merits, they differ from almoſt all other ſects whatſoever. Theſe they reckon *inſeparable*, or rather the *ſame;* becauſe, they argue, God hath expreſsly declared, "He that believeth ſhall be ſaved;" and therefore it is not only abſurd, but impious, and in a manner calling God a liar, for a man to ſay, "*I believe* the Goſpel, but *have doubts* nevertheleſs of my own ſalvation." With regard to the various diſtinctions and definitions that have been given of different kinds of faith, they argue, that "there is nothing incomprehenſible or obſcure in the meaning of this word as uſed in Scripture; but that as faith, when applied to human teſtimony, ſignifies neither more nor leſs than the mere ſimple belief of that teſtimony as true, upon the authority of the teſtifier: ſo, when applied to the teſtimony of God, it ſignifies preciſely the belief of his teſtimony, and reſting upon his veracity alone, without any kind of collateral ſupport from concurrence of any other evidence or teſtimony whatever." And they inſiſt, that as this faith is the gift of God alone, ſo the perſon to whom it is given is as conſcious of poſſeſſing it, as the being to whom God gives life is of being alive; and therefore he entertains no doubts either of his faith or his conſequent ſalvation through the merits of Chriſt, who died and roſe again for that purpoſe. In a word, they argue, that the Goſpel would not be what it is held forth to be, "glad tidings of great joy," if it did not bring full perſonal aſſurance of eternal ſalvation to the believer: which aſſurance, they inſiſt, "is the preſent infallible privilege and portion of every individual believer of the Goſpel." Theſe definitions of faith, and its inſeparable concomitant aſſurance, they prove by a variety of texts, which our room permits us not to quote.

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

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

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

Origin.

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

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publiſhed firſt in the ſecond volume of the American Tranſactions, and afterwards by Nicholſon in N° II. and III. of his Journal.

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

Practice.

Having thus given a conciſe view of the origin and diſtinguiſhing doctrines of Bereaniſm, it only remains to mention a few particulars relative to the practice of the Bereans as a Chriſtian ſociety. Infant baptiſm they conſider as a divine ordinance inſtituted in the room of circumciſion ; and they think it abſurd to ſuppoſe that infants, who all agree are admiſſible to the kingdom of God in heaven, ſhould nevertheleſs be incapable of being admitted into His viſible church on earth. They commemorate the Lord's ſupper in general once a-month ; but as the words of the inſtitution fix no particular period, they ſometimes celebrate it oftener, and ſometimes at more diſtant periods, as may ſuit their general convenience. In obſerving this ordinance, they follow the primitive apoſtolic plan, without any previous days of faſting or preparation ; as they apprehend that ſuch human inſtitutions only tend to make an idol of the ordinance, and to lead people to entertain erroneous ideas of its ſuperior ſolemnity and importance. Equal and univerſal holineſs in all manner of converſation, they recommend at all times, as well as at the table of the Lord. They meet every Lord's day for the purpoſe of preaching, praying, and exhortation to love and good works. With regard to the admiſſion and excluſion of members, their method is very ſimple. When any perſon, after hearing the Berean doctrines, profeſſes his belief and aſſurance of the truths of the Goſpel, and deſires to be admitted into their communion, he is cheerfully received upon his profeſſion, whatever may have been his former manner of life. But if ſuch an one ſhould afterwards draw back from his good profeſſion or practice, they firſt admoniſh him ; and if that has no effect, they leave him to himſelf. They do not think that they have any power to deliver up a backſliding brother to Satan. That text and other ſimilar paſſages, ſuch as, "Whatſoever ye ſhall bind on earth ſhall be bound in heaven," &c. they conſider as reſtricted to the apoſtles and to the inſpired teſtimony alone, and not to be extended to any church on earth, or any number of churches or of Chriſtians, whether deciding by a majority of votes or by unanimous voices. Neither do they think themſelves authoriſed, as a Chriſtian church, to enquire into each others political opinions, any more than to examine into each others notions of philoſophy. They both recommend and practiſe, as Chriſtian duties, ſubmiſſion to lawful authority ; but they do not think that a man, by becoming a Chriſtian, or joining their ſociety, is under any obligation, by the rules of the Goſpel, to renounce his rights of private judgment upon matters of public or private importance. Upon all ſuch ſubjects they allow each other to think and act as each may ſee it his duty. And they require nothing more of their members than a uniform and ſteady profeſſion of the apoſtolic faith, and a ſuitable walk and converſation. With regard to feet-waſhing and the like practices, which ſome other ſects of Chriſtians conſider as duties, the Bereans are of opinion that they are by no means obligatory. They argue, that the example given by our Saviour of waſhing the feet of his diſciples was not an inſtitution of an ordinance, but merely a familiar inſtance, taken from the cuſtom of the country, and adopted by our Lord on that occaſion, to teach his followers that they ought at all times to be ready to perform even the meaneſt offices of kindneſs to each other.

Preſent ſtate.

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

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

BERKENHOUT (Dr John), was about the year 1730 born at Leeds in Yorkſhire, and educated at the grammar-ſchool in that town, His father, who was a merchant, and a native of Holland, intended him for trade; and with that view ſent him at an early age to Germany, in order to learn foreign languages. After continuing a few years in that country, he made the tour of Europe in company with one or more Engliſh noblemen. On their return to Germany they viſited Berlin, where Mr Berkenhout met with a near relation of his father's, the Baron de Bielfeldt, a nobleman then in high eſtimation with Frederick the Great king of Pruſſia; diſtinguiſhed as one of the founders of the Royal Academy of Sciences at Berlin, and univerſally known as a politician and a man of letters. With this relation our young traveller fixed his abode for ſome time; and, regardleſs of his original deſtination, became a cadet in a Pruſſian regiment of foot. He ſoon obtained an enſign's commiſſion, and in the ſpace of a few years was advanced to the rank of captain. He quitted the Pruſſian ſervice on the declaration of war between England and France in 1756, and was honoured with the command of a company in the ſervice of his native country. When peace was concluded in 1760, not chooſing, we ſuppoſe, to lead a life of inactivity on half-pay, he went down to Edinburgh, and commenced ſtudent of phyſic. During his reſidence at that univerſity, he publiſhed his *Clavis Anglica Linguæ Botanicæ;* a book of great utility to all ſtudents of botany.

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

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

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

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

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

Theſe, we believe, are the Doctor's principal publications in the line of his profeſſion; but he wrote on many other ſubjects with equal ability. His tranſlation of *Count Teſſin's Letters*, which was his firſt publication, and dedicated to the preſent king when prince of Wales, evinces his knowledge of the Swediſh language, and ſhews him to have been a good poet. His *Eſſay on Ways and Means*, proves him to have been better acquainted with the ſyſtem of taxation than moſt other men who have written on the ſubject. His biographical powers appear in his *Biographia Literaria*; and in all his works are ſufficient proofs of his claſſical learning, and that the Italian, French, German, and Dutch languages, were familiar to him. He poſſeſſed likewiſe a very conſiderable degree of mathematical ſcience, which he acquired in the courſe of his military ſtudies; and to thoſe more ſolid attainments he is ſaid to have added no ſmall ſkill in the fine arts of painting and muſic. This eminent man, who, for the variety and promptitude of his knowledge, has been compared to the Admirable Crichton, died on the 3d of April 1791.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Impoſſible or *Imaginary Binomial*, is a binomial which has one of its terms an impoſſible or an imaginary quantity; as $a + \surd - b$.

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

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

First binomial $3 + \surd 5$,
2d binomial $\surd 18 + 4$,
3d binomial $\surd 24 + \surd 18$,
4th binomial $4 + \surd 3$,
5th binomial $\surd 6 + 2$,
6th binomial $\surd 6 + \surd 2$.

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

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

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

Birds-Neſts, in cookery. See *Encycl.* and CAP and BUTTON in this *Suppl.*

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

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

plauſe; and Black becoming one of his favourite pupils, was allowed the free uſe of his laboratory, and aſſiſted him in his experiments; by which means he acquired a decided taſte for this branch of natural philoſophy. In 1754 he took the degree of doctor of phyſic in the univerſity of Edinburgh. where he had ſtudied for ſome time; and the choice which he made in regard to the ſubject of his inaugural diſſertation gave a proof of his attachment to chemical purſuits. It was *De humore acido a cibis orto et magneſia alba.* The principles of the doctrine which he brought forward in this theſis he afterwards fully explained in a paper read the next year before a ſociety in Edinburgh, and publiſhed in the ſecond volume of *Eſſays Phyſical and Literary*, 1756; containing experiments on magneſia alba, quick-lime, and alkaline ſubſtances. In this paper, by an ingenious and philoſophical ſeries of reſearches, he evidently proved the exiſtence of an aerial fluid, which he called *fixed air*, the preſence of which gave mildneſs, and its abſence cauſticity, to alkalies and calcareous earths. This noble diſcovery certainly paved the way to all that important knowledge reſpecting aerial bodies which has done ſo much honour to the names of a Cavendiſh, a Prieſtley, and a Lavoiſier, and which have made chemical philoſophy aſſume an entirely new form.

In the year 1756, on the removal of Dr Cullen to Edinburgh, Dr Black became profeſſor of medicine and lecturer on chemiſtry in the univerſity of Glaſgow. Next year he enriched the ſcience of chemiſtry with the curious doctrine of *latent heat*, in which he explained, in what has been hitherto reckoned a clear and ſatisfactory manner, the connection of heat with fluidity, the phenomena of freezing and boiling, and the manner in which they affect the thermometer. Theſe diſcoveries, the reſult of great natural ſagacity and experimental ſkill, certainly laid the foundation of all thoſe important facts relating to this part of chemiſtry which were afterwards brought to light by ſeveral of the moſt eminent philoſophers of the preſent period, and would alone be ſufficient to give celebrity to the name of Black. His reputation indeed was now raiſed ſo high, that a vacancy having taken place in the chemical chair of Edinburgh, by the removal of Dr Cullen, in 1765, to another department, Dr Black was looked up to as the only man capable of ſuſtaining, in this branch of ſcience, the ſuperiority which that celebrated ſchool of medicine had acquired in all others. He was therefore elected to ſucceed Cullen, and for many years diſcharged the duties of the office with univerſal approbation, being much admired for the care, perſpicuity, and elegance, with which he communicated inſtruction in his lectures, and his neatneſs and accuracy in performing experiments. Very complete manuſcript copies of his lectures were taken by many of his ſtudents, particularly in the early part of his teaching, when they contained a great deal of matter then little known to the chemical world; and theſe copies, read with avidity by the lovers of this ſcience, have greatly contributed to ſecure to him the honour of thoſe diſcoveries, and that original mode of reaſoning, which he ſcarcely ever made public in any other form. His lectures have lately been reviſed by his friend Dr Robiſon of Edinburgh; and, enriched with many valuable notes by that genuine philoſopher, are now in the preſs, and will ſpeedily be publiſhed.

After his election to the chemical chair, Dr Black publiſhed nothing but a paper on the Effect of Boiling upon Water, in diſpoſing it to freeze more readily, printed in the ſixty-fifth volume of the Philoſophical Tranſactions for 1774; and an Analyſis of the Water of ſome Hot Springs in Iceland, in the Philoſophical Tranſactions of Edinburgh for 1791. The latter contains ſome obſervations, highly intereſting to the chemiſt, on the formation of the ſiliceous ſtone depoſited by theſe wonderful ſprings; and has long been conſidered as a model of neatneſs and accuracy in the analyſis of mineral waters. Two of his letters on chemical ſubjects have been publiſhed by Crell and Lavoiſier.

Dr Black was long a ſtrenuous oppoſer of the new theories in chemiſtry; but he at length became an avowed convert to the principles of the French chemiſts, and did not heſitate to make amends by his applauſe for his former oppoſition. He never diſtinguiſhed himſelf as a practical phyſician. His manners were ſimple, his temper cold and reſerved, and his habits of life adapted to his own convenience. He was never married; and died ſuddenly, in his ſixty-ſecond year, on the 6th of December 1799, his health having been in a declining ſtate for ſome time before. He was a member of the Royal Societies of London and Edinburgh, and of the Imperial Academy of Sciences at St Peterſburgh; and by the intereſt of Lavoiſier he was choſen one of the eight foreign members of the Academy of Sciences of Paris, when that academy was Royal, and when a philoſopher of Britain could be a member of it without incurring diſgrace.

By thoſe who knew Dr Black intimately, and are capable of forming an eſtimate of the powers of his mind, he is believed to have been capable of becoming in chemiſtry what Newton was in mechanical philoſophy; but an unconquerable indolence, though it could not prevent him from doing his duty as profeſſor, reſtrained him not only from employing, as he might have done, his admirable talents in enlarging the boundaries of ſcience, but even from aſſerting his claim to diſcoveries which were certainly his. Of theſe we hope to have ſome account from his friend the editor of his lectures.

BLACKLOCK (Dr Thomas) deſerves, on ſo many accounts, to have the principal incidents of his life recorded in this work, that to omit ſuch an article from our liſt of biographical ſketches would be unpardonable negligence. We cannot, however, propoſe to write of him any thing which has not been written before, by an author who has repeatedly appeared before the public, and on each appearance has gained poſſeſſion of the public heart. We ſhall therefore content ourſelves with inſerting in this place a ſhort abridgment of the elegant account of the life and writings of Dr Blacklock, which was prefixed to that edition of his works which was publiſhed in 1793; and if we thus leſſen our own labour, we are conſcious that we ſhall at the ſame time increaſe the pleaſure of our readers.

Thomas Blacklock was in 1721 born at Anan, in the county of Dumfries in Scotland, but his parents were natives of the bordering county of Cumberland; ſo that, though a native of Scotland, his deſcent was Engliſh His father was a bricklayer, and his mother the daughter of a conſiderable dealer in cattle. Both were reſpectable in their characters, and poſſeſſed, tho' moving in an humble ſphere, a conſiderable degree of knowledge and urbanity. Their ſon was not quite ſix months old when he loſt his eye-ſight in the ſmall-pox, which rendered him as complete a ſtranger to the viſible world as if he had been blind from the hour of his birth. It rendered him likewiſe incapable of learning any of the mechanical arts; and therefore his father kept him at home, and with the aſſiſtance of ſome friends foſtered that inclination which, at a very early period, he ſhewed for books. This was done by reading to him firſt the ſimple ſort of publications which are commonly put into the hands of children, and then ſeveral of our beſt authors, ſuch as Milton, Spencer, Prior, Pope, and Addiſon. His companions, whom his early gentleneſs and kindneſs of diſpoſition, as well as their compaſſion for his misfortune, ſtrongly attached to him, were very aſſiduous in their good offices, in reading to inſtruct and amuſe him. By their aſſiſtance he acquired ſome knowledge of the Latin tongue, but he never was at a grammar-ſchool till at a more advanced period of life. Poetry was even then his favourite reading; and he found an enthuſiaſtic delight in the works of the beſt Engliſh poets, and in thoſe of his countryman Allan Ramſay. Even at an age ſo early as twelve he began to write poems, one of which is preſerved in the collection that was publiſhed after his death, and is not perhaps inferior to any of the premature compoſitions of boys aſſiſted by the beſt education, which are only recalled into notice by the future fame of their authors.

He had attained the age of nineteen when his father was killed by the accidental fall of a malt-kiln belonging to his ſon-in-law. This loſs, heavy to any one at that early age, would have been, however, to a young man poſſeſſing the ordinary means of ſupport, and the ordinary advantages of education, comparatively light; but to him—thus ſuddenly deprived of that ſupport on which his youth had leaned—deſtitute almoſt of every reſource which induſtry affords to thoſe who have the bleſſings of ſight—with a body feeble and delicate from nature, and a mind congenially ſuſceptible—it was not ſurpriſing that this blow was doubly ſevere, and threw on his ſpirits that deſpondent gloom to which he then gave way in the following pathetic lines, and which ſometimes overclouded them in the ſubſequent period of his life:

" Dejecting proſpect! ſoon the hapleſs hour
" May come; perhaps this moment it impends,
" Which drives me forth to penury and cold,
" Naked, and beat by all the ſtorms of heav'n,
" Friendleſs and guideleſs to explore my way;
" Till on cold earth this poor unſhelter'd head
" Reclining, vainly from the ruthleſs blaſt
" Reſpite I beg, and in the ſhock expire."

He lived with his mother for about a year after his father's death, and began to be diſtinguiſhed as a young man of uncommon parts and genius. Theſe were at that time unaſſiſted by learning; the circumſtances of his family affording him no better education than the ſmattering of Latin which his companions had taught him, and the peruſal and recollection of the few Engliſh authors which they, or his father in the intervals of his profeſſional labours, had read to him. Poetry, however, though it attains its higheſt perfection in a cultivated ſoil, grows perhaps as luxuriantly in a wild one. To poetry, as we have before mentioned, he was devoted from his earlieſt days; and about this time ſeveral of his poetical productions began to be handed about, which conſiderably enlarged the circle of his friends and acquaintance. Some of his compoſitions being ſhewn to Dr Stevenſon, an eminent phyſician of Edinburgh, who was accidentally at Dumfries on a profeſſional viſit, that gentleman formed the benevolent deſign of carrying him to the Scotch metropolis, and giving to his natural endowments the aſſiſtance of a claſſical education. He came to Edinburgh in the year 1741, and was enrolled a ſtudent of divinity in the univerſity there, though at that time without any particular view of entering into the church. In that univerſity he continued his ſtudies under the patronage of Dr Stevenſon till the year 1745, when he retired to Dumfries, and reſided in the houſe of Mr M'Murdo, who had married his ſiſter, during the whole time of the civil war, which then raged in the country, and particularly diſturbed the tranquillity of the metropolis. When peace was reſtored to the nation, he returned to the univerſity, and purſued his ſtudies for ſix years longer. During this laſt reſidence in Edinburgh, he obtained, among other literary acquaintance, that of the celebrated David Hume, who attached himſelf warmly to Mr Blacklock's intereſts, and was afterwards particularly uſeful to him in the publication of the 4to edition of his Poems, which came out by ſubſcription in London in the year 1756. Previouſly to this, two editions in 8vo had been publiſhed at Edinburgh, the firſt in 1746, and the ſecond in 1754.

In the courſe of his education at Edinburgh, he acquired a proficiency in the learned languages, and became more a maſter of the French tongue than was then common in that city. For this laſt acquiſition he was chiefly indebted to the ſocial intercourſe to which he had the good fortune to be admitted in the houſe of Provoſt Alexander, who had married a native of France. At the univerſity he attained a knowledge of the various branches of philoſophy and theology, to which his courſe of ſtudy naturally led, and acquired at the ſame time a conſiderable fund of learning and information in thoſe various departments of ſcience and belles lettres, from which his want of ſight did not abſolutely preclude him.

In 1757, he began a courſe of ſtudy, with a view to give lectures in oratory to young gentlemen intended for the bar or the pulpit. On this occaſion he wrote to Mr Hume, informed him of his plan, and requeſted his aſſiſtance in the proſecution of it. But Mr Hume doubting the probability of its ſucceſs, he abandoned the project; and then, for the firſt time, adopted the decided intention of going into the church of Scotland. After applying cloſely for a conſiderable time to the ſtudy of theology, he paſſed the uſual trials in the preſbytery of Dumfries, and was by that preſbytery licenſed a preacher of the goſpel in the year 1759. As a preacher he obtained high reputation, and was fond of compoſing ſermons, of which he has left ſome volumes in manuſcript, as alſo a Treatiſe on Morals.

The tenor of his occupations, as well as the bent of his mind and diſpoſitions, during this period of his life, will appear in the following plain and unſtudied account, contained in a letter from a gentleman, who was then his moſt intimate and conſtant companion, the Rev. Mr Jameſon,

Jameſon, formerly miniſter of the Epiſcopal chapel at Dumfries, afterwards of the Engliſh congregation at Dantzic, and who lately reſided, and perhaps yet reſides, at Newcaſtle upon Tyne.

"His manner of life (ſays that gentleman) was ſo uniform, that the hiſtory of it during one day, or one week, is the hiſtory of it during the ſeven years that our perſonal intercourſe laſted. Reading, muſic, walking, converſing, and diſputing on various topics, in theology, ethics, &c. employed almoſt every hour of our time. It was pleaſant to hear him engaged in a diſpute, for no man could keep his temper better than he always did on ſuch occaſions. I have known him frequently very warmly engaged for hours together, but never could obſerve one angry word to fall from him. Whatever his antagoniſt might ſay, *he* always kept his temper. '*Semper paratus et refellere ſine pertinacia, et refelli ſine iracundia.*' He was, however, extremely ſenſible to what he thought ill uſage, and equally ſo whether it regarded himſelf or his friends. But his reſentment was always confined to a few ſatirical verſes, which were generally burnt ſoon after.

"I have frequently admired with what readineſs and rapidity he could ſometimes make verſes. I have known him dictate from thirty to forty verſes, and by no means bad ones, as faſt as I could write them; but the moment he was at a loſs for a rhime or a verſe to his liking, he ſtopt altogether, and could very ſeldom be induced to finiſh what he had begun with ſo much ardour."

This account ſufficiently marks that eager ſenſibility, chaſtened at the ſame time with uncommon gentleneſs of temper, which characteriſed Dr Blacklock, and which indeed it was impoſſible to be at all in his company without perceiving. In the ſcience of mind, this is that diviſion of it which perhaps one would peculiarly appropriate to poetry, at leaſt to all thoſe lighter ſpecies which rather depend on quickneſs of feeling, and the ready conception of pleaſing images, than on the happy arrangement of parts, or the ſkilful conſtruction of a whole, which are eſſential to the higher departments of the poetical art. The firſt kind of talent is like thoſe warm and light ſoils which produce their annual crops in ſuch abundance; the laſt, like that deeper and firmer mould on which the roots of eternal foreſts are fixed. Of the firſt we have ſeen many happy inſtances in that ſex which is ſuppoſed leſs capable of ſtudy or thought; from the laſt is drawn that maſculine ſublimity of genius which could build an Iliad or a Paradiſe Loſt.

Dr Blacklock could never dictate till he ſtood up; and as his blindneſs made walking about without aſſiſtance inconvenient or dangerous to him, he fell inſenſibly into a vibratory ſort of motion of his body, which increaſed as he warmed with his ſubject, and was pleaſed with the conceptions of his mind. This motion at laſt became habitual to him; and though he could ſometimes reſtrain it when on ceremony, or on any public appearance, ſuch as preaching, he felt a certain uneaſineſs from the effort, and always returned to it when he could without impropriety. This appearance he deſcribes in a ſhort poem, in which he gives a ludicrous picture of himſelf; a picture indeed, of which, though the outlines are true, the general effect is greatly overcharged. Though his features were hurt by the diſeaſe which deprived him of ſight, there was a certain placid expreſſion in his countenance, which marked the benevolence of his heart, and was calculated to procure to him individual attachments and general regard.

In 1762 he married Miſs Sarah Johnſton, daughter of Mr Joſeph Johnſton ſurgeon in Dumfries; a connection which formed the great ſolace and bleſſing of his future life, and gave him, with all the tenderneſs of a wife, all the zealous care of a guardian and a friend. This event took place a few days before his being ordained miniſter of the town and pariſh of Kircudbright, in conſequence of a preſentation from the crown, obtained for him by the earl of Selkirk, a benevolent nobleman, whom Mr Blacklock's ſituation and genius had intereſted in his behalf. But the inhabitants of the pariſh, whether from that violent averſion to patronage, which was then ſo univerſal in the ſouthern parts of Scotland, from ſome political diſputes which at that time ſubſiſted between them and his noble patron, or from thoſe prejudices which ſome of them might naturally enough entertain againſt a paſtor deprived of ſight, or perhaps from all theſe cauſes united, were ſo extremely diſinclined to receive him as their miniſter, that after a legal diſpute of nearly two years, it was thought expedient by his friends, as it had always been wiſhed by himſelf, to compromiſe the matter, by reſigning his right to the living, and accepting a moderate annuity in its ſtead. With this ſlender proviſion he removed in 1764 to Edinburgh; and to make up by his induſtry a more comfortable and decent ſubſiſtence, he adopted the plan of receiving a certain number of young gentlemen as boarders into his houſe, whoſe ſtudies in languages and philoſophy he might, if neceſſary, aſſiſt. In this ſituation he continued till the year 1787, when he found his time of life and ſtate of health required a degree of quiet and repoſe, which induced him to diſcontinue the receiving of boarders. In 1767 the degree of doctor in divinity was conferred on him by the univerſity and Mariſchal college of Aberdeen.

In the occupation which he thus exerciſed for ſo many years of his life, no teacher was perhaps ever more agreeable to his pupils, nor maſter of a family to its inmates, than Dr Blacklock. The gentleneſs of his manners, the benignity of his diſpoſition, and that warm intereſt in the happineſs of others which led him ſo conſtantly to promote it, were qualities that could not fail to procure him the love and regard of the young people committed to his charge; while the ſociety, which eſteem and reſpect for his character and his genius often aſſembled at his houſe, afforded them an advantage rarely to be found in eſtabliſhments of a ſimilar kind.

In this mixed ſociety he appeared to forget the privation of ſight, and the melancholy which it might at other times produce in his mind. He entered, with the cheerful playfulneſs of a young man, into all the ſprightly narrative, the ſportful fancy, and the humorous jeſt that roſe around him. Next to converſation, muſic was perhaps the ſource of his greateſt delight; for he not only reliſhed it highly, but was himſelf a tolerable performer on ſeveral inſtruments, particularly the flute. He generally carried in his pocket a ſmall *flageolet*, on which he played his favourite tunes; and was not diſpleaſed when aſked in company to play or to ſing them; a natural feeling for a blind man, who thus adds a ſcene to the drama of his ſociety.

Of the happineſs of others, however, we are incompetent judges. Companionſhip and ſympathy bring forth thoſe gay colours of mirth and cheerfulneſs which they put on for a while, to cover perhaps that ſadneſs which we have no opportunity of witneſſing. Of a blind man's condition we are particularly liable to form a miſtaken eſtimate; we give him credit for all thoſe gleams of delight which ſociety affords him, without placing to their full account thoſe dreary moments of darkſome ſolitude to which the ſuſpenſion of that ſociety condemns him. Dr Blacklock had from nature a conſtitution delicate and nervous, and his mind, as is almoſt always the caſe, was in a great degree ſubject to the indiſpoſition of his body. He frequently complained of a lowneſs and depreſſion of ſpirits, which neither the attentions of his friends, nor the unceaſing care of a moſt affectionate wife, were able entirely to remove. The imagination we are ſo apt to envy and admire ſerves but to irritate this diſorder of the mind; and that fancy in whoſe creation we ſo much delight, can draw, from ſources unknown to common men, ſubjects of diſguſt, diſquietude, and affliction. Some of his later poems expreſs a chagrin, though not of an ungentle ſort, at the ſuppoſed failure of his imaginative powers, or at the faſtidiouſneſs of modern times, which he deſpaired to pleaſe.

"Such were his efforts, ſuch his cold reward,
"Whom once thy partial tongue pronounc'd a bard;
"Excurſive, on the gentle gales of ſpring,
"He rov'd, whilſt favour imp'd his timid wing;
"Exhauſted genius now no more inſpires,
"But mourns abortive hopes, and faded fires;
"The ſhort-liv'd wreath, which once his temples grac'd,
"Fades at the ſickly breath of ſqueamiſh taſte;
"Whilſt darker days his fainting flames immure
"In cheerleſs gloom and winter premature."

Theſe lines are, however, no proof of "exhauſted genius," or "faded fires." "Abortive hopes," indeed, muſt be the lot of all who, like Dr Blacklock, reach the period of old age. In early youth the heart of every one is a poet; it creates a ſcene of imagined happineſs and deluſive hopes; it clothes the world in the bright colours of its own fancy; it refines what is coarſe, it exalts what is mean; it ſees nothing but diſintereſtedneſs in friendſhip; it promiſes eternal fidelity in love. Even on the diſtreſſes of its ſituation it can throw a certain romantic ſhade of melancholy that leaves a man ſad, but does not make him unhappy. But at a more advanced age, "the fairy viſions fade," and he ſuffers moſt deeply who has indulged them the moſt.

About the time that theſe verſes were written, Dr Blacklock was, for the firſt time, afflicted with what to him muſt have been peculiarly diſtreſsful. He became occaſionally ſubject to deafneſs, which, though he ſeldom felt it in any great degree, was ſufficient, in his ſituation, to whom the ſenſe of hearing was almoſt the only channel of communication with the external world, to cauſe very lively uneaſineſs. Amidſt theſe indiſpoſitions of body, however, and diſquietudes of mind, the gentleneſs of his temper never forſook him, and he felt all that reſignation and confidence in the Supreme Being which his earlieſt and his lateſt life equally acknowledged. In ſummer 1791 he was ſeized with a feveriſh diſorder, which at firſt ſeemed of a ſlight, and never roſe to a very violent kind; but a frame ſo little robuſt as his was not able to reſiſt it, and after about a week's illneſs it carried him off on the 7th day of July 1791. His wife ſurvives him, to feel, amidſt the heavy affliction of his loſs, that melancholy conſolation which is derived from the remembrance of his virtues.

The writings of Dr Blacklock conſiſted principally of poems, which were publiſhed in 4to in the year 1793; and to that edition was added, *An Eſſay on the Education of the Blind, tranſlated from the French of M. Hauy.* But beſides his avowed works, we have reaſon to believe that he was the author of many articles in the ſecond edition of the *Encyclopædia Britannica*, though we cannot ſay with certainty what thoſe articles were. If our memory does not deceive us, we have been informed that the preface to that edition was furniſhed by him; and we have elſewhere attributed to him, on the beſt authority, the article Blind, and the *Notes* to the article Music: but he undoubtedly contributed much more to the work, and was one of the principal guides of the proprietors.

BLAIR (Dr Hugh), was born in Edinburgh, on the 7th day of April 1718. His father, John Blair, a reſpectable merchant in that city, was a deſcendant of the ancient family of Blair in Airſhire, and grandſon of the famous Mr Robert Blair miniſter of St Andrew's, chaplain to Charles I. and one of the moſt zealous and diſtinguiſhed clergymen of the period in which he lived. This worthy man, though firmly attached to the cauſe of freedom, and to the Preſbyterian form of church government, and though actively engaged in all the meaſures adopted for their ſupport; yet, by his ſteady, temperate conduct, commanded the reſpect even of his opponents. In preference to all the other eccleſiaſtical leaders of the covenanting party, he was ſelected by the king himſelf to fill an office which, from the circumſtances of the time, gave frequent acceſs to the royal perſon; "becauſe (ſaid his majeſty) that man is pious, prudent, learned, and of a meek and moderate calm temper." His talents ſeem to have deſcended as an inheritance to his poſterity. For of the two ſons who ſurvived him, David, the eldeſt, was a clergyman of eminence in Edinburgh, father to Mr Robert Blair miniſter of Athelſtonford, the celebrated author of the poem intitled *The Grave*; and grandfather to his majeſty's ſolicitor general for Scotland, whoſe maſculine eloquence and profound knowledge of law have, in the public eſtimation, placed him indiſputably at the head of the Scottiſh bar. From his youngeſt ſon Hugh, who engaged in buſineſs as a merchant, and had the honour to fill a high ſtation in the magiſtracy of Edinburgh, ſprung the learned clergyman who is the ſubject of this narrative.

The views of Dr Blair, from his earlieſt youth, were turned towards the church; and his education received a ſuitable direction. After the uſual grammatical courſe at ſchool, he entered the humanity claſs in the univerſity of Edinburgh in October 1730, and ſpent eleven years at that celebrated ſeminary, aſſiduouſly employed in the literary and ſcientific ſtudies preſcribed by the church of Scotland to all who are to become candidates for her licence to preach the goſpel. During this important period, he was diſtinguiſhed among his companions both for diligence and proficiency; and obtained from the profeſſors under whom he ſtudied repeated teſtimonies of approbation. One of them deſerves to be mentioned particularly, becauſe, in his own opinion, it determined the bent of his genius towards polite literature. An eſſay Περι του καλου, or, *On the Beautiful*, written by him when a ſtudent of logic in the uſual courſe of academical exerciſes, had the good fortune to attract the notice of profeſſor Stevenſon, and, with circumſtances honourable to the author, was appointed to be read in public at the concluſion of the term or ſeſſion. This mark of diſtinction made a deep impreſſion on his mind; and the eſſay which merited it he ever after recollected with partial affection, and preſerved to the day of his death as the firſt earneſt of his fame.

At this time Dr Blair commenced a method of ſtudy which contributed much to the accuracy and extent of his knowledge, and which he continued to practiſe occaſionally even after his reputation was fully eſtabliſhed. It conſiſted in making abſtracts of the moſt important works which he read, and in digeſting them according to the train of his own thoughts. Hiſtory, in particular, he reſolved to ſtudy in this manner; and, in concert with ſome of his youthful aſſociates, he conſtructed a very comprehenſive ſcheme of chronological tables, for receiving into its proper place every important fact that ſhould occur. The ſcheme deviſed by this young ſtudent for his own private uſe was afterwards improved, filled up, and given to the public by his learned friend Dr John Blair, prebendary of Weſtminſter, in his valuable work, "The Chronology and Hiſtory of the World."

In the year 1739, Dr Blair took his degree of A. M. On that occaſion he printed and defended a theſis, *De Fundamentis et Obligatione Legis Naturæ*, which contains a ſhort but maſterly diſcuſſion of this important ſubject, and exhibits in elegant Latin an outline of the moral principles which have been ſince more fully unfolded and illuſtrated in his Sermons.

The univerſity of Edinburgh, about this period, numbered among her pupils many young men who were ſoon to make a diſtinguiſhed figure in the civil, the eccleſiaſtical, and the literary hiſtory of their country. With moſt of them Dr Blair entered into habits of intimate connection, which no future competition or jealouſy occurred to interrupt, which held them united through life in their views of public good, and which had the moſt beneficial influence on their own improvement, on the progreſs of elegance and taſte among their contemporaries, and on the general intereſts of the community to which they belonged.

On the completion of his academical courſe, he underwent the cuſtomary trials before the preſbytery of Edinburgh, and received from that venerable body a licence to preach the Goſpel on the 21ſt of October 1741. His public life now commenced with very favourable proſpects. The reputation which he brought from the univerſity was fully juſtified by his firſt appearances in the pulpit; and, in a few months, the fame of his eloquence procured for him a preſentation to the pariſh of Coleſſie in Fife, where he was ordained to the office of the holy miniſtry on the 23d of September 1742. But he was not permitted to remain long in this rural retreat. A vacancy in the ſecond charge of the Canongate, a ſuburb of Edinburgh, furniſhed to his friends an opportunity of recalling him to a ſtation more ſuited to his talents. And, though one of the moſt popular and eloquent clergymen in the church was placed in competition with him, a great majority of the electors decided in favour of this young orator, and reſtored him in July 1743 to the bounds of his native city.

In this ſtation Dr Blair continued eleven years, diſcharging with great fidelity and ſucceſs the various duties of the paſtoral office. His diſcourſes from the pulpit in particular attracted univerſal admiration. They were compoſed with uncommon care; and, occupying a middle place between the dry metaphyſical diſcuſſion of one claſs of preachers, and the looſe incoherent declamation of another, they blended together, in the happieſt manner, the light of argument with the warmth of exhortation, and exhibited captivating ſpecimens of what had hitherto been rarely heard in Scotland, the poliſhed, well-compacted, and regular didactic oration.

In conſequence of a call from the town-council and general-ſeſſion of Edinburgh, he was tranſlated from the Canongate to Lady Yeſter's, one of the city churches, on the 11th of October 1754: and on the 15th day of June 1758, he was promoted to the High Church of Edinburgh, the moſt important eccleſiaſtical charge in Scotland. To this charge he was raiſed at the requeſt of the Lords of Council and Seſſion, and of the other diſtinguiſhed official characters who have their ſeats in that church. And the uniform prudence, ability, and ſucceſs, which, for a period of more that forty years, accompanied all his miniſterial labours in that conſpicuous and difficult ſtation, ſufficiently evince the wiſdom of their choice.

Hitherto his attention ſeems to have been devoted almoſt excluſively to the attainment of profeſſional excellence, and to the regular diſcharge of his parochial duties. No production of his pen had yet been given to the world by himſelf, except two ſermons preached on particular occaſions; ſome tranſlations, in verſe, of paſſages of Scripture for the pſalmody of the church; and a few articles in the Edinburgh Review; a publication begun in 1755, and conducted for a ſhort time by ſome of the ableſt men in the kingdom. But ſtanding as he now did at the head of his profeſſion, and releaſed by the labour of former years from the drudgery of weekly preparation for the pulpit, he began to think ſeriouſly on a plan for teaching to others that art which had contributed ſo much to the eſtabliſhment of his own fame. With this view, he communicated to his friends a ſcheme of lectures on compoſition; and having obtained the approbation of the univerſity, he began to read them in the college on the 11th of December 1759. To this undertaking he brought all the qualifications requiſite for executing it well; and along with them a weight of reputation, which could not fail to give effect to the leſſons he ſhould deliver. For, beſides the teſtimony given to his talents by his ſucceſſive promotions in the church, the univerſity of St Andrew's, moved chiefly by the merit of his eloquence, had in June 1757 conferred on him the degree of D. D. a literary honour which at that time was very rare in Scotland. Accordingly his firſt courſe of lectures was well attended, and received with great applauſe. The patrons of the univerſity, convinced that they would form a valuable addition to the ſyſtem of education, agreed in the following ſummer to inſtitute a rhetorical claſs, under his direction, as a permanent part of their academical eſtabliſhment: and on the 7th of April 1762, his Majeſty was graciouſly pleaſed "to erect and endow a pro-

profeſſorſhip of rhetoric and belles lettres in the univerſity of Edinburgh ; and to appoint Dr Blair, in conſideration of his approved qualifications, regius profeſſor thereof, with a ſalary of L.70." The lectures which he read as profeſſor of rhetoric, he publiſhed in 1783, when he retired from the labours of the office ; and the general voice of the public has pronounced them to be a moſt judicious, elegant, and comprehenſive ſyſtem of rules for forming the ſtyle and cultivating the taſte of youth.

About the time in which he was occupied in laying the foundations of this uſeful inſtitution, he had an opportunity of conferring another important obligation on the literary world, by the part which he acted in reſcuing from oblivion the poems of Oſſian. It was by the ſolicitation of Dr Blair and Mr John Home, that Mr Macpherſon was induced to publiſh his *Fragments of Ancient Poetry* ; and their patronage was of eſſential ſervice in procuring the ſubſcription which enabled him to undertake his tour through the Highlands for collecting the materials of Fingal, and of thoſe other delightful productions which bear the name of Oſſian. To theſe productions Dr Blair applied the teſt of genuine criticiſm ; and ſoon after their publication gave an eſtimate of their merits in *a Diſſertation*, which, for beauty of language, delicacy of taſte, and acuteneſs of critical inveſtigation, has few parallels. It was printed in 1763, and ſpread the reputation of its author throughout Europe.

The great objects of his literary ambition being now attained, his talents were for many years conſecrated ſolely to the important and peculiar employments of his ſtation. It was not till the year 1777 that he could be induced to favour the world with a volume of the Sermons which had ſo long furniſhed inſtruction and delight to his own congregation. But this volume being well received, the public approbation encouraged him to proceed : four other volumes followed at different intervals, the laſt of which was publiſhed after his death ; and all of them experienced a degree of ſucceſs of which few publications can boaſt. They circulated rapidly and widely wherever the Engliſh tongue extends ; they were ſoon tranſlated into almoſt all the languages of Europe ; and his preſent Majeſty, with that wiſe attention to the intereſts of religion and literature which diſtinguiſhes his reign, was graciouſly pleaſed to judge them worthy of a public reward. By a royal mandate to the Exchequer in Scotland, dated July 25th 1780, a penſion of L.200 a-year was conferred on their author, which continued unaltered till his death.

In that department of his profeſſional duty which regarded the government of the church, Dr Blair was ſteadily attached to the cauſe of moderation. From diffidence, and perhaps from a certain degree of inaptitude for extemporary ſpeaking, he took a leſs public part in the conteſts of eccleſiaſtical politics than ſome of his contemporaries ; and, from the ſame cauſes, he never would conſent to become moderator of the General Aſſembly of the Church of Scotland. But his influence among his brethren was extenſive : his opinion, guided by that ſound uprightneſs of judgment, which formed the predominant feature of his intellectual character, had been always held in high reſpect by the friends with whom he acted ; and, for many of the laſt years of his life, it was received by them almoſt as a law. The great leading principle in which they cordially concurred with him, and which directed all their meaſures, was to preſerve the church, on the one ſide, from a ſlaviſh, corrupting dependance on the civil power ; and, on the other, from a greater infuſion of democratical influence than is compatible with good order, and the eſtabliſhed conſtitution of the country.

The reputation which he acquired in the diſcharge of his public duties, was well ſuſtained by the great reſpectability of his private character. Deriving from family aſſociations a ſtrong ſenſe of clerical decorum, feeling on his heart deep impreſſions of religious and moral obligation, and guided in his intercourſe with the world by the ſame correct and delicate taſte which appeared in his writings, he was eminently diſtinguiſhed through life by the prudence, purity, and dignified propriety of his conduct. His mind, by conſtitution and culture, was admirably formed for enjoying happineſs. Well balanced in itſelf by the nice proportion and adjuſtment of its faculties, it did not incline him to any of thoſe eccentricities, either of opinion or of action, which are too often the lot of genius :—free from all tincture of envy, it delighted cordially in the proſperity and fame of his companions : ſenſible to the eſtimation in which he himſelf was held, it diſpoſed him to dwell at times on the thought of his ſucceſs with a ſatiſfaction which he did not affect to conceal : inacceſſible alike to gloomy and to peeviſh impreſſions, it was always maſter of its own movements, and ready, in an uncommon degree, to take an active and pleaſing intereſt in every thing, whether important or trifling, that happened to become for the moment the object of his attention. This habit of mind, tempered with the moſt unſuſpecting ſimplicity, and united to eminent talents and inflexible integrity, while it ſecured to the laſt his own reliſh of life, was wonderfully calculated to endear him to his friends, and to render him an invaluable member of any ſociety to which he belonged. Accordingly there have been few men more univerſally reſpected by thoſe who knew him, more ſincerely eſteemed in the circle of his acquaintance, or more tenderly beloved by thoſe who enjoyed the bleſſing of his private and domeſtic connection.

In April 1748, he married his couſin Katharine Bannatine, daughter of the Rev. James Bannatine, one of the miniſters of Edinburgh. By her he had a ſon who died in infancy, and a daughter who lived to her twenty-firſt year, the pride of her parents, and adorned with all the accompliſhments that became her age and ſex. Mrs Blair herſelf, a woman of great good ſenſe and ſpirit, was alſo taken from him a few years before his death, after ſhe had ſhared with the tendereſt affection in all his fortunes, and contributed near half a century to his happineſs and comfort.

Dr Blair had been naturally of a feeble conſtitution of body ; but as he grew up his conſtitution acquired greater firmneſs and vigour. Though liable to occaſional attacks from ſome of the ſharpeſt and moſt painful diſeaſes that afflict the human frame, he enjoyed a general ſtate of good health ; and, through habitual cheerfulneſs, temperance, and care, ſurvived the uſual term of human life.—For ſome years he had felt himſelf unequal to the fatigue of inſtructing his very large congregation from the pulpit ; and, under the impreſſion which this feeling produced, he has been heard at times to ſay with a ſigh, "that he was left almoſt the laſt of his contemporaries." Yet he continued to the end in the regular diſcharge of all his other official duties, and particularly in giving advice to the afflicted, who, from different quarters of the kingdom, ſolicited his correſpondence. His laſt ſummer was devoted to the preparation of the laſt volume of his ſermons; and, in the courſe of it, he exhibited a vigour of underſtanding and capacity of exertion equal to that of his beſt days. He began the winter pleaſed with himſelf on account of the completion of this work; and his friends were flattered with the hope that he might live to enjoy the acceſſion of emolument and fame which he expected it would bring. But the ſeeds of a mortal diſeaſe were lurking unperceived within him. On the 24th of December 1800, he complained of a pain in his bowels, which, during that and the following day, gave him but little uneaſineſs; and he received as uſual the viſits of his friends. On the afternoon of the 26th, the ſymptoms became violent and alarming:—he felt that he was approaching the end of his appointed courſe: and retaining to the laſt moment the full poſſeſſion of his mental faculties, he expired on the morning of the 27th, with the compoſure and hope which become a Chriſtian paſtor.

The lamentation for his death was univerſal and deep through the city which he had ſo long inſtructed and adorned. Its magiſtrates, participating in the general grief, appointed his church to be put in mourning; and his colleague in it, Dr Finlayſon, from whom this account of his life is borrowed*, preached his funeral ſermon, in which his character is drawn in a maſterly manner, though with the almoſt unavoidable partiality of friendſhip.

If we, who know Dr Blair only in his writings, might preſume to eſtimate his intellectual character, we ſhould ſay that he poſſeſſed a ſound judgment rather than what could be called a vigorous mind; that he had more taſte than genius; and that he taught ſucceſsfully, as far as it can be taught, *the art of poetry*, though he could not himſelf have been a poet. His moral character was amiable and reſpectable, though he ſeems, even from a hint dropt by his biographer, to have been in a ſlight degree tinctured with vanity. But this was ſurely a venial weakneſs; for where is the head that would be wholly unaffected by the fumes of incenſe burnt before it for fifty years?

BLEACHING. Since the article *Bleaching* in the Encyclopædia was written, very great improvements have been introduced into the art. Of theſe improvements we ſhall proceed to give an account.

1
Diſcovery of the oxy-muriatic acid.

Mr Scheele of Sweden diſcovered the oxy-muriatic acid, or dephlogiſticated muriatic acid, as he called it, about the year 1774, and ſoon after obſerved its effects on vegetable colours. His method of procuring it was as follows: In a ſand-bath is to be placed a glaſs retort, in which muriatic acid has been poured upon manganeſe; to this ſmall receivers are to be adapted capable of containing about twelve ounces each, into which is to be poured about two drachms of water, without any other lute than a ſlip of blotting-paper about the neck of the retort. In about a quarter of an hour a yellow air is perceived in the receiver, which is to be taken off. If the paper has been properly applied, the air ruſhes out forcibly; the receiver muſt be quickly ſtopped, and another applied. Thus many receivers may be filled with the dephlogiſticated muriatic acid; but it is neceſſary to place the retort in ſuch a manner that the drops which riſe into its neck may be able to fall back. The water ſerves to retain the vapours of the acid. "I uſe (ſays he) many receivers, that I may not be obliged to repeat a ſimilar diſtillation for every experiment. It is not proper to employ large ones, becauſe every time they are opened a great part of the acid is diſſipated in the air. What I ſubmitted to examination with this dephlogiſticated muriatic acid was placed in the neck of the receiver, which I had ſtopped. The cork was turned yellow as by aquafortis. Paper tinged with turnſol became almoſt white; all red, blue, and yellow flowers, as alſo green plants, turned yellow in a ſhort time, and the water in the receiver was changed into pure but weak muriatic acid. Neither alkalis nor acids were able to reſtore the colours of the flowers, or of the plants."

2
Its application to bleaching.

M. Berthollet, in 1785, proved that this acid was compoſed of muriatic acid combined with oxygen; and that when it had deprived vegetable matters of their colour, it was reduced to the ſtate of common muriatic acid; that is, it had loſt the oxygen with which it was united. This oxygen had combined with the colouring particles of the vegetable matter, and had rendered them colourleſs. After making theſe obſervations, it occurred to him that the oxy-muriatic acid might produce the ſame effect upon thoſe particles which give colour to thread and cloth, and which it is the object of bleaching to deſtroy. "At firſt (ſays he) I made uſe of water highly impregnated with this acid; and I renewed it when it was exhauſted, until the thread or cloth appeared white; but I ſoon perceived that they were conſiderably weakened, and that they were entirely loſing their ſolidity. I then weakened the liquor a little, and I ſucceeded in bleaching cloth without damaging it. But it ſpeedily became yellow by keeping, eſpecially if it was warmed, or paſſed through an alkaline ley. I reflected upon the circumſtances of common bleaching, and I endeavoured to imitate its proceſs, becauſe I thought the oxygenated muriatic acid might act in the ſame manner as the expoſition of the cloth in the meadows, which alone does not ſuffice, but which appears only to diſpoſe the colouring parts of the cloth to be diſſolved by the alkali of the ley. I examined dew, not only that which falls from the atmoſphere, but alſo that which comes from the nocturnal tranſpiration of plants; and I obſerved that both of them were impregnated with oxygen, ſufficiently to deſtroy the colour of paper ſlightly tinged with turnſol.

Ann. de Chim. II. 158.

"I therefore employed leys, and the action of oxygenated muriatic acid, alternately, and I then obtained a permanent white; and as, at the finiſhing of the common bleaching, the cloth is paſſed through four milk, or through ſulphuric acid diluted with a very large quantity of water, I alſo tried paſſing the cloth through a very dilute ſolution of ſulphuric acid, and I obſerved that the white was thereby rendered more clear. As ſoon as I made uſe of the leys intermediately, I found that it was not neceſſary to employ a concentrated liquor, or to let the cloth, at every immerſion, remain long therein: by this I avoided two inconveniences, which would have rendered this proceſs impoſſible to be

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* *Blair's Sermons*, vol. v.

be practiſed in the large way. The firſt is the ſuffocating odour of the liquor, which it would be very inconvenient, and even dangerous, to reſpire for any length of time, and which has diſcouraged many perſons who tried to uſe it; the ſecond is, the danger of weakening the cloth. I now alſo left off mixing any alkali with the oxygenated muriatic acid, as I had practiſed in the greateſt part of my firſt trials.

"This is nearly the ſtate in which my experiments were, when I made ſome trials in the preſence of the celebrated Mr Watt. A ſingle view ſufficed for a philoſopher whoſe genius has been exerciſed ſo long upon the arts. In a ſhort time Mr Watt wrote to me from England, that even in the firſt operation he had bleached five hundred pieces of cloth at Mr Grigor's, who has a large bleaching-ground at Glaſgow, and who continues to make uſe of the new proceſs. In the mean time M. Bonjour, who had hitherto aſſiſted me in my experiments, and who joins great ſagacity to a moſt extended knowledge of chemiſtry, aſſociated himſelf with Mr Conſtant, at Valenciennes, in order to form an eſtabliſhment in that city."

M. Caillau made a great number of experiments at Paris reſpecting this new mode of bleaching; but the greateſt part of theſe experiments was made upon cotton, which is more eaſy to bleach, and does not require leys ſo often or ſo ſtrong as flax or hemp. He alſo went to St Quentin, to perform the operation upon the cloth of that country; but he found that all the cloths, which he had bleached to the ſatisfaction of the manufacturers, became again of a reddiſh colour when they were expoſed to a common ley, or even when they were left for ſome time in a warehouſe. Several ſimilar complaints were made by other perſons; and M. Berthollet himſelf had obſerved the ſame thing in his own experiments. M. Bonjour, however, and M. Welter, affirmed that the cloth which they had bleached preſerved its colour perfectly. M. Berthollet ſoon found, that the imperfection in his bleaching was owing to the manner in which he had uſed the leys. "I had contented myſelf (ſays he), in thoſe trials on ſmall pieces which I made in my laboratory, to pour the hot alkaline ſolution into a veſſel where I placed the pieces: it there became cool very rapidly, and therefore did not act with ſufficient power; but when I let theſe pieces remain in the liquor, which I kept nearly in a boiling heat during the ſpace of two or three hours, they were then no longer ſubject to the above mentioned defects: it was therefore merely the weakneſs of the leys which had occaſioned the accidents which were experienced by Meſſrs Caillau, Décroiſille, and myſelf. It is neceſſary that the colour of the cloth ſhould not be changed by the laſt ley, and this is the ſureſt mark that the bleaching is finiſhed; nevertheleſs, after this laſt action of the ley, it is proper to put the cloth, for a few moments, in the bleaching liquor.

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"After this laſt immerſion, it is neceſſary to plunge the cloth in ſour milk, or in water acidulated with ſulphuric acid. I do not know the moſt convenient proportion of ſulphuric acid; but it appeared to me that we might ſucceſsfully, and without danger, make uſe of one part, in weight, of this acid to fifty of water. We muſt keep the cloths during about half an hour in this liquor warmed; after which it is proper to ſqueeze them well, and plunge them directly into common water; for if the evaporation ſhould take place, the ſulphuric acid, becoming thereby concentrated, would corrode them. The cloths being then well waſhed, require only to be dried and dreſſed in the ordinary manner, according to their different ſorts.

"It is of the utmoſt importance to take care that the water is not too ſtrongly impregnated with the ſulphuric acid.

"The bleaching of cotton cloth is much eaſier and ſhorter; two leys, or at moſt three, and as many immerſions in the bleaching liquor, are ſufficient for them. As they are bleached ſo eaſily, it is advantageous, when there are flaxen, hempen, and cotton cloths, to be bleached, to reſerve for the cotton the liquors which have been previouſly weakened by the cloths of flax or hemp; for it is economical to exhauſt the liquors as much as poſſible, and thoſe which are conſiderably weakened ſtill ſuffice for the cotton, although they have ſcarcely any action upon hemp or flax.

"Thread, in the common way of bleaching, is attended with a far greater number of difficulties than cloth; becauſe of the immenſe number of ſurfaces which it is neceſſary to preſent ſucceſſively to the action of the atmoſphere. Some part of theſe difficulties occur in bleaching with the oxygenated muriatic acid; nevertheleſs, in the end, it is more advantageous with reſpect to thread than with reſpect to cloth. M. Welter has formed at Liſle, with two partners, an eſtabliſhment for bleaching thread, with great ſucceſs, and he has already begun ſome others. He has found that ten or twelve leys, and as many immerſions, are required for ſome ſorts of thread; and, that the thread may be ſurrounded with the liquor, it is neceſſary to place it, quite looſely, in a baſket, which permits the liquor to penetrate to all its ſurfaces; when the liquor is much weakened, it is ſtill fit to be uſed for the bleaching of cotton.

"I had, in the beginning of my experiments, tried whether the vapour would not be preferable to the oxygenated muriatic acid in a liquid ſtate, and I obſerved that it bleached with greater quickneſs; but, whatever precautions I employed, it appeared to me that a conſiderable loſs of it took place; that thoſe parts of the cloths which were the moſt expoſed to it were ſubject to be weakened; and that it was more difficult to obtain an equal whiteneſs throughout.

"To prevent all the accidents which may reſult from the liquor acting with too great power, it is important to have a means of meaſuring its force. M. Décroiſille thought of uſing, for that purpoſe, a ſolution of indigo in ſulphuric acid. He takes one part of indigo, reduced into fine powder, and eighteen parts of concentrated ſulphuric acid; this mixture is put into a matraſs, which is kept, during ſome hours, in a water-bath; when the ſolution is finiſhed, it is diluted with a thouſand parts of water. To try the power of the oxygenated muriatic acid, one meaſure of this ſolution is put into a graduated glaſs tube, and ſome of the liquor is gradually added to it, until the colour of the indigo is deſtroyed. We muſt firſt determine how many meaſures of a liquor, the goodneſs of which has been aſcertained by experiments made upon cloth, are neceſſary to deſtroy the colour of one meaſure of the ſolution of indigo, and this number will ſerve to eſtimate the reſpective ſtrength of all the liquors which it may be neceſſary

ceſſary to compare with it. Mr Watt employs, in the ſame manner, a ſolution of cochineal."

3
Method of procuring the acid for bleaching.

M. Berthollet recommended the following method of procuring the oxy-muriatic acid: "If we have good oxide of manganeſe, formed in ſmall cryſtals, and containing but little extraneous matter, the proportions of the ſubſtances to be ſubmitted to diſtillation are the following: Six ounces of calx of manganeſe reduced to powder; one pound of common ſalt, alſo reduced to powder; twelve ounces of concentrated ſulphuric acid, or oil of vitriol; from ten to twelve ounces of water.

"When theſe materials are prepared, we muſt carefully mix the oxide of manganeſe with the common ſalt, and introduce the mixture into the diſtilling veſſel placed upon a ſand bath: we muſt then pour upon it the ſulphuric acid, previouſly diluted (and of which the heat occaſioned by its mixture with water is diſſipated), and immediately apply to the mouth of the matraſs the tube which is to conduct the gas into the intermediate veſſel.—It muſt not be forgot, that in this operation the lutes require particular attention.

"The ſize of the veſſels ſhould be ſuch, that the diſtilling matraſs may be about one-third empty; and, for the quantity above mentioned, the tub ſhould hold 100 quarts of water; there ſhould alſo be an empty ſpace of about 10 quarts, in order that when the gas lodges itſelf in the cavities intended to receive it, the water may have a free ſpace to riſe in.

"Before the commencement of the operation, the pneumatic tub muſt be filled with water. The mixture being made, the gas, which very ſoon begins to diſengage itſelf, drives out the atmoſpherical air which is in the apparatus; when it is judged that the atmoſpheric air has paſſed into the cavities, it is to be drawn off by means of a bent tube, which is to be introduced ſucceſſively under each cavity: to drive out the water which has entered into the tube, this laſt is to be forcibly blown into. The operation is then ſuffered to go on without fire until it is perceived that the bubbles come over but ſlowly: then a little fire is to be applied, which is not to be haſtily increaſed at the beginning, but may be gradually augmented, ſo that at the end of the operation the matter may be brought to a boiling ſtate. It is known to be nearly finiſhed when the tube by which the gas is diſengaged, and the intermediate veſſel, become hot. When the gas is diſengaged only in a ſmall quantity, the fire may be withdrawn; and when the diſtilling veſſel retains but a gentle warmth, it is to be unluted, and warm water is to be poured upon the reſidue, that it may remain in ſolution, and thereby be more eaſily poured out.

"The operation is longer or ſhorter according to the quantity of materials: with that above mentioned, it ſhould laſt five or ſix hours; it is proper not to haſten it, that a larger quantity of gas may be drawn off. A ſingle perſon is able to manage ſeveral diſtillations at the ſame time; to each of which may be given much larger quantities of materials than thoſe which have been pointed out.

"The intermediate veſſel by degrees becomes filled with a liquor, which is pure, though weak, muriatic acid; nevertheleſs, we may perform the operation ſeveral times without extracting it: but when it is ſuppoſed that there is not ſufficient empty ſpace, this acid is to be drawn off by means of a ſyphon, and, when we have collected a ſufficient quantity of it, it may be ſubſtituted for the mixture of vitriolic acid and common ſalt in the operation we have deſcribed, if we have no other uſe to make of it. That there may paſs but a ſmall quantity of muriatic acid, not oxygenated, the firſt tube ought to form a right angle, or even an obtuſe one, with the body matraſs.

"During the operation, the agitator muſt be from time to time put in motion, to favour the abſorption of the gas by the water; when it is finiſhed, the liquor is of a proper ſtrength to uſe in bleaching; or we may put a leſs quantity of water in the tub, and then dilute the liquor according to the proportion already mentioned.

"In this ſtate of concentration, although the liquor has a pretty ſtrong odour, it nevertheleſs is not hurtful, nor even very unpleaſant, to thoſe who uſe it: it is, however, proper to conduct it into the troughs where the cloths are placed by means of wooden canals, which are to be connected with the fauſet or tube which is at the lower part of the tub."—The following is a deſcription of the apparatus:

Plate VII fig. 1.

ABCD is a reverberatory furnace, having, on a line with B, many ſmall openings in its circumference, to ſerve as chimneys; within which, upon a ſand-bath *a*, is placed a matraſs *b*, the neck of which ſtands out above the furnace, running through the opening D; which is to be cloſed with clay. The mouth F, of the neck of the matraſs, is cloſed by a cork G, through the middle of which paſſes a tube H, which forms a communication between the inſide of the matraſs *b*, and the intermediate veſſel K, where it alſo paſſes through a cork I, which cloſes one of the three openings of that veſſel. The corks G and I ought to be prepared before-hand, and well fitted to each end of the tube of communication H, which is to be ſo diſpoſed that it may be fitted in immediately after the mixture is made in the matraſs.

The intermediate veſſel K is about an eighth part full of water; into it is plunged the tube of ſafety L, to prevent danger from regurgitation. This tube ought to be ſo high, that the weight of the water which enters into it, by the preſſure of the gas, may be great enough to cauſe the gas to paſs into the pneumatic tub NOP, by the tube of communication M, which is plunged therein, and reaches to the bottom, where it is bent horizontally, ſo that the gas may be emitted under the firſt of the three wooden, or (if they can be procured) ſtoneware, cavities, or receivers, which are placed in the inſide of the tub, one above the other. O is a handle which ſerves to turn the agitator E, the movement of which facilitates the combination of the gas with the water. P is a ſpigot and fauſet to draw off the liquor.

4
Method o
bleaching

It is neceſſary to prepare the cloth by leaving it to ſoak for 24 hours in water, or, which is better, in ſome old ley. Afterwards it ſhould be ſubmitted to the action of one or two good leys; becauſe all the colouring part which may be extracted by the leys would elſe, without any advantage, conſume a part of that liquor, which it is important to be as ſparing of as poſſible. After this, the cloth is to be carefully waſhed; then it is to be placed in the troughs, without any part being preſſed or confined, in ſuch a manner that it may be thoroughly impregnated with the liquor which is to

run

run thereon. The troughs, as well as the tub, ought to be conſtructed without iron; for that metal, being ruſted by the oxygenated muriatic acid, would produce iron moulds, which could not be taken out but by means of ſalt of ſorrel.

The firſt immerſion ought to be longer than the others; it may be continued for three hours, after which the cloth is to be taken out; it is to be again ſubmitted to the action of ley, and then placed in a trough, that freſh liquor may be poured thereon: it is ſufficient that this immerſion, and the following ones, continue half an hour. When the cloth is taken from the trough, the liquor is to be wrung out, it is to be again ſubmitted to the ley, and afterwards to freſh immerſions. The ſame liquor may ſerve until its ſtrength is exhauſted: when it is much weakened, there may be ſome freſh liquor added to it. When the cloth appears white, except ſome black threads and the liſts, it is to be impregnated with black ſoap, and then ſtrongly rubbed; after which it is to be ſubmitted to the laſt ley and the laſt immerſion. We cannot determine what number of leys and immerſions may be neceſſary, becauſe it varies according to the nature of the cloth: neverthleſs, the limits of this number are between four and eight for linen or hempen cloths.

The manufacturers at Javelle, to whom M. Berthollet had communicated this proceſs, ſoon after publiſhed, in different journals, that they had diſcovered a particular liquor which had the property of bleaching cloth by an immerſion of ſome hours only. The change they had made in the proceſs, performed in their preſence, conſiſted in putting ſome alkali into the water which receives the gas; this enables the liquor to become much more concentrated, ſo that it may be diluted with ſeveral times its own quantity of water before it is uſed.

" Theſe are the proportions which yielded me (ſays Berthollet), a liquor ſimilar to the pretended Javelle ley: two ounces and a half of common ſalt, two ounces of ſulphuric acid, ſix drachms of calx of manganeſe, and, in the veſſel where the gas is to be concentrated, one pound of water, and five ounces of potaſh, which ſhould be diſſolved in the water. The Javelle liquor has a ſomewhat reddiſh appearance, occaſioned by a ſmall quantity of manganeſe, which either paſſes in the diſtillation, becauſe an intermediate veſſel is not uſed, or exiſts in the potaſh; moſt kinds of which contain it, as I have well convinced myſelf.

"This liquor may be diluted with from ten to twelve parts of water; and, after this, it bleaches more ſpeedily than the liquor itſelf; but without ſpeaking of the imperfections of the method which is deſcribed in the publications from Javelle, and which can only ſuffice for cotton, we are not able to bleach near the ſame quantity of cloth with the oxygenated muriatic acid combined in this manner with an alkali, as might be bleached with the ſame quantity of that acid mixed with water alone; becauſe there is formed a portion of that neutral ſalt which is known at preſent by the name of oxygenated muriat of potaſs, and in which the oxygen becomes concentrated. Now all the oxygen which enters into the compoſition of this ſalt is rendered uſeleſs for bleaching; becauſe the oxygenated muriat of potaſh does not deſtroy colours."

This method of bleaching was very ſoon adopted in Britain, and is now almoſt univerſal among bleachers. A great many changes have been made in the proceſs; one of the moſt important of which is ſubſtituting lead veſſels for wooden ones, which, beſides weakening its action exceedingly, were very ſoon deſtroyed by the acid. We believe, too, that the bleachers very generally add ſome alkali to the acid, notwithſtanding the ſtrong objections which Mr Bertholiet has made to that manner of bleaching.

This method of bleaching has been found to anſwer remarkably well: the only objection that has been made to it is, that the cloth is apt to be weakened. And this, no doubt, muſt be the caſe, if care be not taken to prevent the acid from being too much concentrated: but we have little doubt that, with a ſufficient degree of caution, it will prove as ſafe as any other whatever; and, in point of expedition, there cannot ſurely be any compariſon drawn between the old mode of bleaching and the new.

It remains for us now to conſider whether the new diſcoveries in chemiſtry do not throw ſome rays of light upon the theory of bleaching; for it is only by perfecting the theory that we can advance with certainty in our practical improvements. 5 Theory of bleaching.

It has been already obſerved, in the article BLEACHING (*Encycl.*), that cloth, after being bleached, was a good deal lighter than it had been before that operation: It follows, therefore, that it muſt have been deprived of ſomething during the bleaching. Cloth bleached by means of the oxy-muriatic acid likewiſe undergoes a loſs of weight; ſo that, in all probability, both modes act in preciſely the ſame manner.

If raw linen or thread be boiled in a ſolution of cauſtic alkali, properly diluted, it gives out ſomething which tinges the ley of a deep brown, and at the ſame time the alkali loſes its cauſticity. If the linen be boiled in another ſimilar ſolution, it communicates the ſame colour, and even a third may be ſlightly tinged; but after this, alkalies, unleſs ſo much concentrated as to injure the texture of the cloth, have no effect on it whatever. If the linen be now plunged into oxy-muriatic acid, properly prepared, and allowed to remain till it begins to become white, and then plunged into an alkaline ley, the alkali loſes its cauſticity, and aſſumes the ſame deep colour that the firſt ley did. Here, then, we have two alkaline ſolutions; the one ſaturated with colouring matter before the action of the oxy-muriatic acid on the linen, the other after it. When theſe ſolutions are ſaturated with an acid, a yellow-coloured precipitate is obtained, which when dried aſſumes the appearance of a black powder. Preciſely the ſame ſubſtance is obtained from both ſolutions. This colouring matter is almoſt inſoluble in water. Pure or cauſtic potaſs diſſolves about double its own weight of it; carbonat of potaſs not ſo much.

Hence we ſee the uſe of alkalies in bleaching. The colouring matter is not ſoluble in water, but part of it is ſoluble in alkali. However, after the alkali has exhauſted all its power, the linen is not white: colouring matter therefore exiſts in it, which alkalies cannot act upon. But after being plunged in oxy muriatic acid, it alſo becomes ſoluble in acids. Here, then, is the uſe of that acid in bleaching—it communicates ſomething to the colouring matter which renders it ſoluble in alkali. This ſomething, we have already ſeen, is oxygen. It

follows,

follows, therefore, that before the greater part of the colouring matter of linen can be extracted by alkalies, it muſt be combined with oxygen. It is in producing this combination that the uſe of the expoſure to the ſun and air conſiſts; and it is becauſe the oxy-muriatic acid produces it almoſt inſtantaneouſly, that the new mode of bleaching is ſo much more expeditious than the old.

If into the alkaline ſolution of the colouring matter lime-water be poured, there takes place a copious precipitate, which conſiſts of the lime and colouring matter combined. Lime, therefore, has a ſtronger affinity for the colouring matter than alkali has; and as the compound of lime and the colouring matter is not very ſoluble in water, lime-water might be uſed to deprive the alkaline ley of the colouring matter which it has imbibed; after which it might be uſed again. Care, however, muſt be taken, that no lime-water remains in the ley; otherwiſe it might precipitate and fix the colouring matter on the linen, after which it would be very difficult to remove it.

6
Nature of the colouring matter of linen.

From an alkaline ley, ſaturated with the colouring matter of linen yarn, Mr Kirwan, by means of muriatic acid, precipitated the colouring matter. He found it to poſſeſs the following properties: When ſuffered to dry for ſome time on a filter, it aſſumed a dark green colour, and felt ſomewhat clammy like moiſt clay. "I took (ſays he) a ſmall portion of it, and added it to 60 times its weight of boiling water, but not a particle of it was diſſolved. The remainder I dried in a ſand heat; it then aſſumed a ſhining black colour, became more brittle, but internally remained of a greeniſh yellow, and weighed one ounce and a half.

Iriſh Tranſ. 1789.

"By treating eight quarts more of the ſaturated ley in the ſame manner, I obtained a further quantity of the greeniſh depoſite; on which I made the following experiments:

"1ſt, Having digeſted a portion of it in rectified ſpirit of wine, it communicated to it a reddiſh hue, and was in a great meaſure diſſolved: but by the affuſion of diſtilled water the ſolution became milky, and a white depoſite was gradually formed; the black matter diſſolved in the ſame manner.

"2dly, Neither the green nor the black matter was ſoluble in oil of turpentine or linſeed oil by a long-continued digeſtion.

"3dly, The black matter being placed on a red hot iron, burned with a yellow flame and a black ſmoke, leaving a coaly reſiduum.

"4thly, The green matter being put into the vitriolic, marine, and nitrous acids, communicated a browniſh tinge to the two former, and a greeniſh to the latter, but did not ſeem in the leaſt diminiſhed.

"Hence it appears, that the matter extracted by alkalies from linen yarn is a peculiar ſort of reſin, different from pure reſins only by its inſolubility in eſſential oils, and in this reſpect reſembling lacs. I now proceed to examine the power of the different alkalies on this ſubſtance. Eight grains of it being digeſted in a ſolution of cryſtallized mineral alkali, ſaturated in the temperature of 60°, inſtantly communicated to the ſolution a dark brown colour; two meaſures (each of which would contain 11 pennyweights of water) did not entirely diſſolve this ſubſtance. Two meaſures of the mild vegetable alkali diſſolved the whole.

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

"One meaſure of cauſtic vegetable alkali, whoſe ſpecific gravity was 1,039, diſſolved the whole.

"One meaſure of liver of ſulphur, whoſe ſpecific gravity was 1,170, diſſolved the whole.

"One meaſure of cauſtic volatile alkali diſſolved alſo a portion of this matter."

The colouring matter of cotton is much more ſoluble in alkali than that of linen; hence the greater facility with which cotton is bleached.

From theſe obſervations, the great importance of alkalies in bleaching, and the neceſſity of regulating the ſtrength, and aſcertaining the purity, of the leys made uſe of, muſt be apparent. Manufacturers, therefore, lie under very great obligations to Mr Kirwan, who has lately examined the alkaline matters uſed in bleaching with his uſual accuracy and abilities. The reſult of his experiments was as follows:

Table of the quantity of mere alkali in 100 *Avoirdupois pounds of the following ſubſtances.*

Iriſh Tranſ. 1789.

One hundred lbs.	*Mineral Alkali.*
Cryſtallized ſoda	20 lbs.
Sweet barilla	24
Mealy's cunnamara kelp	3,437
Ditto deſulphurated by fixed air	4,457
Strangford kelp	1,25
One hundred lbs.	*Vegetable Alkali.*
Dantzic pearl aſh	63,33 lbs.
Clarke's refined aſh	26,875
Caſhup	19,376
Common raw Iriſh weed-aſh	1,666
Ditto ſlightly calcined	4,666

When linen is allowed to remain for ſome time in oxy-muriatic acid, it becomes white. It is evident, then, that when the colouring matter of linen is ſaturated with oxygen, it becomes colourleſs: But linen bleached in this manner very ſoon becomes yellow, eſpecially when expoſed to heat. Berthollet, to whoſe ingenious experiments and obſervations we are indebted for the greater part of the above remarks, has given the following explanation of the cauſe of this change: He diſtilled the colouring matter of linen, and obtained a thick oil, a little ammonia, and $\frac{24}{100}$ of carbon remained behind. The oil contained carbon; and he ſuppoſed that carbonic acid gas, and carbonated hydrogen gas, were diſengaged. He concluded in conſequence, that one-third of this colouring matter was carbon. The other ingredient in the oil was hydrogen; for Lavoiſier has proved that oil is compoſed of oxygen and hydrogen. The colouring matter of linen, then, is compoſed principally of carbon and hydrogen.

Oxygen combines with hydrogen at a lower temperature than it does with carbon; for if a conſiderable quantity of oxy-muriatic acid be mixed with a ſolution of ſugar (a ſubſtance which conſiſts chiefly of carbon and hydrogen), and the liquor be evaporated, there remains behind little elſe than carbon, the hydrogen having combined with oxygen and formed water, which had paſſed off in the form of vapour. Now, whenever a quantity of hydrogen is ſeparated from a body principally

cipally compoſed of hydrogen and carbon, that body aſſumes a brown or yellow colour, becauſe the carbon becomes predominant; and this colour becomes the deeper the greater the proportion of the carbon is, compared to that of the hydrogen; and at laſt, when nothing but carbon remains, it becomes quite black.

It is probable, then, that when the oxy-muriatic acid renders linen white, a quantity of oxygen has combined with the colouring particles; but that this oxygen gradually enters into a combination with the hydrogen, and forms water which paſſes off; that then the carbon becomes predominant, and the linen in conſequence aſſumes a yellow colour*.

7
Bleaching of wool and ſilk.

The ſame method does not ſucceed in bleaching wool and ſilk which anſwers for linen and cotton. One would be diſpoſed to think that theſe ſubſtances are bleached rather by loſing oxygen than by abſorbing it. Wool, for inſtance, is rendered white very quickly when expoſed to the fumes of ſulphurous acid, which we know has a ſtrong affinity for oxygen, and ſoon ſaturates itſelf with it. But what paſſes during the whitening of animal matters has never yet been properly inquired into, though it would not only greatly elucidate *bleaching*, but *dyeing* likewiſe, and throw much light upon ſome of the obſcureſt parts of chemiſtry. A great improvement, however, has lately been made by M. Baumé in the manner of bleaching ſilk. Of this improvement we ſhall proceed to give an account†.

8
New mode of whitening ſilk.

Before the ſilk is wound off the cocons in which the ſilk worms are encloſed, it is neceſſary to kill the inſects, otherwiſe they would in all probability eat thro' it and deſtroy it. This is commonly done by expoſing the cocons, properly wrapped up, for two hours to the heat of about 158 degrees of Fahrenheit in an oven; after which they are kept for a certain time in a maſs to preſerve their heat, and effectually deſtroy ſuch of the inſects as might have eſcaped the power of the oven. The effect of this proceſs is, that the ſilk is hardened, and is more difficult to wind off than before. Hence the product of ſilk is leſs by one ninth part in quantity, and inferior in quality to what might have been obtained by winding off without this previous baking. M. Baumé, not only from theſe views, but likewiſe becauſe the ſilk which has not been baked proves ſuſceptible of a greater luſtre, was induced to deſtroy the chryſalis by ſpirit of wine. For this purpoſe he diſpoſes them in a wooden box in a ſtratum ſix inches deep: upon each ſquare foot half a pint of ſpirit of wine is to be ſprinkled with a ſmall watering-pot made for that purpoſe. The liquid is to be equally diſtributed, but it is not neceſſary that all the cocons ſhould be wetted. They are then to be mixed by hand. In the next place another ſtratum is to be formed over the firſt, nearly of the ſame depth, which is to be ſprinkled and treated as before. By this method of proceeding, the box becomes filled, and muſt then be covered, and left for 24 hours; during which time they become ſpontaneouſly heated to about 100 degrees, and the vapour of the ſpirit of wine exerts itſelf with wonderful activity. After this treatment they muſt be ſpread out to dry, which happens in a ſhort time, and is abſolutely neceſſary previous to winding off.

The ſpirit of wine to be uſed in this operation ought to be of the ſpecific gravity .847, at the temperature of 55 degrees. It is of the greateſt importance to uſe that ſpirit only which has been kept in veſſels of glaſs, of tinned copper, or of pure tin. Leaden veſſels are abſolutely to be rejected; wooden veſſels tinge the ſpirit, which gives the ſilk a degree of colour of conſiderable permanency, and very inimical to the bleaching proceſs.

The ſilk is wound off upon a reel, while the cocons are kept immerſed in water almoſt boiling. Upon this part of the proceſs M. Baumé remarks, 1. That the dead cocons muſt be ſeparated. Theſe are known by the brown or black ſpots on their ſurface. 2. That well-water, which on account of its clearneſs is almoſt univerſally uſed in the ſilk manufactories, moſtly contains nitre, and is extremely prejudicial to the bleaching proceſs. The preſence of nitrous acid gives a yellow colour, which reſiſts bleaching and even ſcouring; he therefore recommends river-water. 3. In ſome countries a ſmall quantity of alum is uſed. Neither this nor any other ſaline ſubſtance is of the leaſt advantage to the colour, beauty, or quality of the ſilk.

At the four places of contact of the ſilk upon the reel, all the threads ſtick together. It is abſolutely neceſſary that this ſhould be remedied. The method conſiſts in ſoaking the ſilk in a ſufficient quantity of warm water, at about 90 degrees, for about two hours; after which the threads are to be ſeparated by opening the hanks upon a pin, and lightly rubbing the parts which cohere. When the ſilk is dry, it is to be looſely folded in its original form, and is ready for bleaching.

The ſilk while wet is ſoft, and part of its gummy matter is in ſuch a ſtate, that its threads would readily adhere, if wrung while warm for the purpoſe of clearing it of the water. After ſuch improper treatment there would be no other remedy than to ſoak it again in warm water.

The apparatus for bleaching the ſilk conſiſts of a ſtone-ware veſſel, nearly of a conical form, capable of holding about 12 gallons, having a large opening at the one end, and a ſmaller of about an inch diameter at the other end. Common pottery cannot be uſed in this operation, becauſe it is ſoon rendered unſerviceable by the action of the muriatic acid, and the ſtone-ware itſelf is not very durable. This veſſel muſt be carefully examined, to aſcertain that it does not leak in the ſlighteſt degree; after which the inſide is to be rubbed with a pumice-ſtone, to clear it of aſperities which might break the threads. A cover of the ſame material is to be fitted on by grinding; and the ſmaller aperture, which in the uſe is the loweſt, is to be cloſed with a good cork, in the middle of which is thruſt a ſmall glaſs tube about a quarter of an inch in diameter; this is likewiſe ſtopped with a cork, excepting at the time when it is required to draw off the liquid contents of the jar. A ſmall perforated falſe bottom is placed within the veſſel, to prevent this tube from being obſtructed.

Six pounds of yellow raw ſilk are to be diſpoſed in the earthen pot; upon this is to be poured a mixture, previouſly made, of 48 pounds of ſpirit of wine of the ſpecific gravity .867, with 12 ounces of very pure marine acid, abſolutely exempt from all preſence of nitrous acid, and of the ſpecific gravity 1.114. The pot is then to be covered, and the whole left in digeſtion till the following day, or until the liquor, which at firſt aſſumes a fine green colour, ſhall begin to aſſume that of a duſky brown.

The acidulated ſpirit is then to be drawn off, clean

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

† See the memoir in the *Ann. de Chim.* xvii. 156. and abridged in *Nicholſon's Journal*, I. 32. from which laſt we have taken our account of it.

ſpirit of wine poured upon the ſilk, and drawn off repeatedly until it paſſes colourleſs. The ſilk is then ſuffered to drain without ſtirring it. In this ſtate it is ready for a ſecond infuſion.

Forty-eight pounds of ſpirit of wine, acidulated with 12 ounces of marine acid, are now to be poured on the ſilk, and the whole ſuffered to remain for 24 hours or longer, until the ſilk becomes perfectly white. The time required for this ſecond infuſion is commonly longer than for the firſt: it ſometimes amounts to two, three, or even ſix days, according to circumſtances, particularly the temperature and the nature of the ſilk. Silk which has been in the oven is in general more difficult to bleach.

When the ſilk has thus obtained its utmoſt degree of whiteneſs, the acidulated ſpirit is to be drawn off into a ſeparate veſſel. This fluid is but ſlightly coloured, and may be uſed again in the firſt infuſion of other yellow ſilk, with the addition of ſix ounces more of marine acid. The receiving veſſel is to be removed, and another clean veſſel ſubſtituted in its place. The ſilk is then ſprinkled with clean ſpirit, and occaſionally preſſed down with the hand. As ſoon as the ſpirit of wine comes off abſolutely colourleſs, a third infuſion is to be made by pouring upon the ſilk 48 pounds of the pure ſpirit without acid, which is to remain till the following day: it is then to be drawn off, and reſerved for waſhing other ſilk after the firſt infuſion.

After the ſilk has been left to drain, and affords no more ſpirit, it ſtill retains its own weight of that fluid. This is recovered by ſprinkling the ſilk with a ſmall quantity of very clear river-water at a time. While the water applies itſelf and ſubſides along the ſilk, it drives the ſpirit of wine before it, ſo that the firſt portions which flow from the tube are ſcarcely diminiſhed in ſtrength. The addition of water is to be continued until nothing but mere water comes off below.

In this ſituation the ſilk is found to be well bleached, but ſtill retains a portion of marine acid ſufficient to render it harſh to the touch, and after a time brittle. It muſt be waſhed off with water. The beſt method is to put the ſilk looſely into a coarſe woollen bag, which is to be ſecured looſely in another cloth like a ſmall bed or pillow, then placed in a baſket, and left in a running ſtream for five or ſix hours; but where the convenience of a ſtream is wanting, the earthen pot containing the ſilk is to be covered with a cloth, and water pumped through it for five or ſix hours, or until that which iſſues from the lower aperture gives no red colour to the tincture of turnſol. At this period the lower opening is to be cloſed, and the veſſel filled with water, which muſt be changed once or twice in 24 hours.

Though the mineral acids are the moſt powerful and deſtructive of all ſaline ſubſtances, yet they may be applied to ſilk when diluted with ſpirit of wine in very conſiderable doſes. In trials made to aſcertain the maximum, two ounces of marine acid were added to one pound of ſpirit of wine, without altering the ſilk. Two drams of marine acid cauſe a very perceptible alteration in one pound of ſilk.

Spirit of wine which has been mixed with nitrous acid cannot be uſed in bleaching, even though afterwards rectified upon an alkali, becauſe it ſtill retains a portion of nitrous gas. Pure ſpirit of wine without acid extracts a fine yellow colour from ſilk, which does not ſeparate for years, even though expoſed to the ſun's light. Yellow ſilk expoſed to the ſun, loſes its colour in a ſhort time. The acidulated ſpirit which has been uſed in the infuſion of ſilk, is changed by expoſure to the ſun, but not in ſuch a manner as to be rendered fit for uſe a ſecond time. In order to obtain a beautiful white colour, it is eſſential that the ſilk ſhould be immerſed in a large quantity of the fluid, eſpecially at the firſt infuſion. Without this management it would become neceſſary to make three infuſions in the acidulated ſpirit. When the firſt infuſion is well managed, the ſilk will have loſt all its yellow colour, and become conſiderably white, at the ſame time that the liquor will have begun to change colour a little. As long as it continues of a fine green, it is certain that it has not exhauſted its whole action upon the ſilk. The duration of this firſt infuſion may be longer or ſhorter, without inconvenience, according to the temperature. When the temperature is at 77° of Fahrenheit, the firſt infuſion is often made in 10 or 12 hours. In ſmall experiments the heat of the atmoſphere may be ſupplied by the water bath; in which caſe all the infuſions are eaſily made in the courſe of a day.

When the firſt infuſion is finiſhed, and the liquor drawn off, the ſilk appears greeniſh: the ſubſequent waſhings in ſpirit of wine clear it of the liquor it retained. This ſprinkling ſhould be made with the watering pot, otherwiſe the quantity poured will be greater, and the management more waſteful.

Pieces of gauze and entire garments of ſilk have been ſucceſsfully bleached in this way.

The fineſt natural white ſilks are rendered infinitely whiter by this proceſs. Spirit of wine alone has the property of depriving yellow ſilk of its colour, which it brings to the ſtate of the naturally white ſilk. In this ſtate the ſilk is diſpoſed to acquire a greater degree of brightneſs by a ſingle infuſion in the acidulated ſpirit. This proceſs has its advantages over the other, to which it is alſo inferior in certain reſpects; concerning neither of which the author has entered into any detail.

The colouring matter was found to be a reſin perfectly animalized, affording by diſtillation the ſame products as other animal matters, and the concrete volatile alkali.

Silk whitened by ſcouring may be dried freely in the air without affecting its luſtre. This is not the caſe with the ſilk bleached in the gum: if it be left at liberty to dry in the air, it reſembles white flax without any luſtre. The beauty of this ſilk conſiſts in its ſhining brilliancy; to ſecure which it muſt be dried in a ſtate of tenſion. Mr Baumé has contrived a ſimple machine for this purpoſe. It conſiſts of a ſtrong ſquare frame of wood ſtanding upright upon feet: the upper horizontal bar is ſix feet long, and has ſix iron pins driven through it at equal diſtances, ſo as to project on each ſide for the purpoſe of receiving twelve bobbins. The lower horizontal bar is moveable up and down in a mortice, by means of a ſcrew at each end: it is furniſhed with ſix holes adapted to receive as many pins to correſpond with thoſe above. The ſkains of ſilk are to be dreſſed and arranged upon wooden pins, as they are taken out of the ſack from waſhing. As ſoon as there are twelve together, they are to be wrung with a ſtaff; after which the ſkains are to be hung one by one upon as many bobbins put upon the upper pins of the ſquare frame.

frame. Another bobbin with tails is to be inſerted in the lower loop of the ſkain, and faſtened to the correſponding pin of the lower bar, by means of a ſtrap and hook, which need not be deſcribed to ſuch as are ſlightly acquainted with mechanical objects. When the machine is thus ſupplied with ſkains on both ſides, the lower bar of the frame is to be preſſed down by the ſcrews until the ſilk is moderately ſtretched. When it is dry, the ſcrews are to be equally ſlackened, the ſkains taken off and folded with a ſlight twiſt, that they may not become entangled.

To complete the deſcription of this proceſs, it only remains to ſhow how to recover the alcohol, and enſure the purity of the acids made uſe of.

9
Method of recovering the alcohol uſed,

The alcohol which has been uſed in bleaching ſilk is acid, and loaded with colouring matter. In this ſtate it cannot be again uſed. There are two methods of diſtilling it which have their reſpective advantages and inconveniences.

By the firſt the acid is loſt; which is ſaturated with potaſs, in order that the diſtillation may be afterwards performed in a copper alembic. A ſolution of potaſs is to be poured into the acid ſpirit, and ſtirred about to promote the ſaturation. Carbonic acid is diſengaged with ſtrong effervеſcence from the alkali; and the point of ſaturation is known by the uſual teſt, that the fluid does not redden the tincture of turnſol. The diſtillation is then to be made in the copper alembic, and the alcohol reſerved in proper veſſels.

In the ſecond proceſs for diſtilling without alkali, the acid ſpirit is diſtributed into a great number of glaſs retorts, placed in the ſand bath, on the gallery of a furnace. The firſt product is ſcarcely acid; but what follows is more and more ſo, and muſt be kept in veſſels of glaſs or ſtone-ware, which become embarraſſing on account of their number. The fluid which remains in the retorts has the colour of beer ſlightly turbid, and contains the greateſt part of the marine acid. It muſt be poured into one or more retorts, and concentrated by heat gradually applied. The firſt liquor which comes over is ſlightly red, turbid, and ſcarcely acid. This is to be thrown away, and the receivers changed. The ſucceeding product is the colourleſs marine acid, of an aromatic ſmell reſembling the buds of poplar. The reſin of the ſilk remains in the retort decompoſed by the acid. The marine acid thus obtained is weaker than it originally was; which is in fact of little conſequence, as it is pure, and may be ſafely uſed, either by increaſing the doſe proportional to its diminiſhed ſtrength, or by concentrating it if required in the uſual way. If this diſtillation be made in a ſilver alembic, inſtead of retorts of glaſs, and a capital and worm of pure tin be annexed, the alcohol will be obtained ſo ſlightly acid as ſcarcely to redden the tincture of turnſol; but it is ſufficiently acid to receive injury if preſerved in a copper veſſel.

10
And of preparing a pure muriatic acid.

As to the acid, Mr Baumé obſerves that the muriatic acid of commerce is unfit for the purpoſe. It was formerly prepared with the marine ſalt of the ſaltpetre manufacturers; and even when it is made with good ſalt, the decompoſition is effected with common vitriolic acid which contains nitrous acid. Marine acid mixed with a ſmall quantity of nitrous acid does not prevent the ſilk from being beautifully whitened: it even accelerates the proceſs conſiderably, and in the moſt ſatisfactory manner. But the alcohol, every time it is uſed and rectified, becomes charged with the acid and gas of nitre, which aſſume the characters of the nitrous anodyne liquor. In this ſtate neither diſtillations nor repeated rectifications from alkali are ſufficient to ſeparate the nitrous matter from the alcohol. Then it is that the ſucceſs of the operator vaniſhes, with a degree of rapidity equal to the advances which encouraged his hopes at the commencement.

To purify common ſulphuric acid, 100 pounds of it are to be mixed in a large baſon of copper with the ſame quantity of river-water, and ſtirred with a wooden ſpatula. The mixture inſtantly becomes heated to the boiling water point, and a great quantity of red vapour is diſengaged, which has the ſmell of aqua-regia, and ariſes from the nitric and muriatic acids. When this mixture is made, it is proper to immerſe the baſon to a ſuitable depth in a large veſſel of water, to haſten the cooling. As ſoon as it is ſufficiently cooled, it is to be drawn off into bottles, and left to become clear during ſeveral days. It is in the next place to be decanted, and conveyed into retorts by a ſyphon funnel, and the rectification proceeded upon until it becomes perfectly white. Towards the end of the operation a ſmall quantity of ſulphur ſublimes in the neck of the retort. Inſtead of receivers, a ſmall glaſs cup is placed beneath the aperture of each retort, in order to facilitate the diſſipation of the nitric and muriatic acids. When the acid in the retorts is ſufficiently cooled, it is poured a ſecond time into the copper baſon, and mixed with 100 pounds of river-water, as at firſt, and again concentrated in the retorts till it becomes perfectly clear. The muriatic acid is to be diſengaged from common ſalt by the application of this acid in the uſual manner.

11
Bleaching paper.

The oxy-muriatic acid is alſo uſed very generally for bleaching paper, or rather the ſtuff out of which paper is made. It has been alleged, and we believe with ſome truth, that ſince this mode of whitening paper was introduced into this country, the ſtrength of paper is much inferior to what it was formerly. If this be really the caſe, perhaps it is owing to the uſe of too concentrated an acid.

We ſhall finiſh this article with Mr Chaptal's account of this proceſs, who was the firſt perſon that introduced it. "Blotting paper (ſays he), by being put into oxygenated muriatic acid, is bleached without ſuffering any injury; and rags of coarſe bad cloth, ſuch as are uſed in the paper manufactories to make this kind of paper, may be bleached by this acid, and will then furniſh paper of a very ſuperior quality. I bleached by it an hundred weight of paſte, intended to be made into blotting paper, and the increaſe of value in the product was computed at 25 *per cent.* whereas the expence of the operation, when calculated in the ſtricteſt manner, amounted only to 7 *per cent.*

12
Mode of whitening old books,

"The property poſſeſſed by this acid, of bleaching paper without injuring its texture, renders it very valuable for reſtoring old books and ſmoked prints. The latter, when diſcoloured to ſuch a degree that the ſubject of them could hardly be diſtinguiſhed, were re-eſtabliſhed and revived, in ſo aſtoniſhing a manner that they appeared to be new; and old books, ſoiled by that yellow tinge which time always produces, may be ſo completely renewed, that one might ſuppoſe them to be juſt come out of the preſs. The ſimple immerſion of a print in oxygenated muriatic acid (leaving it therein a longer or a ſhorter time, according to the ſtrength of the liquor) is all that is required for bleaching it ; but when a book is to be bleached, ſome farther precautions are to be uſed. As it is neceſſary that the acid ſhould wet every one of the leaves, the book muſt be completely ſpread open, and then, by letting the boards of the binding reſt upon the ſides of the veſſel, the paper only will be immerſed in the liquor. If any of the leaves ſtick together they muſt be carefully ſeparated, that all of them may be equally impregnated. The liquor takes a yellow tinge, the paper grows white ; and after two or three hours the book may be taken out of the liquor, and ſoaked in clean water, which ſhould be changed from time to time, in order to waſh out the acid with which the book is impregnated, and alſo to deprive it of the diſagreeable ſmell it has contracted.

“ The above method, which is the firſt I made uſe of, has generally ſucceeded pretty well: too often, however, the leaves of my books have had a motley appearance, and ſometimes ſeveral pages were not at all bleached ; I was therefore obliged to have recourſe to the following more certain proceſs. I began by unſewing the books, and reducing them into ſheets ; theſe ſheets I placed in diviſions made in a leaden veſſel, by means of thin ſlips of wood, ſo that the leaves when laid flat were ſeparated from each other by very ſmall intervals. I then put the acid into the veſſel, pouring it againſt the ſide, that the leaves might not be diſturbed ; and when the operation was finiſhed, I drew off the acid by means of a cock fixed in the bottom of the veſſel. I then filled the veſſel with clean water, which waſhed the leaves, and took off the ſmell of the oxygenated acid. They may then be dried, ſmoothed, and new bound. In this manner I have reſtored many valuable books, which had become worthleſs from the bad ſtate they were in.

13 And prints. “ When I had to bleach prints ſo torn to pieces that they conſiſted only of fragments fitted together, and paſted upon paper, I was afraid I might loſe ſome of theſe fragments in the liquor, becauſe they ſeparate from the paper by the ſoftening of the paſte : in that caſe therefore I took the precaution of encloſing the print in a large cylindrical bottle, which I turned upſide-down, fixing its mouth to that of a veſſel in which I had put a mixture proper for diſengaging oxygenated muriatic gas. This gas fills the inſide of the bottle, and, acting upon the print, takes off the ſtains, ink-ſpots, &c. while the fragments remain paſted to the paper, and conſequently keep their reſpective places.”

BLOCKS (*Encycl.* Plate XCV. fig. 5.) *a* Repreſents a ſingle block, and *b*, *c*, two double ones of different kinds, without ſtraps ; *e*, *f*, two double tackle blocks, iron bound, the lower one, *f*, being fitted with a ſwivel ; *g*, a double iron block with a large hook ; *h*, a ſmall block ; *i*, a top block ; *k*, a voyal block ; *l*, a clew garnet block ; *m*, the cat block, employed to draw the anchor up to the cat-head. See *Cat-Heads*, Encycl.

CAPE OR LARGE SNOUTED BOAR, a ſpecies of the genus Sus, which, according to M. Vaillant, differs from every known ſpecies, and has not been accurately deſcribed by any writer of natural hiſtory. Buffon, indeed, in the Supplement to his Hiſtory of Quadrupeds, has given a figure of it ; but nothing like the head of the animal is diſcoverable, ſays our author, in that figure, all its characteriſtics having been omitted by the draughtſman. M. Vaillant, during his laſt travels in Africa, ſhot a monſtrous boar of this ſpecies on the banks of Fiſh river, and in the country of the *Greater Nimiquas*. He deſcribes it in the following terms : Its ſnout, inſtead of being taper and in the form of a proboſcis, is, on the contrary, very broad and ſquare at the end. It has ſmall eyes, at a very little diſtance from each other, level with the ſurface, and near the top of the forehead. On each cheek a very thick cartilaginous ſkin projects horizontally, being about three inches long and as many broad. At firſt ſight you would be tempted to take theſe excreſcences for the ears ; particularly as the real ears of the animal, ſticking as it were to the neck, which is very ſhort, are partly concealed by an enormous mane, the briſtles of which, in colour red, brown, and greyiſh, are 16 inches in length on the ſhoulders. Directly below theſe falſe ears is a bony protuberance on each ſide, projecting more than an inch, ſerving the animal to ſtrike with to the right and left. The boar has, beſides, four tuſks, of the nature of ivory, two in each jaw : the upper ones are ſeven or eight inches long ; very thick at the baſe, and terminating in an obtuſe point, grooved, and riſing perpendicularly as they iſſue from the lips : the lower ones are much ſmaller, and ſo cloſe to the upper ones when the mouth is ſhut, that they appear as one. The head is a truly hideous object. It is ſcarcely leſs ſo than that of the hippopotamus, to which at firſt view it appears to have a ſtriking reſemblance. Syſtematiſts, accuſtomed to view nature only according to rules eſtabliſhed by themſelves, will be far from acknowledging this animal to be a boar ; for not to mention its large ſnout, it wants inciſive teeth in both jaws. Notwithſtanding its wide muzzle, it ploughs up the earth to ſeek for roots, on which it feeds. It is very active, though large and bulky ; running with ſuch ſpeed, that the Hottentots give it the name of the *runner*.

Plate VII.

BONNET (Charles), was deſcended from a French family, who being compelled, on account of their religious principles, to emigrate from their native country, eſtabliſhed themſelves at Geneva in the year 1572. His grandfather was advanced to the magiſtracy in that city, and adorned by his integrity an eminent ſtation. His father, who preferred the ſtation of a private citizen, paid unremitted attention to the education of his ſon, who was born on the 13th of March 1720 ; and Charles, at a very early period, recompenſed his father's aſſiduity, by the amiableneſs of his diſpoſition, and the rapid progreſs he made in general literature. When he was about 16 years of age, he applied himſelf, with great eagerneſs, to the peruſal of *Le Spectacle de la Nature* ; and this work made ſuch a deep impreſſion on his mind, that it may be ſaid to have directed the taſte and the ſtudies of his future life. What that publication had commenced, was confirmed by the work of *La Pluche* ; but having accidentally ſeen the treatiſe of *Reaumur* upon inſects, he was in a tranſport of joy. He was very impatient to procure the book ; but as the only copy in Geneva belonged to a public library, and as the librarian was reluctant to intruſt it in the hands of a youth, it was with the utmoſt difficulty that he could obtain his end.

By the poſſeſſion of this treaſure, our aſſiduous youth was enabled to make ſeveral new and curious experiments, which he communicated to Reaumur himſelf; and the high applauſe he gained from ſo great a naturaliſt added freſh vigour to his aſſiduity.

In compliance with his father's deſires, he applied himſelf, though with much reluctance, to the ſtudy of the law. The works of *Burlamaqui* pleaſed him the moſt, on account of the perſpicuous and philoſophic manner in which the ſubject was treated: the inſtitutes of *Heineccius* gave him ſome courage alſo, as he perceived order and connection; but the Roman law terrified him as the *hydra of Lerna.* Notwithſtanding his application to theſe authors, he ſtill continued attached to natural hiſtory, and was very active in making experiments. The experiments which demonſtrate that tree-lice propagate without copulation, was communicated by Reaumur to the Academy of Sciences; and this circumſtance occaſioned an epiſtolary correſpondence between M. Bonnet and that great naturaliſt. This was doubtleſs very flattering to a youth of twenty years. The letter of Reaumur was accompanied with a preſent of that very book which he had borrowed with ſo much difficulty two years before.

Animated by ſuch diſtinguiſhed marks of approbation, he diligently employed every moment he could ſteal from the ſtudy of juriſprudence to the completion of his natural hiſtory of the tree-louſe; to experiments on the reſpiration of catterpillars and butterflies, which he diſcovered to be effected by ſtigmata, or lateral pores; to an examination of the conſtruction of the tænia or tape-worm; in frequent correſpondence with Reaumur; and in aſſiſting Trembley in his diſcoveries and publication concerning millepedes, &c. Having in the year 1743 obtained the degree of doctor of laws, he relinquiſhed a purſuit which he had commenced with ſo much reluctance. In the ſame year he was admitted a fellow of the Royal Society, to which he had communicated a treatiſe on inſects.

Bonnet being now liberated from his other purſuits, applied himſelf, without intermiſſion, to collecting together his experiments and obſervations concerning the tree-louſe and the worm, which he publiſhed in 1744 under the title of *Inſectology.* This work acquired deſerved approbation from the public, and was honoured by the commendation of the celebrated B. de Juſſieu. He was reproached, however, in a periodical publication, with having paid too little attention to the delicacy of his reader; though his patience and accuracy were acknowledged to be deſerving of praiſe. Such unremitted application and labour could not fail of becoming injurious to his health. Inflammations, nervous fever, ſore eyes, &c. compelled him to relinquiſh the uſe of the microſcope and the ſtudy of inſects. This prevention was ſo extremely mortifying to a man of his taſte and activity of mind, that he was thrown into a deep melancholy, which could only be ſubdued by the reſolution inſpired by philoſophy, and the conſolations of religion: theſe gradually rouſed him from a dejected ſtate of mind. About the end of the year 1746 our philoſopher was choſen member of the Literary Inſtitution at Bologna, which introduced him to a correſpondence with the famed Zanotti, who may be deemed the Fontenelle of Italy.

In the year 1747 he undertook a very difficult work on the leaves of plants; which, of all his publications in natural hiſtory, bore the ſtrongeſt marks of originality, both with reſpect to the manner in which his experiments were made, and the diſcoveries reſulting from them. His extreme attachment to natural hiſtory gradually led him to a ſtudy of a very different nature; ſpeculative philoſophy now engaged his whole attention. The firſt fruits of his meditations in this department was his *Eſſay on Pſychology.* In this work the principal facts obſervable in human nature, and the conſequences reſulting from them, are ſtated in a conciſe and conſpicuous manner. He contemplated man from the firſt moment of his exiſtence, and purſued the developement of his ſenſes and faculties from ſimple growth up to intelligence. The work, which was publiſhed without his name, met with great oppoſition, and was criticiſed with ſeverity; but the cenſures were directed more againſt his expreſſions than his principles; nor were they of ſufficient importance to impede the general acceptance of the publication.

His analyſis of the mental faculties was ſimply a developement of the ideas contained in the preceding work. It engaged his inceſſant attention for the ſpace of five years; nor was it completed before 1759. It is ſomewhat ſingular that both he and the Abbé de Condillac ſhould have illuſtrated their principles by the ſuppoſition of a ſtatue, organized like the human body, which they conceived to be gradually inſpired with a ſoul, and the progreſſive developement of whoſe powers they carefully traced. In the year 1760 this work was publiſhed at Copenhagen, by order and at the expence of Frederick V. and it was followed in 1762 by contemplations on organized bodies. In this the author had three principal objects before him: the firſt was to give a conciſe view of every thing which appears intereſting in natural hiſtory, reſpecting the origin, developement, and reproduction of organized bodies; the ſecond was to confute the two different ſyſtems founded upon the Epigeneſis; and the third was to explain the ſyſtem of Germs, indicate the ground upon which it was founded, its correſpondence with facts, and the conſequences reſulting from it. This work was received with much ſatisfaction by natural philoſophers. The Academy of Berlin, which had propoſed the ſame ſubject as a prize queſtion for 1761, declared that they conſidered the treatiſe as the offspring of cloſe obſervation and profound reaſoning; and that the author would have had an indubitable right to the prize, if he had confined his labours to the preciſe ſtatement of the queſtion. It muſt alſo be recorded, to the honour of the great *Maleſherbes,* that he reverſed the interdict which the public cenſor had laid upon this book, under the pretext that it contained dangerous principles.

The Contemplation of Nature appeared in 1764. In this work the author firſt enlarged upon the common conceptions entertained concerning the exiſtence and perfections of God; and of the order and uniformity obſervable in the univerſe. He next deſcends to man, examines the parts of his compoſition, and the various capacities with which he is endowed. He next proceeds to the plants; aſſembles and deſcribes the laws of their economy; and, finally, he examines the inſects, indicates the principal circumſtances in which they differ from larger animals, and points out the philoſophical inferences that may legitimately be deduced from theſe differences; and he concludes with obſervations reſpecting the induſtry of inſects. This work being of a popular nature, the author ſpared no pains in beſtowing upon it thoſe ornaments of which it was ſuſceptible. The principles which he thus diſcovered and explained, induced him to plan *a ſyſtem of moral philoſophy;* which, according to his ideas, conſiſted ſolely in the obſervance of that relation in which man is placed, reſpecting all the beings that ſurround him. The firſt branch would have comprehended, various means which philoſophy and the medical ſcience have diſcovered for the prevention of diſeaſe, the preſervation and augmentation of the corporeal powers, and the better exertion of their force: in the ſecond, he propoſed to ſhew, that natural philoſophy has a powerful tendency to embelliſh and improve our mind, and augment the number of our rational amuſements, while it is replete with beneficial effects reſpecting the ſociety at large. To manifeſt the invalidity of opinions, merely hypothetical, he undertook, in the third place, to examine, whether there were not truths within the compaſs of human knowledge, to which the moſt ſceptical philoſopher muſt be compelled to yield his conſent, and which might ſerve as the baſis of all our reaſonings concerning man and his various relations. He then would have directed his attention to a firſt cauſe, and have manifeſted how greatly the idea of a Deity and Supreme Lawgiver favoured the concluſions which reaſon had drawn from the nature and properties of things: but it is deeply to be regretted that his health, impaired by inceſſant labour, would not permit him to complete the deſign.

His laſt publication was the *Palingeneſis*, which treats of the prior exiſtence and future ſtate of living beings.

Of his publications in natural hiſtory, thoſe deemed the moſt excellent are, his Treatiſe on the beſt Means of Preſerving Inſects and Fiſh in Cabinets of Natural Hiſtory; a Diſſertation on the Loves of the Plants; ſundry pieces on the Experiments of *Spallanzani*, concerning the Reproduction of the Head of the Snail; a Diſſertation on the *Pipa*, or Surinam Tod; and different Treatiſes on Bees.

In the year 1783 he was elected honorary member of the Academy of Sciences at Paris; and of the Academy of Sciences and the Belles Lettres at Berlin.

Much of his time was employed in a very extenſive correſpondence with ſome of the moſt celebrated natural philoſophers and others. Of this number were *Reaumur*, *De Geer* the Reaumur of Sweden, *Du Hamel*, the learned *Haller*, the experimental philoſopher *Spallanzani*, *Van Swieten*, *Merian*, and that ornament of Switzerland the great *Lambert*. He entertained, however, the utmoſt averſion to controverſy. He thought that no advantage to be obtained by it could compenſate for the loſs of that repoſe which he valued, with Newton, as the *rem prorſus ſubſtantialem*. He never anſwered remarks that were made to the prejudice of his writings, but left the deciſion with the public; yet, ever ready to acknowledge his errors, he was ſincerely thankful to every one who contributed to the perfection of his works. He was uſed to ſay that one confeſſion, *I was in the wrong*, is of more value than a thouſand ingenious confutations.

His literary occupations, and the care he was obliged to take of his health, prevented him from travelling. He delighted in retirement, and every hour was occupied in the improvement of his mind. The laſt 25 years of his life were ſpent in the ſame rural ſituation where he had paſſed the greater part of his early days; yet notwithſtanding the purſuit of literature was his ſupreme delight, he never refuſed to ſuſpend his ſtudies, when the good of his country ſeemed to demand his ſervices.

He was choſen in 1752 member of the Grand Council in the republic of Geneva: and he aſſiſted regularly at their deliberations till the year 1768, where he diſtinguiſhed himſelf by his eloquence; his moderation, united with firmneſs; by his good ſenſe and penetration in caſes of difficulty; and by the zeal with which he endeavoured to reclaim his fellow-citizens to that ancient ſimplicity of manners which had been ſo conducive to the welfare of the ſtate, and to the love of virtue, ſo eſſential to the exiſtence of genuine liberty. His conduct, in every caſe, was conſiſtent with his principles. He took no pains to accumulate wealth, but remained ſatisfied with a fortune equal to his moderate wants, and to the exerciſe of his benevolence. The perfect correſpondence between his extenſive knowledge and virtuous deeds procured him univerſal eſteem.

In the year 1788 evident ſymptoms of an *hydrops pectoris* manifeſted themſelves; and from this time he gradually declined. He ſuſtained his indiſpoſition with unremitted cheerfulneſs and compoſure. After various fluctuations, uſual in that complaint, he died on the 20th of May 1793, in the 73d year of his age; retaining his preſence of mind to the laſt moment, adminiſtering comfort to ſurrounding friends and relatives, and attempting to alleviate the diſtreſs of his diſconſolate wife, in whoſe arms he expired.

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

BOOK-KEEPING, is an art of which the importance is univerſally known; and as commonly practiſed, it has been ſufficiently explained in the Encyclopædia Britannica. But ſince that ariticle was written, a great improvement has been introduced into the art, or rather a new method of book-keeping has been invented by Mr Edward Thomas Jones of the city of Briſtol, accountant, who calls it the *Engliſh ſyſtem of book-keeping;* and thinks that by it accounts may be more regularly kept, and errors in accounts more eaſily detected, than by any other method hitherto known. We are much inclined to be of his opinion; and ſhall therefore lay before our redears his deſcription of this method, as we find it in the ſpecification of the patent which was granted to him January 26. 1796.

The Engliſh Syſtem of Book-Keeping requires three books, called a *day-book* or *journal*, an *alphabet*, and a *ledger*, which muſt be ruled after the following method, *viz.* the day-book to have three columns on each page, for receiving the amount of the tranſactions; one column of which to receive the amount of debits and credits, one column to receive the debits only, and one column to receive the credits only; or it may be ruled with only two columns on each page, one column to receive the amount of the debits, and one column to receive the amount of the credits. There muſt alſo be on each page of the day-book four other columns ruled,

two

two on the left ſide next the amount of the debits, and two on the right ſide next the amount of the credits, for receiving the letter or mark of poſting, and the page of the ledger to which each amount is to be poſted.

The alphabet need not be ruled at all; but muſt contain the name of every account in the ledger, the letter that is annexed to it as a mark of poſting, and the page of the ledger.

The ledger muſt be ruled with three, four, five, or ſeven columns on each page, as may be moſt agreeable, for receiving the amounts of the different tranſactions entered in the day-book. And the proceſs for uſing theſe books, or making up books of accounts on this plan, is as follows:

When a perſon enters into trade, whether by himſelf or with copartners, he muſt have an account opened with himſelf in the ledger; entering firſt in the day-book, and then to the credit of his account in the ledger, the amount of the property he advances into trade: The account may be headed either with his name only, or elſe called his ſtock-account.

If you buy goods, give the perſon credit of whom you purchaſe; when you ſell goods, debit the perſon to whom ſaid goods are ſold. If you pay money, debit the perſon to whom paid, not only for what you pay, but alſo for any diſcount or abatement he may allow, and give the caſhier credit for the neat amount paid. If you receive money, credit the perſon of whom you receive it, not only for what he pays, but alſo for any diſcount or abatement you may allow, and debit the caſhier for the neat amount received; taking care in theſe entries to have nothing myſterious or obſcure, but merely a plain narrative of the fact, introducing not one uſeleſs word, and avoiding every technical term or phraſe except the words debit and credit, which are full and comprehenſive, and the only terms that are applicable to every tranſaction, and may be affixed to every entry.

But as a hurry of buſineſs will ſometimes take place in almoſt every counting-houſe, which may cauſe the entries to be made to the debit inſtead of the credit of an account in the day-book, and to the credit inſtead of the debit, Mr Jones has endeavoured as much as poſſible to counteract the evil, by having only one column for receiving the amount of every tranſaction, whether debits or credits, at the inſtant of making the entry; and, for the convenience of ſeparating the debits from the credits, previous to poſting, which is neceſſary to prevent confuſion and perplexity, he has two other columns on the ſame page; that on the left ſide into which the amount of every debit muſt be carefully entered, and that on the right for the amount of the credits, which columns muſt be caſt up once a month. The column of debits and credits of itſelf forming one amount; the column for the debits producing a ſecond amount; and the column of credits a third amount; which ſecond and third amounts added together, muſt exactly agree with the firſt amount, or the work is not done right.

By this means the man of buſineſs may obtain monthly ſuch a ſtatement of his affairs as will ſhow how much he owes for that month, and how much is owing to him; and the debits being added together for any given time, with the value of the ſtock of goods on hand, will, when the amount of the credit is ſubtracted therefrom, ſhew the profits of the trade.

Our author now proceeds to the proceſs of poſting: which begins with opening an account in the ledger with every perſon to whoſe debit or credit there has been an entry made in the day-book; affixing to each account a letter, which is to be uſed as a mark of poſting. The perſon's name, place of abode, and the folio of the ledger, muſt then be entered in the alphabet, with the ſame letter prefixed to each name as is affixed to the account in the ledger. Next, the page of the ledger on which each account is opened (and which will be ſeen in the alphabet) muſt be affixed to each amount in the day-book, in the column for that purpoſe. The date and amount of each debit muſt then be poſted in the columns for receiving it in the ledger, on the left or debit ſide of that account to which it relates; entering, as a mark of poſting in the day-book, againſt each amount, the ſame letter that is affixed to the account in the ledger, to which ſaid amount may be poſted. Obſerving that the debits of January, February, March, &c. muſt be poſted into the column for thoſe months in the ledger, and the credits muſt alſo be poſted in like manner, filling up each account in the centre, at the expiration of every month, with the whole amount of the month's tranſactions; thus having, in a ſmall ſpace, the whole ſtatement of each perſon's account for the year; in the columns to the right and left the amount ſeparately of each tranſaction; and in the centre a monthly ſtatement.

Having deſcribed the proceſs of this method of book-keeping, he thus ſhews how to examine books kept by this method, ſo as to aſcertain, to an abſolute certainty, if the ledger be a true repreſentation of the day-book; *i. e.* not only if each tranſaction be correctly poſted, as to the amount thereof, but alſo if it be rightly entered to the debit or credit of its proper account. This examination differs from the modes that have heretofore been practiſed, as well in expedition as in the certain accuracy which attends the proceſs; it being only neceſſary to caſt up the columns through the ledger debits and credits, according to the examples given; and the amount of thoſe columns, if right, muſt agree with the columns in the day-book for the ſame correſponding ſpace of time. Theſe caſtings ſhould take place once a month; and if the amounts do not agree, the poſting muſt then, but not elſe, be called over: and when the time, whether it be one, two, three, or four months, that is allotted to each column of the ledger is expired, the amount of each column ſhould be put at the bottom of the firſt page, and carried forward to the bottom of the next, and ſo on to the end of the accounts; taking care that the amount in the day-book, of each month's tranſactions, be brought into one groſs amount for the ſame time.

But although this proceſs muſt prove that the ledger contains the whole contents of the day-book, and neither more nor leſs, yet it is not complete without the mode of aſcertaining if each entry be poſted to its right account; which may be aſcertained by the following method: He has laid down a rule that a letter, which may be uſed alphabetically in any form or ſhape that is agreeable, ſhall be affixed to each account in the ledger, and the ſame letter prefixed to the names in the alphabet, theſe letters being uſed as marks of poſting, and affixed to each account in the day-book as it is poſted: it is only neceſſary therefore to compare and ſee that the letter affixed to each entry in the day-book is the ſame as is prefixed to the ſame name in the alphabet; a difference here ſhews of courſe an error, or elſe it muſt be right.

At the end of the year, or at any other time, when perſons balance their accounts, if there be no objections to the profits of the trade appearing in the books, the ſtock of goods on hand at prime coſt may be entered in the day book, either the value in one amount, or the particulars ſpecified, as may be moſt expedient, and an account opened for it in the ledger, to the debit of which it muſt be poſted. The caſting up of the ledger muſt then be completed: and when found to agree with the day-book, and the amount placed at the bottom of each column, ſubtract the credits from the debits, and it will ſhew the profit of the trade; unleſs the credits be the greater amount, which will ſhew a loſs. In taking off the balances of the ledger, one rule muſt be obſerved, and it cannot be done wrong: As you proceed, firſt ſee the difference between the whole amounts of the credits and debits on each page for the year, with which the difference of the outſtanding balances of the ſeveral accounts on each page muſt exactly agree, or the balances will not be taken right. By this means every page will be proved as you proceed, and the balances of ten thouſand ledgers, on this plan, could not unobſervedly be taken off wrong.

BOSCOVICH (Roger Joſeph), one of the moſt eminent mathematicians and philoſophers of the preſent age, was born of virtuous and pious parents, on the 11th of May 1711, in the city of Raguſa, the capital of a ſmall republic of the ſame name, lying on the eaſtern coaſt of the Adriatic Sea. At baptiſm, the name of Roger was given him, to which he added that of Joſeph when he received the ſacrament (A) of confirmation.

He ſtudied Latin grammar in the ſchools which were taught by the Jeſuits in his native city. Here it ſoon appeared that he was endued with ſuperior talents for the acquiſition of learning. He received knowledge with great facility, and retained it with equal firmneſs. None of his companions more readily perceived the meaning of any precept than he; none more juſtly applied general rules to the particular caſes contained under them. He enounced his thoughts with great perſpicuity, and came ſoon to compoſe with propriety and elegance. His application was equal to his capacity, and his progreſs was rapid. At the beginning of the 15th year of his age, he had already gone through the grammar claſſes with applauſe, and had ſtudied rhetoric for ſome months. His moral behaviour had likewiſe been very good: he was reſpectful and obedient to his parents and maſters, affable and obliging to his equals, and exemplary in all the duties of religion. It was now time for him to determine what courſe he would ſteer through life; nor did he heſitate long in coming to a reſolution.

The Jeſuit fathers, by teaching the ſciences to youth, were very uſeful, and at the ſame time had a fine opportunity of obſerving their ſcholars, and of drawing into their ſociety thoſe boys who ſeemed fit for their purpoſe. Such a ſubject as the young Boſcovich could not eſcape their attention. They ſhewed him particular kindneſs, to which he was not inſenſible. He had an ardent thirſt for learning; to advance in which he felt himſelf capable; and he thought he could nowhere have a better opportunity of gratifying this laudable inclination than in their order, in which ſo many perſons had ſhone in the republic of letters. Accordingly, with the conſent of his parents, he petitioned to be received among them; and his petition was immediately granted, becauſe it was deſired by thoſe to whom it was made.

It was a maxim with the Jeſuits to place their moſt eminent ſubjects at Rome, as it was of importance for them to make a good figure on that great theatre. Wherefore, as Roger's maſters had formed great expectations of him, they procured his being called to that city; whither he was ſent in the year 1725, and entered the noviceſhip with great alacrity. This noviceſhip was a ſpace of two years, in which the candidate made a trial of his new ſtate of life; and in the mean time his new ſuperiors obſerved him, and deliberated whether or not they would admit him into their body. During theſe two years, the novice was principally employed in exerciſes of piety, in ſtudying books of Chriſtian morality, and in becoming perfectly acquainted with the rules and conſtitutions of the order. After theſe two years were paſt, the Jeſuits were willing to retain Boſcovich, and he was no leſs deſirous of remaining with them. He therefore paſſed to the ſchool of rhetoric; in which, for two other years under the moſt expert maſters of the ſociety, young men perfected themſelves in the arts of writing and ſpeaking, which was of ſo great conſequence to perſons who were deſtined to treat ſo much with their neighbours. Here Boſcovich became perfectly well acquainted with all the claſſical authors, and applied with ſome predilection to Latin poetry.

After this he removed from the noviciate to the Roman College, in order to ſtudy philoſophy, which he did for three years. In order to underſtand the doctrine of phyſics, it was neceſſary to premiſe the knowledge of the elements of geometry, which is alſo otherwiſe proper for forming the mind, and for giving to it a true taſte for truth. Here it was that our young philoſopher came to be in his true element; and it now appeared how extremely fit his genius was for this kind of ſtudy. His maſter, though he was able and expert, inſtead of leading him on, was ſcarcely able to keep pace with him, and his condiſciples were left far behind. He likewiſe found the application of the mathematics to natural philoſophy pleaſant and eaſy. From all this, before the end of the three years, he had made a great advancement in phyſical and mathematical knowledge; and his great merit was generally acknowledged by his companions, and well known to his ſuperiors. He had already begun to give private leſſons on mathematics.

According to the ordinary courſe followed by the Jeſuits, their young men, after ſtudying philoſophy, were

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(A) For this article we are indebted to a dignified clergyman of the church of Rome, who was one of Boſcovich's favourite pupils.

were wont to be employed in teaching Latin and the belles lettres for the ſpace of five years, that ſo they might become ſtill better acquainted with polite learning, and arrive at the ſtudy of theology and the prieſthood at a riper age. But as Roger had diſcovered extraordinary talents for geometrical ſtudies, it was thought by his ſuperiors that it would be a pity to detain him from his favourite purſuits in a drudgery for which ſo many others were fit enough. He was therefore diſpenſed with from teaching thoſe ſchools, and was commanded to commence the ſtudy of divinity.

During the four years that he applied to that ſublime ſcience, he ſtill found ſome leiſure for geometry and phyſics; and even before that ſpace was ended, he was named profeſſor of his beloved mathematics.

He was now placed in an office for which he was ſuperlatively fit, and for which he had a particular predilection. Beſides having ſeen all the beſt modern productions on mathematical ſubjects, he ſtudied diligently the ancient geometricians, and from them learned that exact manner of reaſoning which is to be obſerved in all his works. Although he himſelf perceived eaſily the concatenation of mathematical truths, and could follow them into their moſt abſtruſe receſſes, yet he accommodated himſelf with a fatherly condeſcenſion to the weaker capacities of his ſcholars, and made every demonſtration clearly intelligible to them. When he perceived that any of his diſciples were capable of advancing faſter than the reſt, he himſelf would propoſe his giving them private leſſons, that ſo they might not loſe their time; or he would propoſe to them proper books, with directions how to ſtudy them by themſelves, being always ready to ſolve difficulties that might occur to them.

To the end that he might be the more uſeful to his ſcholars, he took time from higher purſuits to compoſe new elements of arithmetic, algebra, plain and ſolid geometry, and of plain and ſpheric trigonometry; and although theſe ſubjects had been well treated by a great many authors, yet Boſcovich's work will always be eſteemed by good judges as a maſterly performance, well adapted to the purpoſe for which it was intended. To this he afterwards added a new expoſition of conic ſections; in which, from one general definition, he draws, with admirable perſpicuity, all the properties of thoſe three moſt uſeful curves. He had meditated a complete body of pure and mixed mathematics, in which were to be comprehended treatiſes on muſic, and on civil and military architecture; but from accompliſhing this he was prevented by other neceſſary occupations.

According to the cuſtom of ſchools, every claſs in the Roman College, towards the end of the ſcholaſtic year, gave to the public ſpecimens of their proficiency. With this view Boſcovich publiſhed yearly a diſſertation on ſome intereſting phyſico-mathematical ſubject. The doctrine of this diſſertation was defended publicly by ſome of his ſcholars, aſſiſted by their maſter. At theſe literary diſſertations there was always a numerous concourſe of the moſt learned men in Rome. His new opinions in philoſophy were here rigorouſly examined and warmly controverted by perſons well verſed in phyſical ſtudies: but he propoſed nothing without ſolid grounds; he had foreſeen all their objections, anſwered them victoriouſly, and always came off with great applauſe and increaſe of reputation. He publiſhed likewiſe diſſertations on other occaſions; and theſe works, though ſmall in ſize, are very valuable both for the matter they contain, and alſo for the manner in which it is treated. The principal ſubjects of theſe diſſertations are the following: The ſpots in the ſun; the tranſit of mercury under the ſun; the geometrical conſtruction of ſpheric trigonometry; the aurora borealis; a new uſe of the teleſcope for the determination of celeſtial objects; the figure of the earth; the arguments made uſe of by the ancients to prove the rotundity of the ſame; the circles which are called oſculators; the motion of bodies projected in a ſpace void of reſiſtance; the nature of infinities and of infinitely little quantities; the inequality of gravity in different parts of the earth; the annual aberration of the fixed ſtars; the limits of the certainty to which aſtronomical obſervations can arrive; a diſcuſſion on the whole of aſtronomy; the motion of a body attracted by certain forces towards an immoveable centre in ſpaces void of reſiſtance; a mechanical problem on the ſolid of greateſt attraction; a new method of uſing the obſervation of the phaſes in the lunar eclipſes; the cycloid; the logiſtic and certain other curve lines; the forces that are called *living;* the comets; the flux and reflux of the ſea; light; whirlwinds; a demonſtration and illuſtration of a paſſage in Newton concerning the rainbow; the demonſtration and illuſtration of a method given by Euler, regarding the calculation of fractions; the determination of the orbits of a planet by means of catoptrics, certain conditions of its motions being given; the centre of gravity and that of magnitude; the atmoſphere of the moon; the law of continuity, and the conſequences of it in the elements of matter and their forces; the law of the forces that exiſt in nature; lenſes and dioptrical teleſcopes; the perturbation which appears to be cauſed mutually by Jupiter and Saturn, and that chiefly about the time of their conjunction; the diviſibility of matter and the elements of bodies; the objective micrometer;—beſides other ſubjects of the like nature, of which he has treated in ſeparate pieces, or in communications inſerted in the tranſactions of literary ſocieties or academies, he being a member of thoſe that are moſt famous in Europe. It was in ſome of the above-mentioned diſſertations that Boſcovich made known firſt to the world his ſentiments concerning the nature of body, which he afterwards digeſted into a regular theory, which is juſtly become ſo famous among the learned.

Father Noceti, another Jeſuit, had compoſed two excellent poems on the rainbow and the aurora borealis. Theſe poems were publiſhed with learned annotations by Boſcovich; in which, among other things, he with great ſagacity diſcovers errors in optics into which De Dominis, Kepler, and others, had fallen.

His countryman, Benedict Stay, after having publiſhed the philoſophy of Deſcartes in Latin verſe, attempted the ſame with regard to the more modern and more true philoſophy, and has executed it with wonderful ſucceſs, to the admiration of all good judges. The two firſt volumes of this elegant and accurate work were publiſhed with annotations and ſupplements by Boſcovich. Theſe ſupplements are ſo many ſhort diſſertations on the moſt important parts of phyſics and mathematics. Here is to be found a ſolution of the problem of the centre of oſcillation, to which Huygens had come by a wrong method ; here he confutes Euler, who had imagined that the *vis inertiæ* was neceſſary in matter ; here he refutes the ingenious efforts of Riccati on the Leibnitzian opinion of the forces called *living*. He likewiſe ſhews the falſehood of the mathematical prejudice, according to which the right line is conſidered as eſſentially more ſimple than curves, and makes it appear that the notion of the ſaid right line is commonly accompanied with many paradoxes. He demonſtrates, by the doctrine of combinations, ſome beautiful theorems concerning the ſpace occupied by the ſmall maſſes of body, with many uſeful obſervations on ſpace and time.

Benedict XIV. who was a great encourager of learning, and a beneficent patron of learned men, was not ignorant how valuable a ſubject Rome poſſeſſed in Boſcovich ; and this pope gave him many proofs of the eſteem he had for him. Two fiſſures which had been perceived in the cupola of the church of St Peter's on the Vatican had occaſioned ſome alarm. The pope deſired Boſcovich and ſome other mathematicians to make their obſervations, and give their opinion on the ſame. They obeyed, and their opinion was printed. They ſhewed that there was no cauſe to apprehend danger ; but, for greater ſecurity, they propoſed certain precautions, which were adopted and put in execution.

The high opinion which the pope had formed of his talents, and the favour in which he was with Cardinal Valenti, miniſter of ſtate, proved hinderances to his going to America, for which a propoſal was made to him by the court of Liſbon. Some differences had long ſubſiſted between Spain and Portugal concerning the boundaries of their reſpective dominions in that great continent ; and John V. of Portugal wiſhed that Boſcovich would go over and make a topographical ſurvey of the country in diſpute. He was not unwilling to undertake ſuch a taſk, which was entirely to his taſte ; and he was reſolved at the ſame time to meaſure a degree of the meridian in Brazil, which might be compared with that meaſured at Quito by the French academicians Bouguer and Condamine, with the Spaniards Ulloa and Doy. But the pope hearing of this propoſal, ſignified to the Portugueſe miniſter at Rome, that his maſter muſt needs excuſe him for detaining Boſcovich in Italy, where he had occaſion for him, and could by no means conſent to part with him.

Accordingly a commiſſion was given to Boſcovich by Benedict to correct the maps of the papal eſtate, and to meaſure a degree of the meridian paſſing through the ſame. This he performed with great accuracy, aſſiſted by F. Chriſtopher Maire an Engliſh Jeſuit, and likewiſe a great mathematician. Their map was engraved at Rome, and is perhaps the moſt exact piece of the kind that ever was printed, as all the places are laid down from triangular obſervations made by the ableſt hands. Boſcovich alſo publiſhed, in a quarto volume in Latin, an account of the whole expedition, which appeared at Rome in the year 1755, and was afterwards printed at Paris in French in the year 1770. Here he gives a detail of their obſervations and of the methods they followed, and likewiſe of the difficulties they encountered, and how they were ſurmounted. One of theſe embarraſſed them a good deal at the time, but was afterwards matter of diverſion to them and others. Some of the inhabitants of the Apennines, ſeeing them paſs from hill to hill with poles and ſtrange machines, imagined that they were magicians come among their mountains in ſearch of hidden treaſures, of which they had ſome traditions : and as tempeſts of thunder and hail happened about the ſame time, they ſuppoſed that theſe calamities were cauſed by the ſorceries of their new viſitants. They therefore inſiſted that Boſcovich and Maire ſhould depart ; and it was not eaſy to convince them that their operations were harmleſs. In this work there is inſerted a deſcription of the inſtruments made uſe of in determining the extent of the degree of the meridian ; and the whole work may be extremely uſeful to practical geometricians and aſtronomers.

In the year 1757 the republic of Lucca intruſted Boſcovich with the management of an affair which was to them of conſiderable importance. Between that republic and the regency of Tuſcany there had ariſen a diſagreeable diſpute concerning the draining of a lake, and the direction to be given to ſome waters near the boundaries of the two ſtates. The Lucchese ſenate choſe our philoſopher to treat of this buſineſs on their part. He repaired to the ſpot, conſidered it attentively, and drew up a writing, accompanied with a map, to ſhew more clearly what appeared to him moſt equitable and moſt advantageous for both parties. In order to enforce his reaſons the more effectually, it was thought proper that he ſhould go to Vienna, where the Emperor Francis I. who was likewiſe grand duke of Tuſcany, reſided. He was ſo ſucceſsful in this negociation, that he obtained every thing that Lucca deſired, and at the ſame time acquired great eſteem at the Imperial court. In proof of this, the Empreſs Queen made his opinion be aſked concerning the ſtability of the Ceſarean library, and the repairs to be made in it ; which he gave in writing, and it was received with thanks, as being very well grounded.

When he had concluded the affair which had brought him to Vienna, he foreſaw that, for a month or two, the ſnows in the Alps would not allow him to return to Italy. He therefore reſolved to employ that time in completing his ſyſtem of natural philoſophy, on which he had been meditating for the ſpace of thirteen years. He publiſhed his work on that great ſubject in the beginning of the year 1758, in the above-mentioned city. We ſhall in the end give an account of that celebrated ſyſtem, and here go on with our narration.

On his return to Lucca, he not only met with the approbation of all he had done for the intereſt of the republic ; but alſo the ſenate, in teſtimony of their gratitude, made him preſents, and enrolled him in the number of their nobility, which was the greateſt honour they had in their power to confer on him.

He, who was thus uſeful to foreigners, could not refuſe to be ſerviceable to his own country when an occaſion of being ſo offered itſelf. The Britiſh miniſtry had been informed, that ſhips of war, for the French, had been built and fitted out in the ſea-ports of Raguſa, and had ſignified their diſpleaſure on that account. This occaſioned uneaſineſs to the ſenate of Raguſa, as their ſubjects are very ſea-faring, and much employed in the carrying-trade ; and therefore it would have been inconvenient for them to have cauſed any diſguſt againſt them in the principal maritime power. Their countryman Boſcovich was deſired to go to London, in order to ſatisfy that court on the above-mentioned head ;

and with this deſire he complied cheerfully on many accounts. His ſucceſs at London was equal to that at Vienna. He pleaded the cauſe of his countrymen effectually there, and that without giving any offence to the French, with whom Raguſa ſoon after entered into a treaty of commerce.

Boſcovich came to London the more willingly, as he was deſirous of converſing with the learned men of Britain. He was received by the preſident and principal members of the Royal Society with great reſpect; and to that great body he dedicated his poem on the eclipſes of the ſun and moon, which was printed on this occaſion at London, in the year 1760. This is one of his works on which he himſelf put the greateſt value, and it has been much eſteemed by the learned. An edition of it was publiſhed at Venice the year following, and a third at Paris, which is the moſt correct: a tranſlation of it into French has likewiſe been publiſhed at Paris. In this very elegant Latin poem he gives an exact compend of aſtronomy, which ſerves as an introduction to the ſubject; he then explains all that belongs to the doctrine of eclipſes, and their uſe in geography; he conſiders the phenomena that are obſerved in the eclipſes of the ſun, and likewiſe of the moon; he propoſes a theorem, which is his own, concerning the diſtribution of light refracted from the atmoſphere of the earth by the ſhadow of the moon, which happens in the lunar eclipſes; he explains the phenomenon of the reddiſh colour which often appears in the moon when ſhe is eclipſed, of which a ſufficient explication had not before been given: this the author draws from the fundamental doctrine of Newton's theory concerning light and colours; and hence takes occaſion to give a clear idea of the principal conſequences of the ſaid theory. All this is clothed with a beautiful poetical dreſs, and is adorned with pleaſant epiſodes, not to mention the learned annotations which are ſubjoined. This poem was compoſed, for the moſt part, whilſt the author was in journeys, or by way of amuſement, when he was obliged to wait for the opportunities of making aſtronomical obſervations.

The fellows of the Royal Society invited Boſcovich to accompany ſome of their number to America, to obſerve the tranſit of Venus, which was to happen in the year 1762; but being otherwiſe engaged, he could not accept of that invitation. He intended, however, by all means to obſerve that remarkable phenomenon, and had fixed on Conſtantinople as a proper place for doing ſo. He was conducted thither in a Venetian man of war, and much honoured by one of the baylos of that republic, who commanded the veſſel; but, to his great regret, they arrived too late. He returned, by land, in the company of the Engliſh ambaſſador; and a relation of that journey was publiſhed in French and afterwards in Italian.

During theſe journeys, Boſcovich's place in the Roman College was well filled by ſome of thoſe whom he himſelf had trained up in mathematical learning. He was now called by the ſenate of Milan to teach mathematics in the univerſity of Pavia, with the offer of a very conſiderable ſalary. He and his ſuperiors thought proper to accede to this propoſal, and he was received without being ſubjected to any previous examination; which was always obſerved, excepting in ſuch an extraordinary caſe, by the decrees of the univerſity. Here he taught, with great applauſe, for the ſpace of ſix years, having at the ſame time the care of the obſervatory of the Royal College of Brera. About the year 1770, the Empreſs Queen made him profeſſor of aſtronomy and optics in the Palatine ſchools of Milan; requiring of him, however, that he ſhould continue to improve the obſervatory of Brera; which, under his direction, became one of the moſt perfect in Europe.

Here he was extremely happy, teaching the ſciences, applying to his favourite ſtudies, and converſing and correſponding with men of learning and of poliſhed manners; when an event happened which cauſed to him the moſt ſenſible affliction. In the year 1773, the ſociety to which he belonged, and to which he had been from his youth warmly attached, was, to his great regret and diſappointment, aboliſhed. They who had been Jeſuits were allowed no longer to teach publicly; nor was there any exception made in favour of Boſcovich, neither (ſuch was his humour then) would he have accepted of it, though it had been offered him. Propoſals were made to him by ſeveral perſons of diſtinction: and, after ſome deliberation, he choſe Paris for his place of abode; to which he was induced by the circumſtance of his being intimately acquainted with the prime miniſter at that court. He had not been many months at Paris when the univerſity of Piſa ſent him an invitation to go thither, in order to profeſs aſtronomy. But the French miniſter, underſtanding this, declared to the miniſter of Tuſcany, that it was the intention of his moſt Chriſtian majeſty to make his dominions agreeable to Boſcovich, by giving him liberal appointments. In fact he was ſoon naturalized, and two large penſions were beſtowed on him: the one as an honourable ſupport, to the end that he might proſecute his ſublime ſtudies at his eaſe and in affluence; the other as a ſalary annexed to a new office, created in his favour, under the name of *Director of Optics for the Sea Service*, and with the ſole obligation of perfecting the lenſes which are uſed in achromatical teleſcopes.

At Paris he remained ten years, applying principally to optics, and much regarded, not only by the moſt reaſonable men of letters, but likewiſe by the princes and miniſters, both of France and of other nations. But the greateſt men are not exempt from being envied. Some of the French were diſpleaſed that a foreigner ſhould appear ſuperior to themſelves; others of them could not forget that Boſcovich had diſcovered and expoſed their miſtakes. The irreligion which prevailed too much among thoſe who bore the name of philoſophers, was diſagreeable to him. Theſe, and other ſuch circumſtances, made him wearied of Paris, and he deſired to reviſit his friends in Italy; for which purpoſe he obtained leave of abſence for two years.

The firſt place in Italy in which he made any ſtay was at Baſſano, a town in the territories of Venice. Here, mindful of his obligations, he printed what he had been preparing for the preſs during his ſtay in France; and this compoſes five volumes in large octavo, and is a treaſure of optical and aſtronomical knowledge. The ſubjects treated of in theſe volumes are as follow: A new inſtrument for determining the refracting and diverging forces of diaphanous bodies; a demonſtration of the falſehood of the Newtonian analogy between light and ſound; the algebraic formulæ regarding the focuſes of lenſes, and their applications for calculating the ſphericity of thoſe which are to be uſed in achromatical teleſcopes; the corrections to be made in ocular lenſes, and the errors of the ſphericity of certain glaſſes; the cauſes which hinder the exact union of the ſolar rays by means of the great burning glaſſes, and the determination of the loſs ariſing from it; the method of determining the different velocities of light paſſing through different mediums by means of two dioptrical teleſcopes, one common, the other of a new kind, containing water between the objective glaſs and the place of the image; a new kind of objective micrometers; the defects and inutility of a dioptrical teleſcope propoſed and made at Paris, which gives two images of the ſame object, the one direct, the other inverſe, with two contrary motions of moveable objects; maſſes floating in the atmoſphere, as hail of an extraordinary ſize, ſeen on the ſun with the teleſcope, and reſembling ſpots; the aſtronomical refractions, and various methods for determining them; various methods for determining the orbits of comets and of the new planet, with copious applications of theſe doctrines to other aſtronomical ſubjects, and ſtill more generally to geometry and to the ſcience of calculation; the errors, the rectifications, and the uſe of quadrants, of ſextants, of aſtronomical ſectors, of the meridian line, of teleſcopes called the inſtruments of tranſits, of the meridian, and of the parallactic machine; the trigonometrical differential formulæ, which are of ſo much uſe in aſtronomy; the uſe of the micrometical rhombus, extended to whatever oblique poſition; the error ariſing from refractions in uſing the aſtronomical ring for a ſundial, and the correction to be made; the appearing and the diſappearing of Saturn's ring; the methods of determining the rotation of the ſun by means of the ſpots, propoſed formerly by the author, and now perfected; the greateſt exactneſs poſſible in determining the length of a pendulum oſcillating every ſecond of middle time by the compariſon of terreſtrial and celeſtial gravity; a compend of aſtronomy for the uſe of the marine, containing the elements of the heavenly motions, and of the aſtronomical inſtruments to be explained to a prince in the courſe of one month; a method for determining the altitude of the poles with the greateſt exactneſs, by means of a gnomon alone, where other inſtruments are not to be had; the determination of the illuminated edge of the moon to be obſerved on the meridian; a method of uſing the retrograde return of Venus to the ſame longitude, for determining the leſs certain elements of her orbit; a method for correcting the elements of a comet, of which the longitude of the node is given, and the inclination of the orbit has been found nearly; another method for the ſame purpoſe, and for finding the elliptical orbit, when the parabolic one does not agree with the obſervations; a method for correcting the elements of a planet by three obſervations; the projection of an orbit inclined in the plane of the ecliptic; the projection of an orbit inclined in any other plane; the calculation of the aberration of the ſtars, ariſing from the ſucceſſive propagation of light; ſome beautiful theorems belonging to triangles, which are of great uſe in aſtronomy, reduced to moſt ſimple demonſtrations.

After having ſeen the impreſſion of theſe five volumes finiſhed, Boſcovich left Baſſano, made an excurſion to Rome, and viſited his old friends there and in other places of Italy. He then took up his abode at Milan, and applied to the reviſing of ſome of his old works, and to the compoſing of new ones. He ſet himſelf particularly to prepare annotations and ſupplements to the remaining two volumes of Stay's Modern Philoſophy, which he had not had time to publiſh ſooner, and which he lived not to publiſh.

He was happy at Milan in the neighbourhood of Brera, where was his favourite obſervatory; and in the company of many friends, who were become the more dear to him by his long abſence from them. But he began to conſider, with grief, that his two years of abſence were drawing to an end. He was very unwilling to leave Italy and return to France. He thought of applying for a prolongation of his abſence; he thought of making intereſt at the Imperial court for ſome honourable commiſſion, which might be a pretext to him for remaining at Milan: but he was afraid that the propoſal of never returning to France might appear indelicate and ungrateful to a nation from which he was receiving conſiderable penſions. He apprehended that thoſe perſons at Paris who had before oppoſed him, would take occaſion to tax him with ingratitude, and that hence his reputation would be tarniſhed. Theſe, and other ſuch thoughts, occaſioned a great perplexity of mind, which was followed by a deep melancholy; and this could not be alleviated by the advice and comfort of his friends, becauſe by degrees he became incapable of hearing reaſon, his ideas being quite confuſed, and his imagination diſordered. To this diſagreeable change the ſtate of his health perhaps contributed. A gout had been wandering for ſome time through his body, and he had caught a ſevere cold; nor would he admit of medical aſſiſtance, of which he had always been very diffident. It may alſo be that his long and intenſe application had hurt the organs of the brain, which in ſome manner are ſubſervient to the uſe of reaſon as long as the ſoul is united to the body. Be that as it will, during the laſt five months of his life, this great man, who had been ſo far ſuperior in reaſoning to his ordinary fellow-creatures, was much inferior to every one of them who is endued with the right uſe of the underſtanding. He had indeed ſome lucid intervals, and once there were hopes of a recovery; but he ſoon relapſed, and an impoſthume breaking in his breaſt, put an end to his mortal exiſtence. He died at Milan on the 13th of February 1787, in the 76th year of his age.

He was tall in ſtature, of a robuſt conſtitution, of a pale complexion. His countenance was rather long, and was expreſſive of cheerfulneſs and good humour. He was open, ſincere, communicative, and benevolent. His friends ſometimes regretted that he appeared to be too irritable, and too ſenſible of what might ſeem an affront or neglect, which gave himſelf unneceſſary uneaſineſs. He was always unſtained in his morals, obedient to his ſuperiors, and exact in the performance of all Chriſtian duties, as became a Catholic prieſt, and in the obſervance of the particular rules of his order. His great knowledge of the works of Nature made him entertain the higheſt admiration of the power and wiſdom of their Creator. He ſaw the neceſſity and advantages of a divine revelation, and was ſincerely attached to the Chriſtian religion; having a ſovereign contempt of the preſumption and fooliſh pride of unbelievers, and being fully perſuaded that we cannot make a more noble uſe of our underſtanding than by ſubjecting it humbly to the authority of the Supreme Being, who knows numberleſs truths far beyond the utmoſt limits of our narrow comprehenſion, and who may juſtly require our belief of any of them that he ſees fit to propoſe to us.

The death of our philoſopher, who truly deſerved that name, was heard with regret by the learned through Europe, and more than ordinary reſpect has been paid to his memory. At Raguſa funeral exequies were performed for him with great ſolemnity by order of the ſenate, who aſſiſted at them in a body; on which occaſion an eloquent oration in praiſe of him was pronounced. By a decree of the ſame ſenate, a Latin inſcription to his honour, engraved on marble, was placed in the principal church of their city. Of this inſcription the following is a copy:

Boſcovichii Elogium Raguſæ,
Marmore Inſculptum.
Rogerio. Nicolai. F. Boſcovichio,
Summi. Ingenii. Viro. Philoſopho. Et. Mathematico. Præſtantiſſimo
Scriptori. Operum. Egregiorum
Res. Phyſicas. Geometricas. Aſtronomicas
Plurimis. Inventis. Suis. Auctas. Continentium
Celebriorum. Europæ. Academiarum. Socio
Qui. In. Soc. Jeſu. Cum. Eſſet. Ac. Romæ. Matheſim. Profiteretur
Benedicto. XIV. Mandante
Multo. Labore. Singulari. Induſtria
Dimenſus. Eſt. Gradum. Terreſtris. Circuli
Boream. Verſus. Per. Pontificiam. Ditionem. Tranſeuntis
Ejuſdemque. Ditionis. In. Nova. Tabula. Situs. Omnes. Deſcripſit.
Stabilitati. Vaticano. Tholo. Reddundæ
Portubus. Superi. Et. Inferi. Maris. Ad. Juſtam. Altitudinem. Redigendis
Reſtagnantibus. Per. Campos. Aquis. Emittendis. Commonſtravit. Viam
Legatus. A. Lucenſibus. Ad. Franciſcum. I. Cæſarem. M. Etruriæ. Ducem.
Ut. Amnes. Ab. Eorum. Agro. Averterentur. Obtinuit
Merito. Ab. Iis. Inter. Patricios. Cooptatus
Mediolarum. Ad. Docendum. Mathematicas. Diſciplinas. Evocatus
Braidenſem. Extruxit. Inſtruxitque. Servandis. Aſtris. Speculam
Deletæ. Tum. Societati. Suæ. Superſtes
Lutetiæ. Pariſiorum. Inter. Galliæ. Indigenas. Relatus
Commiſſum. Sibi. Perficiundæ. In. Uſus. Maritimos.
Opticæ. Munus. Adcuravit
Ampla. A. Ludovico. XV. Rege. Xmo. Attributa. Penſione
Inter. Hæc. Et. Poeſim. Mira. Ubertate. Et. Facilitate: Excoluit
Doctas. Non. Semel. Suſcepit. Per. Europam. Perigrinationes
Multorum. Amicitias. Gratia. Virorum. Principum. Ubique. Floruit
Ubique. Animum. Chriſtianarum. Virtutum
Veræque. Religionis. Studioſum. Præ-ſe-tulit
Ex. Gallia. Italiam. Reviſens. Jam. Senex
Cum. Ibi. In. Elaborandis. Edendiſque. Poſtremis. Operibus
Plurimum. Contendiſſet. Et. Novis. Inchoandis. Ac. Veteribus. Abſolvendis
Seſe. Adcingeret
In Diuturnum. Incidit. Morbum. Eoque. Obiit. Mediolani
Id. Feb. An. MDCCLXXXVII. Natus. Annos LXXV. Menſes IX. Dies II.
Huic. Optime. Merito. De. Republica. Civi
Quod. Fidem. Atque. Operam. Suam. Eidem. Sæpe. Probaverit
In. Arduis. Apud. Exteras. Nationes
Bene. Utiliterque. Expediundis. Negotiis
Quodque. Sui. Nominis. Celebritate. Novum. Patriæ. Decus. Adtulerit
Poſt. Funebrem. Honorem. In. Hoc. Templo. Cum. Sacro. Et. Laudatione
Publice. Delatum
Ejuſdem. Templi Curatores
Ex. Senatus. Conſulto
M. P. P.

This inſcription was compoſed by his friend and countryman the celebrated poet Benedict Stay. Zamagna, another of his countrymen, who had likewiſe been his fellow-jeſuit, publiſhed a panegyric on him in elegant Latin. A ſhort encomium of him is to be found in the *Eſtratto della Litteratura Europea*; and another, in form of a letter, was directed by M. de la Lande to the Pariſian journaliſts, and by them given to the public. A more full elogium has been written by M. Fabroni; and another is to be met with in the journal of Modena; a third was publiſhed at Milan by the Abbate Ricca; and a fourth at Naples by the Dr Julius Bajamonti, of which a ſecond edition was made in the year 1790. Of this laſt chiefly uſe has been made here.

But what muſt ſecure to Boſcovich the eſteem of poſterity are his works, of the greater part of which we have:

Boſcovich.

have already taken notice. We have mentioned, 1. His Elements of Mathematics, with his Treatiſe on Conic Sections; 2. His many diſſertations publiſhed during his profeſſorſhip in the Roman college; 3. His account of his Survey of the Pope's Eſtate; 4. His Theory of Natural Philoſophy; 5. His Poem on the Eclipſes; 6. His five volumes printed at Baſſano.

To theſe we may add his hydrodynamical pieces. He had made a particular ſtudy of the force of running water, and of its effects in rivers; and he was often conſulted concerning the beſt means to prevent rivers from corroding their banks, and from overflowing the neighbouring plains, which often happens in Italy, where the Alps and Apennines pour down ſo many impetuous ſtreams. He gave a writing on the damages done by the Tiber at Porto Felice; another on the project of turning the navigation to Rome from Fiumicino to Maccareſe; a third on two torrents in the territory of Perugia; a fourth on the bulwarks on the river Panaro; a fifth on the river Sidone, in the territory of Placentia; a ſixth on the entrance into the ſea of the Adige. He wrote other ſuch works on the bulwarks of the Po; on the harbours of Ancona, of Rimini, of Magna Vacca, and Savona, beſides others, almoſt all which were printed. He had likewiſe received a commiſſion from Clement XIII. to viſit the Pomptin lakes, on the draining of which he drew up his opinion in writing, to which he added further elucidations at the deſire of Pius VI. On theſe occaſions he ſhewed how uſeful philoſophy may be to the public; and of this he gave another proof when it was referred entirely to his judgement to determine whether or not the cupola of the cathedral of Milan could bear the weight of a very high ſpire, which it was propoſed to raiſe on it, and which was actually erected according to his directions.

His application to abſtruſe ſtudies did not hinder him from paying ſome attention to what is more pleaſant. We have ſeen that he was a poet: he was alſo well acquainted with hiſtory, and particularly with that of the Greeks and Romans, and with their antiquities. He wrote a diſſertation on an ancient villa diſcovered in his time upon the Tuſculan Hill, and on an ancient dial found there; which diſſertation was publiſhed at Rome in a literary journal. He wrote likewiſe three letters on the obeliſk of Cæſar Auguſtus, two of which were printed with his own name, and the third under the name of another.

Beſides all theſe works that were given to the public in his lifetime, many writings of his remained in manuſcript in the hands of different perſons, and particularly with his friend M. Gaetani, and many more with Count Michael de Sorgo, a Raguſan ſenator, who inherited all his papers that were in his own hands at his death. Theſe, it is hoped, have either been already ſent to the preſs or will be ſo; as nothing came from the pen of Boſcovich which was not uſeful and deſerving to ſee the light.

Boſcovich's Syſtem of Natural Philoſophy.

IT now remains that we give an account of his THEORY OF NATURAL PHILOSOPHY; and in doing this we ſhall, in the *firſt* place, lay before our readers a view of this ſyſtem. We ſhall, in the *ſecond* place, relate, from what principles and by what ſteps it was deduced. We ſhall, *thirdly*, take notice of the principal objections made to it, and ſubjoin the author's anſwers to the ſame. We ſhall, *finally*, ſhew how happily it may be applied to explain the general properties of matter, as well as the particular qualities of all the claſſes of bodies, which have been examined according to what it teaches.

1
View of Boſcovich's ſyſtem of natural philoſophy.

1. In this ſyſtem, therefore, the whole maſs of matter, of which all the bodies of the univerſe are compoſed, conſiſts of an exceeding great, yet ſtill finite number of ſimple, indiviſible, inextended, atoms. Theſe atoms are endued with *repulſive* and *attractive* forces, which vary and change from the one to the other, according to the diſtance between them, in the following manner: In the leaſt and innermoſt diſtances they repel one another; and this repulſive force increaſes beyond all limits as the diſtances are diminiſhed, and is conſequently ſufficient for extinguiſhing the greateſt velocity, and for preventing the contact of the atoms. In the ſenſible diſtances, this force is *attractive* and decreaſes, at leaſt ſenſibly, as the ſquares of the diſtances increaſe, conſtituting univerſal gravity, and extending beyond the ſphere of the moſt diſtant comets. Between this innermoſt repulſive force and the outermoſt attractive one, in the inſenſible diſtances, many varieties and changes of the force, or determination to motion, take place: for the repulſive force decreaſes as the diſtance increaſes. At a certain diſtance it comes to vaniſh entirely; and, when that diſtance is increaſed, attraction begins, increaſes, becomes leſs, vaniſhes; and the diſtance becoming greater, the force becomes repulſive, increaſes, leſſens, and vaniſhes as before. Many varieties and changes of this kind happen in the inſenſible diſtances, ſometimes more rapidly, ſometimes more ſlowly, and ſometimes one of the forces may come to nothing, and then return back to the ſame without paſſing to the other. For all this there is full room in the diſtances that are inſenſible to us, ſeeing the leaſt part of ſpace is diviſible *in infinitum*. Beſides theſe repulſive and attractive forces, our atoms have that *vis inertiæ* which is admitted by almoſt all modern philoſophers. Theſe atoms, endued with theſe forces, conſtitute the whole ſubſtance of Boſcovich's ſyſtem; which, however ſimple and ſhort it may appear to be, has numberleſs and very wonderful conſequences, as we ſhall ſee afterwards. But, that a more clear idea of the whole theory may be eaſily formed, we ſhall make uſe of a geometrical figure well accommodated to that purpoſe. The right line C'AC is an axis, from which, in the point A, is drawn the right line AB at right angles. AB is conſidered as an *aſymptote*; on each ſide of which the two curves, quite ſimilar and equal, DEFGHIKLMNOPQRSTVU on the one ſide, and D'E'F'G' on the other, are placed. Now, if ED be ſuppoſed to be *aſymptotical*, and be extended, it will ſtill approach to BA, but will never come to touch it. This curve ED approaches to the axis C'C, comes to it in E, cuts it and departs to a certain diſtance in F, after which it again approaches the ſame axis and cuts it in G. In like manner it forms the arches GHI, IKL, LMN, NOP, PQL. At laſt it goes on in T *p s* V, which is aſymptotical, and approaches to the axis; ſo that the diſtances from it are in a duplicate reciprocal proportion of the diſtances from the right line BA. If from any points of the axis, as from *a*, *b*, *d*, we raiſe the per-

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

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perpendiculars *a g*, *b r*, *d h*, the ſegments of the axis A *a*, A *b*, A *d*, are called *abſciſſes*, and repreſent the diſtances of any two points of matter from one another; and the perpendiculars *a g*, *b r*, *d h*, are called *ordinates*, and exhibit the repulſive or attractive force, according as it lies on the ſame ſide with D, or on the other ſide of the axis.

Now it is evident that, in this form of the curve line, the *ordinate a g* will be increaſed beyond whatever limits, if the abſciſs A *a* be leſſened likewiſe beyond whatever limits; that if this abſciſs be increaſed to A *b*, the *ordinate* will be leſſened, and will paſs into *b r*, which will ſtill be leſſened as it approaches from *b* to E, where it will come to nothing; that then, the axis being increaſed to A *d*, the *ordinate* will change its direction into *b h*, and, on the oppoſite ſide, will increaſe at firſt to F, then it will decreaſe through *i l* as far as G, where it will again vaniſh, and again change its direction in *m n* to the former; and that, in the ſame manner, it will vaniſh and change its directions in all the ſections I, L, N, P, R, until the *ordinates o p*, *v s*, become of a conſtant direction, and decreaſe, at leaſt ſenſibly, in a reciprocal duplicate proportion of the abſciſſes A *o*, A *v*. Wherefore, it is manifeſt, that by ſuch a curve are expreſſed our forces; at firſt *repulſive* and increaſing beyond all limits, the diſtances being leſſened in like manner, and which decreaſe, the ſame diſtances being augmented; then vaniſh, change their direction, and become *attractive;* vaniſh again, and become *repulſive;* till at laſt, at ſenſible diſtances, they remain on the ſide oppoſite to D, and are *attractive* in a duplicate reciprocal proportion of the diſtances.

We may alſo obſerve that the *ordinates* may increaſe or decreaſe rapidly, as in *y v*, *z t*, or ſlowly, as in *v x*, *z c*; and, conſequently, that the forces may increaſe or decreaſe in like manner. We may add, that the curve may return back without interſecting, or even touching, the axis, as in *f*, and may return after having touched the ſame axis.

Although this curve expreſſes very clearly the *repulſive* and *attractive* forces of our ſyſtem, yet, at firſt ſight, it may appear to be a complicated irregular line. But the author ſhews that his curve is uniform and regular, and may be expreſſed by one uniform algebraical equation; which it will be neceſſary for us to conſider, in order to give ſatisfaction to our readers, and to do juſtice to the theory.

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Wherefore, from what we have ſeen, the curve muſt have the following ſix conditions: *1ſt*, It muſt be regular and ſimple, and not compoſed of an aggregate of arches of different curves. *2dly*, It is neceſſary that it cut the axis C′AC in certain given points only, at two equal diſtances on each ſide AE′, AE, AG , AG, and ſo on. *3dly*, That to every *abſciſs* an *ordinate* correſpond. *4thly*, That if we take equal *abſciſſes* on each ſide of A, they have equal *ordinates*. *5thly*, That the right line AB be an *aſymptote*, the area BAED being aſymptotical, and conſequently infinite. *6thly*, That the arches terminated by any two interſections may be varied at pleaſure, and recede to any diſtance from the axis C′AC, and approach at pleaſure to whatever arches of whatever curves, cutting them, touching them, or oſculating them, in any place and manner.

In order to find an algebraical formula expreſſing the nature of a curve line that would anſwer all theſe ſix conditions, let us call the ordinate *y*, the abſciſs *x*, and let it be made $xx = z$. Then let us take the values of all the abſciſſes AE, AG, AI, &c. with the negative ſign, and let the ſum of the ſquares of all theſe values be called *a*, the ſum of the products of every two ſquares *b*, the ſum of the products of every three, *c*, and ſo on; and let the product of all of them be called *f*, and the number of the ſame values *m*. All this being ſuppoſed, let it be made $z^m + a z^{m-1} + b z^{m-2} + c z^{m-3}$ &c. $+ f = P$. If we ſuppoſe P equal to nothing, it is clear that all the roots of that equation will be real and poſitive; that is, the ſquares only of the quantities AE, AG, AI, &c. which will be the values of *z*; and therefore, as it is $x = \pm \sqrt{z}$, becauſe it is $xx = z$, it is likewiſe clear that the values of *x* will be both AE, AG, AI, poſitive, and $A'E'$, $A'G'$, &c. negative.

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This being done, let any quantity be multiplied by *z*, providing it hath no common diviſor with P, leſt *z* vaniſhing, it likewiſe might vaniſh; and having made *x* an infiniteſim of the firſt order, it may become an infiniteſim of the ſame, or of a lower order, as will be whatever formula $z^r + g z^{r-1} + h z^{r-2}$ &c. $+ l$; which, being ſuppoſed equal to *o*, may have as many imaginary, and as many and whatever real roots, providing none of them be thoſe of AG, AE, AI, &c. either poſitive or negative. If then the whole formula be multiplied by *z*, let this product be called Q.

If we make $P - Q f = o$, this equation will ſatisfy the five firſt conditions above mentioned; and the value of Q being properly determined, the ſixth condition alſo may be complied with.

For, in the firſt place, ſeeing the value P and Q are made equal to *o*, they have no common root, and therefore no common diviſor. Hence this equation cannot be reduced to two by diviſion; and therefore it is not compoſed of two equations, but is ſimple, and therefore exhibits one ſimple continued curve, which is not compoſed of any others; which is the firſt condition.

Secondly, The curve thus expreſſed will cut the axis C′AC in all the points E′, G, I, &c. and G′, &c. and in them only: for it will cut that axis only in thoſe points in which $y = o$, and in all of them. Moreover, where it will be $y = o$, it will alſo be $Q y = o$; and therefore, becauſe of $P - Q y = o$, it will be $P = o$. But this will happen only in thoſe points in which *z* will be one of the roots of the equation $P = o$; that is, as we have ſeen above, in the points E, G, I, or E′, G′, &c.: wherefore, only in thoſe points will *y* vaniſh, and the curve cut the axis. Again, that the ſame curve will cut it in all theſe points, is clear from this, that in them all it will be $P = o$. Wherefore it will likewiſe be $Q y = o$; but it will not be $Q = o$, ſeeing there is no common root of the equations $P = o$ and $Q = o$: it muſt therefore be $y = o$, and the curve will cut the axis: and thus the ſecond condition is ſatisfied.

Beſides, whereas it is $P - Q x = o$, it will be $y = \frac{P}{Q}$. the abſciſs *x* being, however, determined, we will have a certain determinate quantity for *z*; and thus P, Q, will be determined, and the only two of the kind. Wherefore *y* alſo will be ſole and determined; and therefore to every abſciſs *z*, one only ordinate *y* will correſpond. This is the third condition.

Again, whether *x* be aſſumed poſitive or negative,

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providing it be of the ſame length, ſtill the value $z = xx$ will be the ſame, and therefore the values of both P and Q will be the ſame: wherefore y will ſtill be the ſame. Taking, therefore, equal abſciſſes z on both ſides of A, the one poſitive, the other negative, they will have equal correſponding ordinates. This is the fourth condition.

If x be leſſened beyond all limits, whether it be poſitive or negative, z likewiſe will be leſſened beyond all limits, and will become an infiniteſim of the ſecond order: wherefore, in the value P, all the terms will decreaſe *in infinitum*, except in y, becauſe all the reſt beſides it are multiplied by z; and thus the value P will be as yet finite. But the value Q, which has the formula multiplied by z, will be leſſened *in infinitum*, and will be an infiniteſim of the ſecond order: therefore $\frac{P}{Q} = y$ will be augmented *in infinitum*, ſo as to become an infinite of the ſecond order. Wherefore the curve will have the right line AB for an *aſymptote*, and the area BAED will increaſe *in infinitum*: and if the ordinate y be aſſumed poſitive on the ſide AB, and expreſs repulſive forces, the aſymptotic arch ED will lie on the ſame ſide AB. This is the fifth condition.

Now the value Q can be varied in infinite manners; ſo that ſtill the conditions for which it was aſſumed may be fulfilled; and therefore the arches of the curve intercepted by the interſections may be varied in infinite manners; ſo that the firſt five conditions of the curve may be implemented: whence it follows that they may be ſo varied that the ſixth condition may alſo be anſwered.

For if there be given, however many, and whatever arches of whatever curve, providing they be ſuch that they recede always from the aſymptote AB, and thus no right line parallel to that aſymptote cut theſe arches in more than one point, and in them let there be taken as many points as you pleaſe, and as near one another; it will be eaſy to aſſume ſuch a value of P, that the curve ſhall paſs through all theſe points, and the ſame may be varied infinitely; ſo that ſtill the curve will paſs through all the ſame points.

Let the number of points aſſumed be what you pleaſe $= r$, and, from every one of ſuch points, let right lines be drawn parallel to AB, as far as the axis C′AC, which muſt be the ordinates of the curve that is ſought; and let the abſciſſes from A to the ſaid ordinates be called M^1, M^2, M^3, &c. and the ordinates $'N^1, 'N^2, 'N^3$, &c. Let there now be taken a certain quantity $Az^r + Bz^{r-1} + Cz^{r-2} + Gz$, and let this quantity be ſuppoſed equal to R. Then let another ſuch quantity T be aſſumed, ſo that z vaniſhing, whatſoever term of it may vaniſh, and ſo that there be no common diviſor of the value of P, and of the value of $R + T$: which may be eaſily done, ſeeing all the diviſors of the quantity P are known. Let it now be made $Q = R + T$, and then the equation of the curve will be $P - Ry - Ty = o$. After this, let there be put in the equation M1, M2, M3, ſucceſſively for x, and N1, N2, N3, &c. for y; we will have a number of equations equal to r, which will contain the values of A, B, C, ... G, each of them of one dimenſion, in number likewiſe equal to r; and, beſides, we will have the given values of M1, M2, &c. N1, N2, N3, &c. and the arbitrary values which in T are the coefficients of z.

By theſe equations, which are in number r, it will be eaſy to determine the values A, B, C, ... G, which are likewiſe in number r, aſſuming in the firſt equation, according to the uſual method, the value A, and ſubſtituting it in all the following equations; by which means the equations will become $r-1$. Theſe, again, by throwing out the value B, will be reduced to $r-2$, and ſo on until we come to one only; in which the value Q being determined by means of it, going back, all the preceding values will be determined, one by each equation.

The values A, B, C, ... G, being in this manner determined, in the equation $P - Ry - Ty = o$, or $P - Qy = o$, it is clear that the values M1, M2, M3, &c. being ſucceſſively put for x, the values of the ordinate y muſt ſucceſſively be N1, N2, N3, &c.; and, therefore, that the curve muſt paſs through theſe given points in thoſe given curves; and ſtill the value Q will have all the preceding conditions. For z being leſſened beyond whatever limits, every one of its terms will be leſſened beyond whatever limits, ſeeing all the terms of the value of T are leſſened which were thus aſſumed, and likewiſe the terms of the value R are leſſened, which are all multiplied by z; and, beſides this, there will be no common diviſor of the quantities P and Q, ſeeing there is none of the quantity P and $R + T$.

But if two of the neareſt of the points aſſumed in the arches of the curves, on the ſame ſide of the axis, be ſuppoſed to accede to one another beyond whatever limits, and at laſt to coincide, which will be done by making two M equal, and likewiſe two N equal; then the curve ſought will touch the arch of the given curve; and if three ſuch points coincide, they will *oſculate* it: nay, as many points as we pleaſe may be made to meet together where we pleaſe; and thus we may have *oſculations* of what order we pleaſe, and as near one another as we pleaſe, the arch of the given curve approaching as we pleaſe, and at whatever diſtances we pleaſe, to whatever arches of whatever curves, and yet ſtill preſerving all the ſix conditions required for expreſſing the law of the repulſive and attractive forces. And whereas the value of T can be varied in infinite manners, the ſame may be done in an infinite number of ways; and therefore a ſimple curve, anſwering the given conditions, may be found out in an infinite number of ways. *Q. E. F.*

What we have ſaid will, we hope, ſatiſfy our readers, and eſpecially thoſe of them who are in the leaſt acquainted with high geometry, that Boſcovich's curve is ſimple, regular, and uniform; and that therefore the law of repulſive and attractive forces, expreſſed by it, is ſimple and regular.

II. If this ſyſtem were a mere hypotheſis, it would ſtill be very ingenious, and, from what we ſhall ſay afterwards, would ſtill be well adapted for explaining the phenomena of nature. But its author is far from looking upon it as an arbitrary ſuppoſition; he aſſures us that he was led to it by a chain of ſtrict reaſoning, from evident principles. We ſhall now give an abridgement of that reaſoning from his Diſſertations on the Law of *Continuity*, and from his Theory of Natural Philoſophy.

4
Proofs of the theory.

He tells us, then, that in the examination of Leibnitz's opinion of the *vires vivæ*, he came to conſider the colliſion of bodies, and took for example two equal bodies. A proceeding with ſix degrees of velocity, and B following with the velocity of 12: after the colliſion,

ſion, they proceed jointly with the common velocity 9. Now, in the moment of colliſion, it either happens that A paſſes abrubtly from the velocity 6 to the velocity 9, without paſſing through the velocity 7 and 8, and B paſſes from 12 of velocity to 9, without paſſing through 11 and 10; or elſe there muſt be ſome cauſe which accelerates the one and retards the other before they come to contact. In the firſt caſe, the law of continuity is broken; in the ſecond, immediate contact of bodies would be rejected. Maclaurin ſaw this difficulty, and mentioned it in his work on *Newton's Diſcoveries*, l. 1. c. 4. He, not having courage to recede from the common opinion, allowed a breach, in ſuch caſes, of the law of continuity; but Boſcovich maintains the univerſality of the law of continuity; and holds that no bodies touch one another really and mathematically, but only phyſically and ſenſibly to us.

5
The law of continuity proved

The law of continuity is that by which variable quantities, paſſing from one magnitude to another, paſs through all the intermediate magnitudes, without ever abruptly paſſing over any of them. This law Boſcovich proves to be univerſal, in the firſt place, from induction. Thus we ſee that the diſtances of two bodies can never be changed without their paſſing through all the intermediate diſtances. We ſee the planets move with different velocities and directions; but in this they ſtill obſerve the law of continuity. In heavy bodies projected, the velocity decreaſes and increaſes through all the intermediate velocities: the ſame happens with regard to elaſticity and magnetiſm. No body becomes more or leſs denſe without paſſing through the intermediate denſities. The light of the day increaſes in the morning and decreaſes at night through all the intermediate poſſible degrees. In a word, if we go through all nature, we ſhall ſee the law of continuity ſtrictly take place, if all things be rightly conſidered. It is true, we ſometimes make abrupt paſſages in our minds; as when we compare the length of one day with that of another immediately following, and ſay that the ſecond is two or three minutes longer or ſhorter than the former, paſſing all at once, in our way of ſpeaking, round the globe; but if we take all the longitudes, we ſhall find days of all the intermediate lengths. We likewiſe ſometimes confound a quick motion with an inſtantaneous one: thus, we are apt to imagine that the ball is thrown abruptly out of the gun; but, in truth, ſome ſpace of time is required for the gradual inflammation of the powder, for the rarefaction of the air, and for the communication of motion to the ball. In like manner, all the objections made againſt the law of continuity may be ſolved to ſatisfaction.

6
A breach of this law impoſſible.

But however ſtrong this argument from judgment may appear to be, yet Boſcovich goes farther, and maintains, that a breach of this law, in the proper caſes, is metaphyſically impoſſible. This argument he draws from the very nature of continuity. It is eſſential to continuity that, where one part of the thing *continued* ends and another part begins, the limit be common to both. Thus, when a geometrical line is divided into two, an indiviſible point is the common limit to both; thus time is *continued;* and therefore where one hour ends, another immediately begins, and the common limit is an indiviſible inſtant. Now, as all variations in variable quantities are made in time, they all partake of its continuity; and hence none of them can haſten by an abrupt paſſage from one magnitude to another, without paſſing through the intermediate magnitudes. As we cannot paſs from the ſixth hour to the ninth without paſſing through the ſeventh and eighth; becauſe, if we did, there would be a common limit between the ſixth hour and the ninth, which is impoſſible: ſo likewiſe you cannot go from the diſtance 6 to the diſtance 9 without paſſing through the diſtances 7 and 8; becauſe, if you did, in the inſtant of paſſage you would be both at the diſtance 6 and at the diſtance 9, which is impoſſible. In like manner, a body that is condenſed or rarefied cannot paſs from the denſity 6 to the denſity 9, or *vice verſa*, without paſſing through the denſities 7 and 8; becauſe, in the abrupt paſſage, there would be two denſities, 6 and 9, in the ſame inſtant. The body muſt paſs through all the intermediate denſities. This it may do quickly or ſlowly, but ſtill it muſt evidently paſs through them all. The like may be ſaid of all variable quantities; and thence we may conclude, that the law of continuity is univerſal.

7
Objections to this law anſwered.

But, in creation, is there not an inſtance of an abrupt paſſage from *non-exiſtence* to *exiſtence?* No, there is not; becauſe before exiſtence a *being* is nothing, and therefore incapable of any ſtate. In creation, a *being* does not paſs from one ſtate to another abruptly; it paſſes over no intermediate ſtate: it begins to exiſt and to have a ſtate, and exiſtence is not diviſible. Do we not, at leaſt, allow of an abrupt paſſage from repulſive to attractive forces in our very theory itſelf? We do not. Our repulſive forces diminiſh, through all the intermediate magnitudes, down to nothing; through which, as a limit, they paſs to attraction. In the building of a houſe or ſhip, neither of them is augmented abruptly; becauſe the additions made to them are effected ſolely by a change of diſtances between the parts of which they are compoſed: and all the intermediate diſtances are gone through. The like may be ſaid of many other ſuch caſes; and ſtill the law of continuity remains firm and conſtant.

8
Impoſſibility of contact between bodies.

Let us now apply this doctrine to the caſe above mentioned of the colliſion of two bodies. We ſay that the body B cannot paſs from the velocity 6 to the velocity 9 without paſſing through the velocities 6 and 7; becauſe if it did, in the moment of contact of the two ſuperficies it would have the velocities 6 and 9. Now a body cannot have two velocities at the ſame inſtant. For if it had two *actual* velocities at the ſame time, it would be in two different places at the ſame time: if it had two different *potential* velocities or determinations to a certain velocity, it would be capable of being, after a given time, in two places at once—both which are impoſſible. It is therefore neceſſary that it go through the velocities 7 and 8, and through all the parts of them. What we have ſaid of the bodies A and B may be ſaid univerſally of all bodies. Therefore no two bodies in motion can come to immediate contact; but their velocities muſt undergo the ſucceſſive neceſſary change before contact. And as the velocity to be extinguiſhed may be increaſed beyond all limits, an adequate cauſe to effect this extinction muſt be admitted.

9
Repulſive forces

This naturally leads us to the interior repulſive forces of our ſyſtem; for the cauſe retarding the one body and accelerating the other muſt be a *force*, becauſe by this we mean a determination to motion; and it muſt be repulſive, becauſe it acts *from* the body; and it muſt increaſe

increaſe beyond all limits, ſeeing the velocity of the incurring bodies may be increaſed beyond all limits. It muſt likewiſe be mutual, becauſe action and reaction are always equal, as may be proved by induction.

10
Inextended atoms.

From theſe repulſive forces Boſcovich deduces the inextenſion of his atoms: for this repulſion being common to all matter, muſt cauſe a perfect ſimplicity in the firſt elements of body. If theſe elements were extended, and conſequently compounded of particles of an inferior order, theſe particles might poſſibly be ſeparated, and then they might meet, and an abrupt paſſage from one velocity to another might take place, which we have excluded from nature by induction, and by a poſitive argument.

Beſides this, by rejecting the extenſion of the firſt elements of matter, we get rid at once of all the difficulties ariſing from continued extenſion in body, which have always perplexed the philoſophers, and have never been ſatisfactorily explained. If the elements of matter are extended, each of them may be divided *in infinitum*, and each part may ſtill be divided *in infinitum*. Can this diviſion be actually made by the power of God or not? Can there be one *infinite* in number greater than another? Can there be a *compound* without a *ſimple* of the ſame kind? Theſe difficulties regard not ſpace, which is no real being; but they would regard matter if it had continued extenſion. All theſe perplexities are removed by maintaining, as Boſcovich does, that the firſt elements of bodies are perfectly ſimple, and therefore inextended (A).

11
Attractive forces.

With regard to the exterior attractive forces of our ſyſtem, there can be no queſtion; ſeeing they conſtitute univerſal gravity, the effects of which we ſee and feel every day. But between the interior repulſive and exterior attractive forces we muſt admit many tranſitions from repulſion to attraction, and from attraction back to repulſion, in inſenſible diſtances, which are indicated to us by coheſion, fermentation, evaporation, and other phenomena of nature. And thus we have given, in ſhort, Boſcovich's proofs of his whole ſyſtem.

12
Objections to the ſyſtem anſwered.

III. This ſyſtem has been well received by the learned in Europe, and has contributed much to render its author famous; yet many objections againſt it have been propoſed. Some are ſtartled at the rejection of all immediate contact between bodies: and indeed Boſcovich is perhaps the firſt of mankind who advanced that opinion; but he allows that bodies approach ſo near to one another, as to leave no ſenſible diſtance between them; and his repulſive forces make the ſame impreſſion on the nerves of our ſenſes as the ſolid bodies could do. And therefore this opinion of his, however new, is nowiſe contrary to the teſtimony of our ſenſes. He only removes a prejudice which was before univerſal.

Some ſay, that they cannot even form an idea of an inextended atom, and that Boſcovich reduces all matter to nothing: but certainly extenſion is not neceſſary for the eſſence of a *being*, as muſt be allowed by all thoſe who hold that ſpirits are inextended. Becauſe all the bodies that fall under our ſenſes are extended, we are apt to look upon extenſion as eſſential to matter: but this error may be corrected by reflection, and an idea of an inextended atom may be formed, by conſidering the nature of a mathematical point, which is the limit of any two contiguous parts of a line.

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

We may here obſerve, that among the ancients Zeno, and among the moderns Leibnitz, held, that the firſt principles of matter are inextended points. But both held this opinion with the inconſiſtency, that they maintained the continued extenſion of bodies, without ever being able to ſhew how continued extenſion could ariſe from inextended elements.

It has been objected likewiſe, that our repulſive and attractive forces are no better than the occult qualities of the Peripatetics. The like objection has been made to Newton's attraction: but the anſwer is eaſy. We obſerve the effects, and take notice of them: for them we muſt admit an adequate cauſe, without being able to determine, whether that cauſe is an immediate law of the Creator, or ſome mediate inſtrument that he makes uſe of for that purpoſe.

Some are unwilling to give up the idea of motion occaſioned by immediate impulſe: but can they ſhow a good reaſon why *ſome diſtance* may not occaſion motion as well as *no diſtance?* Theſe are the principal objections that have been made againſt the Boſcovichian ſyſtem.

13
Obſervations with regard to the curve.

IV. Before we proceed to the explication of phenomena by means of our theory, we muſt advert, that in the curve expreſſing this theory, the abſciſſes denote the diſtances between the atoms that are under conſideration; the ordinates give the preſent *force*, and the area between any two of theſe ordinates gives the ſquare of the velocity generated between them; the arches are either repulſive or attractive, according as they fall upon the ſame ſide with the aſymptotic curve EG, or on the oppoſite ſide.

14
Limits of coheſion, &c.

We muſt, in the next place, conſider the paſſages from one ſide of the axis to the other. Sometimes the paſſage is from repulſion to attraction, at other times from attraction to repulſion. The firſt are called *limits of coheſion*, becauſe a particle removed from that limit returns back to it; becauſe if it is removed to a greater diſtance it is attracted back, and if it is removed nearer it is repelled back. The ſecond are called *limits of non-coheſion;*

(A) If a particle of matter is not extended, in what reſpect does it differ from a point of ſpace? Says Boſcovich, it is endowed with attractive and repulſive forces. What is this *it* before it is thus endowed? Does it *then* differ from a point of ſpace? We can form no notion of any ſuch difference. But a point of ſpace, conſidered as an individual, is diſtinguiſhed from another individual only by its ſituation; it is therefore immoveable, but matter is moveable. Have theſe forces, then, which make matter an object of ſenſe, any ſubſtratum, any thing in which they are inherent as qualities? What are the things which theſe qualities diſtinguiſh from each other as individuals?

coheſion; becauſe a particle removed thence to a greater diſtance is repelled ſtill further, and if removed nearer it is attracted ſtill nearer. Of the firſt kind are E, I, N; of the ſecond are G, L. Likewiſe, when the curve touches the axis, it may either be an attractive part of the curve, or a repulſive part. Theſe limits may be nearer one another, or farther away; and the limits of coheſion may be ſtronger or weaker, according as the forces near them are greater or leſs.

15 ompoſi- on of bo- es.

Boſcovich conſiders minutely the effects of theſe varieties of limits and forces; firſt with regard to two points, then with regard to three and four, demonſtrating the great variety of forces that may ariſe from theſe various combinations, and ſhewing how from ſimple atoms a great variety of bodies may be formed. He particularly proves, that, from the various poſition of the atoms, they may either always repel or always attract other atoms, or do neither. Four atoms may form a pyramid, eight may form a cube, and ſo on, in regular or irregular figures. Particles of the loweſt order may compoſe particles of a ſecond order, theſe of a third, and ſo on. This he exemplifies by a library, in which the letters of the books ſhould be compoſed of ſmall points, placed ſo near one another as that their diſtance could not be perceived without the help of a microſcope. Here the letters will be compoſed of points, the words of letters, and all the variety of books on different ſubjects, and in different languages, would be compoſed of words. In like manner, he ſays, his atoms may compoſe particles, theſe may compoſe others of different orders, of which may be formed various bodies, animal, vegetable, air, fire, water, earth, whole planets, central bodies, the whole univerſe.

16 e ſyſtem plied to count for

But to be more particular, our author proceeds to apply his ſyſtem to mechanics, and demonſtrates, with his uſual accuracy and originality, what regards the centre of gravity, action and reaction, the colliſion of bodies, the centre of equilibrium, and of oſcillation. Of theſe ſubjects he treats in the ſecond part of his *Theoria;* to which we muſt refer our learned readers, as it cannot be eaſily abridged.

17 penetra- ity,

In the third part of the ſame work he proceeds to account for the general properties of matter, beginning with *impenetrability*. This naturally flows from the interior repulſive forces, which prevent the compenetration of any two points. Beſides, as the leaſt part of ſpace is diviſible *in infinitum*, it is infinitely improbable that any two points ſhould ever meet, ſeeing they have an infinite number of other lines in which they can move, beſides the one that would join them. But an apparent compenetration might take place, if one body ſhould meet another with ſo great a velocity as not to give time to the repulſive forces to exert their action. Thus an iron ball may paſs ſwiftly near a ſtrong magnet, without being ſenſibly attracted by it, which it would be if it moved more ſlowly. Thus a ball from a gun paſſes through a piece of wood ſo quickly as to make only a paſſage for itſelf, without breaking the neighbouring parts, which it would do were its motion more ſlow. Of this kind of compenetration we have a reſemblance in *light* paſſing through pellucid bodies.

18 eſion,

Coheſion has never been well accounted for by any philoſopher before Boſcovich. From his ſyſtem it follows naturally, as we have ſeen in ſpeaking of the limits of coheſion; for when two atoms are placed in a limit of that kind, they neceſſarily cohere more or leſs ſtrongly, according as that limit is ſtronger or weaker. From the coheſion of the atoms ariſes the coheſion of compounded particles, and conſequently of ſenſible bodies.

19 Extenſion,

From the coheſion of particles ariſes the extenſion of bodies; becauſe there muſt always be ſpace between the particles. However, it is evident that this extenſion is not formed of a continuity of matter; though it may appear to be ſo to our ſenſes, which cannot perceive the ſmall intermediate diſtance between the parts of ſome bodies, and much leſs the diſtances between the ſimple elements of which they are compoſed.

20 Figure,

Extenſion of bodies involves *figurability;* becauſe every extended body muſt be ſurrounded by ſome ſuperficies of a certain figure; but the ſuperficies of bodies can never be accurately determined, upon account of the inequalities in all ſurfaces. We take, however, that figure for the true one which the body appears to come neareſt. Thus we call the earth a globe, notwithſtanding the hills and valleys that are on it.

Under the ſame figure, and of the ſame magnitude, there may be contained very different quantities of matter. Hence we come to the conſideration of *denſity*. That body is moſt denſe which contains in the ſame ſpace the greateſt number of atoms, and *vice verſa*.

21 Denſity,

This denſity may be increaſed beyond any given limits by the nearer approach of the atoms to one another. Hence a body of any given magnitude, however ſmall, may come to be diviſible beyond any given limits.

22 Mobility,

Mobility, which is likewiſe reckoned among the general properties of body, is eſſential to our ſyſtem, ſeeing an eſſential part of it conſiſts in *forces*, which are determinations to motion, at leaſt in certain diſtances.

23 Gravity,

Univerſal gravity in ſenſible diſtances is likewiſe a branch of our theory. On which ſubject it may be obſerved, that perhaps our curve, after it has extended beyond the ſphere of the comets moſt diſtant from the ſun, may depart from its aſymptotical nature, and approach to the axis, interſect it, and paſs to repulſion. This would effectually anſwer the objection made by ſome againſt Newton's attraction, when they allege, that, from his opinion, it would follow, that the fixed ſtars, and all matter, would be drawn together into one maſs. If ſuch a repulſion takes place, it may ſoon paſs again into attraction, and form limits of coheſion; ſo that our ſun may be in ſuch a limit with regard to the fixed ſtars, and our planetary ſyſtem make only a ſmall part of the whole univerſe. And this may ſuffice concerning the general properties of matter.

24 Fluidity,

Let us now deſcend to ſome particular claſſes of bodies, of which ſome are fluid, others ſolid. The parts of fluid bodies are eaſily ſeparated, and eaſily moved round one another, becauſe they are ſpherical and very homogeneous; and hence their forces are directed more to their centres than to one another, and their motions through one another are leſs obſtructed. Between the particles of ſome of them there is very little attraction, as in fine ſand or ſmall grains of ſeed, which approach much to fluidity. The particles of ſome others of them attract one another ſenſibly, as do thoſe of water, and ſtill more thoſe of mercury. This variety ariſes from the various combinations of the particles themſelves, of which we have already taken notice. But in air the particles repel one another very ſtrongly; and hence comes that great rarefaction, when it is not compreſſed by an external force. Its particles muſt be placed in ample limits of repulſion.

25 Solidity, Solid bodies are formed of parallelopipeds, fibres, and of irregular figures. This occaſions a greater coheſion than in fluids, and prevents the motion of the parts round one another; ſo that when one part is moved all the reſt follow. Of theſe bodies ſome are harder, whoſe particles are placed in limits which have ſtrong repulſive arches within them; others are ſofter, whoſe particles have thoſe arches of repulſion weaker. **26 Softneſs, flexibility, and elaſticity.** Some are flexible, the particles of which are placed in limits that have weak arches of repulſion and attraction on each ſide; and if thoſe arches are ſhort, the particles may come to new limits of coheſion, and remain bent: but if the arches are longer, the former repulſion and attraction will continue to act, and bring back the body to its former poſition; nay, in doing this with an accelerated velocity, the parts will paſs their former limits, and vibrate backwards and forwards, as may be ſeen in a bended ſpring. Thus elaſticity is accounted for.

27 Viſcoſity. Viſcous bodies ſtand in the middle between ſolid and fluid. Their particles have leſs coheſion than the firſt, and more than the ſecond: they ſtick to other bodies by an attraction which their particles have from their compoſition. In like manner water itſelf ſticks to ſome bodies, and is repelled by others. All which ariſes from the different compoſition of the particles, which gives a variety of reſpective forces.

28 Organization. What appears very wonderful in nature, is the compoſition of organic bodies. But if we conſider that particles may be ſo formed, that they may repel ſome and attract others, the whole of vegetation, nutrition, and ſecretion, may be underſtood, and follows from our ſyſtem. And as one particle may attract another in one part only, and repel it in every other ſituation, hence may be gathered the orderly ſituation of the particles in many cryſtallizations. The great variety of repulſive and attractive forces, or limits of coheſion, of the poſition of atoms, and of combinations of particles, will account for all theſe phenomena.

29 Chemical operations. The chemical operations, which are ſo curious in themſelves, and ſo uſeful to ſociety, are well explained by Boſcovich's ſyſtem, and ſerve as a confirmation of its truth. Of this we ſhall give ſome inſtances. When ſome ſolids are thrown into ſome liquids, there happens to be a greater attraction between the particles of the ſolid and of the liquid than there is between the particles of the ſolid itſelf. Hence the particles of the ſolid are detached and ſurrounded by the fluid; this mixture retaining the form of globules, and therefore continuing to be fluid. This is called *ſolution*. But when the ſolid particles are covered to a certain depth, the attractive forces ceaſe on account of the different diſtances, and no more of the ſolid is detached. Then the fluid is ſaid to be *ſaturated*. If into this mixture another ſolid be put, the particles of which attract the fluid more ſtrongly, and perhaps at greater diſtances than the particles of the former; then the fluid will abandon the former and cleave to the latter, diſſolving them, and the particles of the former will fall to the bottom in the form of powder, into which they had been reduced by the ſolution. This ſeparation is called *precipitation*. Perhaps rain ariſes from a precipitation of this kind, when the aqueous particles are left by the air, which is more ſtrongly attracted by ſome other particles floating in the atmoſphere.

Fluids of the ſame ſpecific gravity are eaſily mixed; and even though the ſpecific gravity be different, the particles of the one attract thoſe of the other, in ſuch a manner that they ſeem to form one fluid by a kind of ſolution. Nay, it happens that two fluids mixed together form a ſolid, becauſe their particles come to be in the limits of coheſion. They may even occupy leſs ſpace than they did before, by being attracted into leſs diſtances between their parts.

Fermentation is a neceſſary conſequence of our ſyſtem. For when bodies, whoſe particles, by the variety of their compoſition, are endued with different forces, come to be mixed, there muſt ariſe an agitation of the parts, and an oſcillation among them; ſometimes greater, ſometimes leſs, according to the nature of the particles. This agitation is ſtopped by the expulſion of ſome particles, by the intruſion of others into vacant ſpaces, and by the impreſſion of external bodies; but always there is a change in what remains, becauſe there is a new diſpoſition of particles.

30 Fire and fuſion, &c. Fire conſiſts in a violent fermentation of ſulphureous matter, eſpecially when it meets with the matter of light in any quantity. This fermentation agitates ſtrongly the parts of other bodies, ſeparates them from one another, and often throws them into a ſtate of fuſion; the coheſion between their parts being broken, and they being thrown into a circular motion. In this ſtate they may be often mixed together, ſo as to form one body; they may be again ſeparated by the action of the ſame fire, which evaporates ſome of them ſooner, ſome later. Hence the art of ſmelting metals.

When, in the agitation occaſioned by fire, ſome of the particles are thrown out into an arch of repulſion, they may fly off and evaporate. Sometimes the whole body may be thrown into a ſtrong repulſion and volatilization, or a ſudden exploſion take place; when, before the particles are near an equilibrium, a ſmall force may occaſion a great change; as the foot of a bird may occaſion the fall of a great rock, which was before almoſt detached from a mountain. In evaporation, the bodies that remain aſſume a particular figure, as all ſalts do; and this upon account of their particles having certain parts only that attract one another, and conſequently occaſion a particular diſpoſition. All theſe chemical operations evidently prove that there are in nature repulſive and attractive forces between the particles of bodies at ſmall diſtances: which greatly confirms our whole ſyſtem.

31 Light. Boſcovich holds, that light is an *effluvium*, emitted with great velocity from the luminous bodies by a ſtrong repulſion. He explains all the moſt remarkable properties of this extroardinary matter according to his own principles, and that with great acuteneſs. On this ſubject it is obſervable, that Newton ſaw the neceſſity of admitting repulſive forces for the reflexion of light, which extend at ſome diſtance from the reflecting ſurface, and therefore reſemble the repulſive forces of our theory.

32 Electrici and mag netiſm. Our author gives likewiſe a probable explication of electricity, according to Franklin's ingenious hypotheſis, and likewiſe of magnetiſm, deducing the whole of the appearances from various attractions and repulſions.

He ſuppoſes that fire and the electrical fluid differ only in this, that fire is in actual fermentation, and not ſo the electrical fluid.

33 enſation.

Finally, he explains our bodily ſenſations, in which he agrees pretty much with other philoſophers; excepting in this, that what they attribute to the immediate contact of bodies, or of certain particles emitted from them, he aſcribes to attractions and repulſions; which indeed are particularly fit for cauſing that motion in our nerves, which is ſuppoſed to take place in the organs of ſenſation, and to be thence communicated to the brain.

It is to be obſerved, that although Boſcovich maintains that the very firſt elements of matter are void of extenſion; yet he allows, that of theſe elements, combined in a certain manner, may be formed extended particles of various figures, the parts of which may be ſo coherent as to be inſeparable by any power in nature. By theſe means the opinion of thoſe philoſophers, who are ſo fond of extended particles, may be in ſo far gratified. Nay, the Peripatetics may, if they pleaſe, adopt Boſcovich's inextended atoms for their *Materia Prima* without any inconſiſtency; and his repulſive and attractive forces may ſerve for their *ſubſtantial forms*. And as God can make impreſſions on our ſenſes independently of the atoms, their abſolute accidents may in ſome ſenſe be admitted. Nor would ſome ſuch extraordinary exertions of Divine Power favour idealiſm in the ordinary courſe of nature.

34 econciliaon of this ith other ſtems,

But what is of more conſequence, it is more than probable, that had Newton lived to be acquainted with the Boſcovichian theory, he would have paid to it a very great regard. This we may conjecture from what he ſays in his laſt queſtion of optics; where, after having mentioned thoſe things which might be explained by an attractive force, ſucceeded by a repulſive one on a change of the diſtances, he adds, "And if all theſe things are ſo, then all nature will be very ſimple, and conſiſtent with itſelf, effecting all the great motions of the heavenly bodies by the attraction of gravity, which is mutual between all thoſe bodies, and almoſt all the leſs motions of its particles by another certain attractive and repulſive force, which is mutual between thoſe particles." And a little after, treating of the elementary particles, he ſays: "Now it ſeems that theſe elementary particles not only have in themſelves the *vis inertiæ*, and thoſe paſſive laws of motion which neceſſarily ariſe from that force, but that they likewiſe perpetually receive a motion from certain active principles; ſuch as gravity, and the cauſe of fermentation, and of the coheſion of bodies. And I conſider theſe principles, not as occult qualities, which are feigned to flow from the ſpecific forms of things, but as univerſal laws of nature, by which the things themſelves were formed. For that truly ſuch principles exiſt, the phenomena of nature ſhew, although what may be their cauſes has not as yet been explained. To affirm that every ſpecies of things is endued with ſpecific occult qualities, by which they have a certain power, is indeed to ſay nothing; but to deduce two or three general principles of motion from the phenomena of nature, and then to explain how the properties and action of all corporeal things follow from thoſe principles, this truly would be to have made a great advancement in philoſophy, although the cauſes of thoſe principles were not as yet known. Wherefore I do not heſitate to maintain the above ſaid principles of motion, ſeeing they extend widely through all nature." From this paſſage we may ſafely conclude, that the great Britiſh philoſopher would have been highly pleaſed, had he ſeen all nature ſo well explained by the one ſimple law of forces propoſed by the Raguſan.

35 ſpecially hat of ewton.

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

Boſcovich himſelf was ſo fully convinced of the truth of his ſyſtem, that he was wont to make uſe of the following compariſon: When a letter has been written in occult characters, and we are endeavouring to decypher it, we make various ſuppoſitions of alphabets; and when we have found one according to which the whole letter comes to have a reaſonable meaning, agreeable to all the circumſtances of time, place, perſons, and things, we can entertain no doubt of our having diſcovered the true key of the cypher—ſo, ſaid he, my ſyſtem explains ſo well all the phenomena to which it has been properly applied, that I muſt flatter myſelf that I have diſcovered the true key of nature.

37 Exiſtence of God.

The being accuſtomed to contemplate ſo deeply the univerſe and the materials of which it is compoſed, made Boſcovich ſee moſt clearly the evident neceſſity of admitting an all-powerful, intelligent, ſelf-exiſtent Being, for the creation of thoſe materials, and for the arrangement of them into their preſent beautiful form. He was at a loſs to find words ſtrong enough to expreſs his ſurpriſe, that there ſhould be any man, not to ſay any one pretending to the name of philoſopher, who could be ſo deaf as not to hear the voice of nature loudly proclaiming its Author from all, even the leaſt of its parts. He gives us his ſentiments on this, the moſt important of all ſubjects, in the appendix to his *Theoria*, in which he treats of God and of the ſoul of man.

38 The world cannot be the effect of chance;

There, in the firſt place, he ſhows the abſurdity of their opinion, who maintain that this world may have been the work of *chance*, the effect of a jumble of ſelf-exiſtent, ſelf-moving atoms; becauſe chance is an empty word without a real meaning. Whatever exiſts has its determinate cauſe, and can only be called *fortuitous* by us on account of our ignorance of that cauſe. Beſides this, though the number of atoms compoſing this world is finite, yet their poſſible combinations are many times *infinitely infinite*: for they may be placed in infinite places of an infinite line; of theſe lines there is an infinite number in every *plane*, and of theſe planes there is an infinite number in ſpace. Again, theſe points may have an infinite number of velocities in an infinite number of directions. From all this it is evident, that the combinations in which the points of matter may be, is infinite in a high degree, whereas *duration* can be infinite in only one dimenſion. Hence it is infinitely improbable that ever the preſent combination of things could come out by chance. And this is ſo much the more infinitely improbable, becanſe the diſorderly, chaotic combinations are infinitely more than the regular ones. The whole of matter might roll about in a blind motion for a boundleſs eternity, without ever being capable to produce one ſingle muſhroom.

Moreover, had matter been in motion from all eternity, every atom would have deſcribed an infinite line, and then a part of that line would be aſſignable at an infinite diſtance from the point of ſpace in which the atom is at preſent; but an infinite line can never be run over; therefore the atom could never have come to its preſent place; and therefore the ſuppoſition is abſurd. Nothing ſucceſſive can be eternal with a *paſt* eternity, though it can continue without end. God alone can be eternal and actually infinite; but his eternity and infinity are beyond our comprehenſion.

39 Nor have exiſted from eternity.

Neither can the world have exiſted of itſelf in any thing like to its preſent form from all eternity; for matter is perfectly indifferent to numberleſs ſtates, and to its preſent ſtate it muſt be determined. This preſent ſtate is perfectly incapable of determining itſelf, becauſe this determination muſt be previous to its exiſtence. It muſt be determined by the preceding ſtate, which is alſo incapable of determining itſelf, and for its determination we muſt have recourſe to the ſtate before. Thus, though we go back to eternity, we ſhall ſtill find a nullity of determination; now an infinite ſum of *nothing* is *nothing:* and therefore as the preſent ſtate of things could have no determination, it could not poſſibly exiſt.

It is therefore evident that there muſt be a Determiner extrinſic to the material word. This Determiner muſt have an infinite knowledge of all the poſſible combinations, and an infinite elective creative power to chuſe and create freely the combination he pleaſed, in that point of eternity that he choſe, with all the numberleſs circumſtances that are agreeable to him.

40 Attributes of God which appear in the creation.

And here what a vaſt field of contemplation is laid open to a philoſophic mind! What a truly infinite knowledge was requiſite to foreſee ſo many ends, and ſo many means requiſite for obtaining thoſe ends, as are contained in the creation! Let us conſider light, for example, which was to be emitted for ſo many ages from ſo many luminous bodies, with ſo great velocity, ſo as to penetrate ſo many mediums with different degrees of reflectibility and refrangibility, with ſo many other wonderful qualities; at the ſame time, ſo many bodies were to be perfectly fitted for reflecting this light in a certain manner, and the animal eye was to be ſo formed as to have a picture of viſible objects painted on the bottom of it. – How many particular combinations were neceſſary for all this? What ſhall we ſay of the ſo many herbs, flowers, trees, and animal bodies, as there are on this our earth? All their kinds and ſpecies, all the ſeries of their individuals, all their parts and particles, were foreſeen, intended, and contrived, by one act of the Divine Mind. Again, how wonderful are the heavenly bodies, of what ſurpriſing magnitude, moving in the moſt beautiful order, at an immenſe diſtance from one another? To ſay nothing of the numberleſs creatures that are beyond the reach of the beſt teleſcope, or below that of the microſcope. He who reflects ever ſo little on theſe things, muſt neceſſarily ſee the moſt evident proofs of an infinite power, wiſdom, and providence; and he muſt be filled with admiration and awful reſpect for the Creator and Ruler of the univerſe.

41 Natural religion.

Nor are we unconcerned ſpectators of this grand ſcene. God has been pleaſed to make us enter deeply into his great plan of creation. He ſingled us out among an infinite number of poſſible human beings, in order to call us into exiſtence at a fixed period; and he has made a vaſt number of his creatures contribute to the formation of theſe wonderful machines, our bodies, as likewiſe to our nouriſhment, to our preſervation, to our neceſſities, conveniences, and gratifications. Every moment that we exiſt, we are enjoying a great number of benefits, expreſsly deſigned for us by that Supreme Being. This evidently demands from us the higheſt degree of gratitude, love, and obedience.

42 Revelation.

Let us go a ſtep ſtill farther: Is it not very reaſonable to ſuppoſe, that our God, who affords us ſo many inſtances of his beneficence towards us in the natural order, will alſo, out of compaſſion to our weakneſs and ignorance, have favoured us with a more full and explicit manifeſtation of himſelf, of our duties towards him, and of his intentions concerning us? According to Boſcovich and all true philoſophers, reaſon itſelf alone, and true philoſophy, point out to us the probability at leaſt of God's having given us a ſtill better and ſurer guide, by whoſe direction we may attain to that perfect happineſs which we naturally thirſt after, and to which we muſt have been deſigned by our Maker. This is probable from reaſon alone; and of this great fact we are aſcertained by unqueſtionable authority.

BOSHMEN have been generally deſcribed as a diſtinct race of Hottentots, who are enemies to the paſtoral life (ſee *Boshies-Men*, Encycl.) This M. Vaillant affirms to be a miſtake; and we think he has completely proved that it is ſo. "Theſe infamous wretches (ſays he) do not form a particular nation, nor are they a people who have had their origin in the places where they are now found. *Boſhmen* is a name compoſed of two Dutch words, which ſignify *buſh-men*, or *men of the woods*; and it is under this appellation that the inhabitants of the Cape, and all the Dutch in general, whether in Africa or America, diſtinguiſh thoſe malefactors or aſſaſſins who deſert from the colonies, in order to eſcape puniſhment. In a word, they are what in the Britiſh and French Weſt India iſlands are called *Maroon Negroes*. Theſe Boſhmen, therefore, far from being a diſtinct ſpecies, are only a promiſcuous aſſemblage of mulattoes, negroes, and maſtizos, of every ſpecies, and ſometimes of Hottentots and baſters (ſee BASTER, *Supplement*), who all differing in colour, reſemble each other in nothing but in villany. They are land pirates, who live without laws and without diſcipline, abandoned to the utmoſt miſery and deſpair; baſe deſerters, who have no other reſources but plundering and crimes. They retire to the ſteepeſt rocks and the moſt inacceſſible caverns, and there they paſs their lives. From theſe elevated places they command an extenſive proſpect over the ſurrounding plains, lie in wait for the unwary traveller and the ſcattered flocks, pour down upon them with the velocity of an arrow, and ſuddenly falling upon the inhabitants and their cattle, ſlaughter them without diſtinction. Loaded with booty, and whatever they can carry with them, they then repair to their gloomy caves, which they never quit till, like the lions, hunger again impels them to freſh maſſacres. But as treachery always marches with a trembling ſtep, and as the preſence of one reſolute perſon is ſufficient to overawe whole troops of theſe banditti, they carefully ſhun thoſe plantations where they are certain that the owners themſelves reſide. Artifice and cunning, the uſual reſources of timid ſouls, are the only means which they employ, and the only guides that accompany them in their expeditions."—*Vaillant's Travels into the Interior Parts of Africa* (A).

(A) Since this article was firſt publiſhed, a different account has been given of the *Boſhmen* or BOJESMANS by Mr

Boſwell.

BOSWELL (James), known to the learned world as the author of a life of Dr Johnſon and of ſeveral other valuable works, was born, we believe, at Auchinleck in Airſhire, in 1740. The family from which he ſprung was ancient and honourable. At the time of his birth his father was a well employed lawyer at the Scotch bar; but was afterwards raiſed to the dignity of Judge, and filled that important ſtation with acknowledged learning, probity, and honour. His title was Lord Auchinleck, taken from his family inheritance; and he died in 1782: on which occaſion Dr Johnſon wrote an elegant and inſtructive letter to the ſubject of this brief memorial; of which we ſhall tranſcribe a paſſage that alludes to ſome ſlight domeſtic differences, which did not happen in vain, ſince they gave riſe to ſuch ſalutary advice:

"Your father's death had every circumſtance that could enable you to bear it. It was at a mature age, and it was expected; and as his general life had been pious, his thoughts had, doubtleſs, for many years paſt, been turned upon eternity. That you did not find him ſenſible muſt doubtleſs grieve you; his diſpoſition towards you was undoubtedly that of a kind, though not of a fond father. Kindneſs, at leaſt actual, is in our own power, but fondneſs is not; and if, by negligence or imprudence, you had extinguiſhed his fondneſs, he could not at will rekindle it. Nothing then remained between you but mutual forgiveneſs of each other's faults, and mutual deſire of each other's happineſs."

The occaſion of this family diſſention is unknown to us. It might originate in the difference of their political principles, Mr Boſwell being a zealous Tory, and his father, as he repreſents him, a rancorous Whig; or it may have ariſen from the celebrated Douglas cauſe, which ſet many friends at variance in Scotland, and in which, though Lord Auchinleck and his ſon took the ſame ſide, they took it with very different degrees of ardour. The Judge ſaw not the propriety of illuminating his windows when the cauſe was finally decided by the Houſe of Peers; and to compel him to illuminate, the advocate got poſſeſſion of a Chineſe *gong*, and at the head of a number of young men and boys patrolled the ſtreets of Edinburgh, and made a loud and exulting noiſe at the windows of his father's houſe, where there was no ſymptom diſplayed of the general joy.

In 1762 Mr Boſwell made his firſt journey to London; where, under the auſpices of Dodſley the bookſeller, he publiſhed, "The Cub at Newmarket, a Tale." By the title of *Cub* he meant to characteriſe himſelf, as the reader will perceive in the following lines, which we ſhall give as a ſpecimen of the poem:

Lord Eglintoune, who loves, you know,
A little daſh of whim, or ſo,
By chance a curious Cub had got,
On Scotia's mountains newly caught.

During his ſtay in London Mr Boſwell was introduced to Dr Johnſon, with whom it is well known he continued to live in intimacy from that time till Johnſon's death in 1784; and this intimacy procured him the friendſhip of Burke, Goldſmith, Sir Joſhua Reynolds, and many other men of eminence, who compoſed what was called *The Literary Club*. In the latter end of 1765 he became acquainted with General Paoli when on his travels; and after his return he publiſhed, in 1768 or 1769, his account of Corſica, with the "Journal of a Tour to that Iſland."

Of this work, which gained him ſome diſtinction in the world, his great friend Johnſon writes thus: "Your hiſtory is like all other hiſtories, but your journal is in a very high degree curious and delightful. There is between the hiſtory and the journal that difference which there will always be found between notions borrowed from without and notions generated within. Your hiſtory was copied from books; your journal roſe out of your own experience and obſervation. You expreſs images which operated ſtrongly upon yourſelf, and you have impreſſed them with great force upon your readers. I know not whether I could name any narrative by which curioſity is better excited or better gratified."

In 1770 Mr Boſwell, who was then in good practice at the Scotch bar, married an amiable woman, by whom he had two ſons and three daughters, who ſurvived him. In 1773 he was choſen a member of the LITERARY CLUB; and in the autumn of the ſame year he viſited the Hebrides in company with his illuſtrious friend Johnſon; after whoſe death he publiſhed a very entertaining account of their tour, the places they ſaw, the characters with whom they converſed, and their own remarks on the different converſations. To many perſons, both in England and Scotland, this book gave great offence, as it brought before the public the unguarded talk of private ſocial circles; but it ſurely furniſhed much entertainment, as it exhibited a more faithful picture of Hebridian manners than the Britiſh public had ever before ſeen.

In 1784, when Mr Fox's famous India bill was before Parliament, Mr Boſwell publiſhed a "Letter to the People of Scotland on the Preſent State of the Nation;" in which he contends, that no charter would be ſafe if that bill ſhould paſs into a law; and more than inſinuates, that the principle of it was equally inimical to the liberties of the ſubject and to the prerogative of the king. Dr Johnſon ſeems to have thought of that bill as he did; for having read the letter, he writes to the author his approbation of it in the following words: "I am very much of your opinion; and, like you, feel great indignation at the indecency with which the king is every day treated. Your paper contains very conſiderable knowledge of the hiſtory and of the conſtitution, very properly produced and applied."

In 1785, Mr Boſwell quitted the Scotch bar, and went to reſide in London, where he continued till the day of his death. Having entered himſelf in one of the inns of court, and ſtudied the Engliſh law, he became a barriſter in England: but we have reaſon to believe that

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Mr Barrow, who travelled into the interior of Southern Africa in 1797 and 1798. According to him, they are a diſtinct race, extremely ſavage, who neither cultivate the ground nor breed cattle, but ſubſiſt in part on the natural produce of their country, and ſupply its deficiency by depredations on the coloniſts on one ſide, and the neighbouring tribes of people that are more civilized than themſelves, on the other.

that his practice there was not ſo ſucceſsful as it had been in his own country. He enjoyed, however, more completely than he could do in Edinburgh, the converſation of the great, the wiſe, the witty, and the good; and ſuch converſation he always valued above wealth. He frequently viſited his native country, and eſpecially Auchinleck, the ſeat of his anceſtors; and ſoon after his return from one of thoſe viſits he was ſeized with a diſorder which proved fatal, on Tueſday the 19th of May 1795.

Such were the principal events in the life of Mr Boſwell. Of his character, it would be difficult to ſay *much more* than he has ſaid himſelf in his "Journal of a Tour to the Hebrides;" and which may, with ſome propriety, be copied here:

"I have given a ſketch of Dr Johnſon. My readers may wiſh to know a little of his fellow-traveller. Think, then, of a gentleman of ancient blood; the pride of which was his predominant paſſion. He was then in his 33d year, and had been about four years happily married. His inclination was to be a ſoldier; but his father, a reſpectable Judge, had preſſed him into the profeſſion of the law. He had travelled a good deal, and ſeen many varieties of human life. He had thought more than any body ſuppoſed, and had a pretty good ſtock of general learning and knowledge. He had all Dr Johnſon's principles, with ſome degree of relaxation. He had rather too little than too much prudence; and his imagination being lively, he often ſaid things of which the effect was very different from the intention. He reſembled ſometimes

'The beſt good man, with the worſt-natur'd muſe.'

"He cannot deny himſelf the vanity of finiſhing with the encomium of Dr Johnſon, whoſe friendly partiality to the companion of this tour, repreſents him as one 'whoſe acuteneſs would help my inquiry, and whoſe gaiety of converſation, and civility of manners, are ſufficient to counteract the inconveniences of travel, in countries leſs hoſpitable than we have paſſed.'

Few of Mr Boſwell's friends, we believe, could add much to this candid confeſſion. His enemies, if he had any, might dwell upon his failings; but his failings were few, and injurious to no perſon. In his character good nature was predominant. He appeared to entertain ſentiments of benevolence to all mankind, and to be incapable of *intentionally* injuring a human being. His converſation talents were always pleaſing, and often faſcinating. But can we wonder at this in him who, with a capacity to learn, had been the companion of Johnſon for more than 20 years? His attachment to the Doctor for ſo long a period, was a meritorious perſeverance in the deſire of knowledge. To it the world is indebted for the moſt finiſhed picture of an eminent man that ever was executed. We know there are objections to the *mode* of giving the life of Johnſon. It has been thought that ignorance has been wantonly expoſed, and the privacy of ſocial life endangered. We ſhall not enter deeply into this queſtion. All that we can certainly affirm is, that the work has been read with avidity and pleaſure; and that he who does not wiſh to read it again may be ſuſpected to be deficient in taſte and in temper.

Mr Boſwell has been accuſed of vanity; but when this accuſation is brought againſt him, it ſhould not be forgotten that he enjoyed advantages which rendered that conſpicuous in him from which no man can claim an exemption. We know not the man who would not have been vain to poſſeſs ſo much of Dr Johnſon's converſation, and proud to give it to the world, in hopes that he who venerated Johnſon would not be unthankful to his biographer. From the Doctor, however, he appeared to his friends to have imbibed a portion of melancholy, of which indeed he complained himſelf during the laſt two or three years of his life; and he flew for relief where perhaps it is beſt to be found, to the ſociety of the learned and the gay. Here, as he confeſſes, he "had rather *too little* than too much *prudence*;" and, with more attachment to the activity of rural life, he might, probably, have lengthened his days. But as his "belief in revelation was unſhaken," and his religious impreſſions deep, and recurring frequently, let us hope that he has now attained that ſtate from which imperfection and calamity are alike excluded.

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

BOUGUER (Peter), an eminent mathematician and mechanical philoſopher, was born at Croiſic, in Lower Bretagne, on the 10th of February 1698. His father John Bouguer, who was likewiſe a conſiderable mathematician, was then profeſſor royal of hydrography at that port; and under him young Bouguer ſtudied mathematics, and the application of them to ſhip-building, almoſt from the period when he began to ſpeak; ſo that he was a proficient in theſe ſciences before he had reached beyond the years of childhood. He was, however, removed from Croiſic to the Jeſuits college at Vannes, where, at 13 years of age, he triumphed, in a public conteſt, over a profeſſor of mathematics, who had advanced a mathematical propoſition erroneouſly. Two years after this he loſt his father, whom he was appointed to ſucceed in the office of hydrographer, after being publicly examined, and giving the moſt complete proof of his being duly qualified to fill the vacant chair. He was indeed qualified by prudence as well as by ſcience; for however ſurpriſing it may be, he filled it both with dignity and with abilities, though then not more than 15 years of age.

In the years 1727, 1729, and 1731, he gained the prizes ſucceſſively propoſed by the Academy of Sciences for eſſays on the beſt way of equipping ſhips with maſts, on the beſt method of obſerving at ſea the height of the ſtars, and on the moſt advantageous way of obſerving the declination of the magnetic needle or the variation of the compaſs. In 1729 he publiſhed an *Optical Eſſay upon the Gradation of Light*, in which he examined the intenſity of light, and determined its degrees of diminution in paſſing through different pellucid mediums, and particularly in traverſing the earth's atmoſphere. Of this eſſay, which was written upon a ſubject that till then had not attracted the attention of philoſophers, the reader will find ſome account in the *Encyclopædia Britannica*, under the title OPTICS, n° 32, &c.

In 1730 Bouguer was removed from the port of Croiſic to that of Havre. In 1731 he obtained, in the Academy of Sciences, the place of aſſociate geometrician, vacant by the promotion of Maupertuis to that of penſioner; and in 1735 he was promoted to the office of penſioner-aſtronomer. The ſame year he was ſent on the commiſſion to South America, along with Meſſrs Godin,

Godin, Condamine, and Jeuſſieu, to determine the meaſure of the degrees of the meridian, and the figure of the earth. In this painful and troubleſome buſineſs of ten years duration, chiefly among the lofty Cordelier mountains, our author, beſides attending to the object of the voyage, made many ſcientific obſervations; viz. on the effect of the Cordeliers on the polarity of the magnetic needle; on the expanſion and contraction of metals and other ſubſtances, by the ſudden and alternate changes of heat and cold among thoſe mountains; and on the refraction of the atmoſphere from the tops of the ſame, with the ſingular phenomenon of the ſudden increaſe of the refraction, when the ſtar can be obſerved below the line of the level. He likewiſe aſcertained the laws of the denſity of the air at different heights, from obſervations made at different points of thoſe enormous mountains; he diſcovered that the mountains have an effect upon a plummet, though he did not aſſign the quantity of that effect; he found out a method of eſtimating the errors committed by navigators in determining their route; gave a new conſtruction of the log for meaſuring a ſhip's way; and made ſeveral other uſeful improvements. M. Bouguer made at different times ſome important experiments on the famous reciprocation of the pendulum; he invented in 1747 the HELIOMETER (ſee that article *Encycl.*); and made many diſcoveries relating to the intenſity of light (for which ſee OPTICS-*Index*, Encycl.) His unremitting application to ſtudy undermined his health, and he died on the 15th of Auguſt 1758, in the 61ſt year of his age.

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

His papers that were inſerted in the Memoirs of the Academy are very numerous and important: as, in the Memoirs for 1726, compariſon of the force of the ſolar and lunar light with that of candles; 1731, obſervations on the curvilinear motion of bodies in mediums; 1732, upon the new curves called the *lines of purſuit*; 1733, to determine the ſpecies of conoid, to be conſtructed upon a given baſe which is expoſed to the ſhock of a fluid, ſo that the impulſe may be the leaſt poſſible; determination of the orbit of comets; 1734, compariſon of the two laws which the earth and the other planets muſt obſerve in the figure which gravity cauſes them to take; on the curve lines proper to form the arches in domes; 1735, obſervations on the equinoxes; on the length of the pendulum; 1736, on the length of the pendulum in the torrid zone; on the manner of determining the figure of the earth by the meaſure of the degrees of latitude and longitude; 1739, on the aſtronomical refractions in the torrid zone; obſervations on the lunar eclipſe of the 8th September 1737, made at Quito; 1744, ſhort account of the voyage to Peru by the members of the Royal Academy of Sciences, to meaſure the degrees of the meridian near the equator, and from thence to determine the figure of the earth; 1745, experiments made at Quito and divers other places in the torrid zone, on the expanſion and contraction of metals by heat and cold; on the problem of the maſting of ſhips; 1746, treatiſe on ſhips, their ſtructure and motions; on the impulſe of fluids upon the fore parts of pyramidoids, having their baſe a trapezium; continuation of the ſhort account given in 1744 of the voyage to Peru for meaſuring the earth; 1747, on a new conſtruction of the log, and other inſtruments for meaſuring the run of a ſhip; 1748, of the diameters of the larger planets; the new inſtrument called a *heliometer*, proper for determining them, with obſervations of the ſun; obſervation of the eclipſe of the moon the 8th of Auguſt 1748; 1749, ſecond memoir on aſtronomical refractions, obſeved in the torrid zone, with remarks on the manner of conſtructing the tables of them; figure of the earth determined by MM. Bouguer and Condamine, with an abridgment of the expedition to Peru; 1750, obſervation of the lunar eclipſe of the 13th December 1750; 1751, on the form of bodies moſt proper to turn about themſelves, when they are puſhed by one of their extremities, or any other point; on the moon's parallax, with the eſtimation of the changes cauſed in the parallaxes by the figure of the earth; obſervation of the lunar eclipſe the 2d of December 1751; 1752, on the operations made by ſeamen, called *corrections*; 1753, obſervation of the paſſage of Mercury over the ſun the 6th of May 1753; on the dilatations of the air in the atmoſphere; new treatiſe of navigation, containing the theory and practice of pilotage, or working of ſhips; 1754, operations, &c. for diſtinguiſhing, among the different determinations of the degree of the meridian near Paris, that which ought to be preferred; on the direction which the ſtring of a plummet takes; ſolution of the chief problems in the working of ſhips; 1755, on the apparent magnitude of objects; ſecond memoir on the chief problems in the working of ſhips; 1757, account of the treatiſe on the working of ſhips; on the means of meaſuring the light.

BREAD is ſo eſſential an article of food that every uſeful method of making it ſhould be generally known. Much has accordingly been ſaid on that ſubject (*Encycl.*) under the titles BAKING, BARM, BREAD, and YEAST: but, ſince the laſt of theſe articles was publiſhed, we have ſeen, in Dr Townſon's *Travels in Hungary*, a method of making bread at Debretzen; of which, as it may ſometimes be adopted with advantage in this country, an account may, with propriety, be inſerted here.

In the baking of this bread, a ſubſtitute is uſed for yeaſt, which is thus made: Two good handfuls of hops are boiled in four quarts of water: this is poured upon as much wheaten bran as can be well moiſtened by it: to this are added four or five pounds of leaven; when this is only warm, the maſs is well worked together to mix the different parts. This maſs is then put in a warm place for 24 hours; and after that, it is divided into ſmall pieces about the ſize of a hen's egg, or a ſmall orange, which are dried by being placed upon a board, and expoſed to a dry air, but not to the ſun; when dry, they are laid by for uſe, and may be kept half a year. This is the ferment; and it may be uſed in the following manner: For a baking of ſix large loaves, ſix good handfuls of theſe balls, broken into fragments, are taken and diſſolved in ſeven or eight quarts of warm water. This is poured through a ſieve into one end of the bread trough, and three quarts more of warm water are poured through the ſieve after it, and what remains in the ſieve is well preſſed out. This liquor is mixed up with ſo much flour as to form a maſs of the ſize of a large loaf: this is ſtrewed over with flour; the ſieve, with its contents, is put upon it, and then the whole is covered up warm, and left till it has riſen enough, and its ſurface has begun to crack: this forms the leaven. Then 15 quarts of warm water, in which ſix handfuls of ſalt have been diſſolved, are poured through the ſieve upon it, and the neceſſary quantity of flour is added, and mixed and kneaded with the leaven: this is covered up warm, and left for about an hour. It is then formed into loaves, which are kept in a warm room half an hour; and after that, they are put in the oven, where they remain two or three hours, according to the ſize. The great advantage of this ferment is, that it may be made in great quantities at a time, and kept for uſe. Might it not on this account be uſeful on board of ſhips, and likewiſe for armies when in the field?

Bread, in whatever way it is made, is a dear article; and it may be a deſirable object to many of our readers to know at what price the baker can afford to ſell it. This depends upon the price of wheat, the quantity of flour which the wheat may give, the loſs at the mill, the expence of grinding, and the expence of baking.

Of the price of wheat we can ſay nothing with preciſion, becauſe it varies according to the goodneſs or badneſs of the crop, and other circumſtances; but a buſhel of Eſſex wheat, Wincheſter meaſure, may be taken, on an average, as weighing 60 lb. Sixty pounds of wheat will yield, excluſive of the loſs in grinding and dreſſing, $45\frac{1}{2}$ lb. of that kind of flour which is called *ſeconds;* which alone is uſed, through the greateſt part of England, for bread, and which makes, indeed, the beſt of all bread, though not the whiteſt. A peck of this flour, weighing 14 lb. will take up between ſix and ſeven pints of water, and give 18 lb. of excellent bread; or a buſhel of flour, weighing 56 lb. will yield 72 lb. of bread. The expence of baking a buſhel of ſuch flour is, in Eſſex and ſome other Engliſh counties, about ninepence; viz. yeaſt, on an average, twopence; ſalt, before the late tax, one halfpenny; and baking, ſixpence.

But *ſeconds* is not all that is got from wheat. A buſhel of 60 lb. of wheat gives, beſides $45\frac{1}{2}$ lb. of ſeconds, 13 lb. of offal, i. e. of *pollards* and *bran;* for the utmoſt loſs in grinding and dreſſing a buſhel of wheat ſhould not exceed 1 pound 8 ounces. The millers, indeed, uſually reckon on two pounds of loſs; but we can ſay, with the utmoſt confidence, that the actual loſs is rather leſs than we have ſtated it. A correſpondent of ours, on whoſe accuracy we can depend, weighed, in 1795, two buſhels, Wincheſter meaſure, the one of white and the other of red wheat, and found the weight of them both to be 122 lb. This wheat was ground by his own ſervants, and it yielded $121\frac{1}{2}$ lb. of meal, ſo that there was here but $\frac{1}{2}$ lb. loſt of two buſhels, or of 122 lb. in grinding. He admits that he ſuffered the ſtones to turn too cloſe, and that the loſs ſhould therefore have been ſomewhat greater. The meal was dreſſed, as the wheat had been ground, under his own eye; and every poſſible precaution being taken to prevent his being deceived in the reſult, he had of flour, or *ſeconds*, $93\frac{1}{2}$ lb. and of bran and pollard $25\frac{1}{2}$ lb.; ſo that he loſt, of two buſhels, but $2\frac{1}{2}$ lb. both in grinding and dreſſing. The offal, or bran and pollard, being dreſſed in a bolting mill, yielded as follows:

Sharps -	6 lb.	0 oz.
Fine pollard	5	8
Coarſe pollard	7	8
Broad bran	5	8
Altogether	24	8

There was loſt, therefore, in bolting, only one pound; and of the ſharps, about three pounds, if ſifted, would have been good flour. Indeed were the ſharps and fine pollard to be added to the flour, the bread would, perhaps, be better, and more wholeſome, than without ſuch addition. From theſe data, which we believe to be very accurate, it will be eaſy to calculate, if the price of wheat be given, what ſhould be the price of flour per buſhel and peck, the price of bread per pound, and the quantity of bread that ſhould be ſold for a ſhilling.

It is a fact, however, which ſhould be attended to, that loaves are not always of the ſame weight, though made of equal quantities of the very ſame dough. This was fully aſcertained ſome years ago at Paris. On a violent complaint that the bread was not always of the ſame ſtandard weight, the bakers of the city were called before the police officers. They admitted the fact, that loaves, baked at the ſame time, and in the ſame oven, were ſeldom, if ever, of the ſame weight; but they inſiſted that they contained, each, the ſtandard quantity of dough, and that the variety of weight among them muſt proceed from ſome cauſe, which they did not pretend to aſcertain. The matter was referred to the Royal Academy of Sciences, which appointed one of its members to ſuperintend, for ſome days, the whole proceſs of baking. This being done, it was found that, of loaves baked in a large oven, thoſe were always heavieſt which occupied the centre of the oven, and that the bakers were innocent of the crime with which they were charged. The fact, we think, may eaſily be accounted for. Even in an oven there muſt be ſome condenſation of ſteam; and, from the very ſhape of the oven, the greateſt quantity muſt be condenſed towards the centre. Hence the loaves in the centre are neceſſarily wetter and heavier than thoſe round the circumference, if the plain of the oven has been equally heated.

BREAD of Rice might occaſionally be of great uſe in many countries during a ſcarcity of wheat; but the method of making it is not generally known. It is indeed impoſſible to make bread of the flour of rice, which is harſh and dry like ſand or aſhes, by treating it in the manner in which wheat-flour is commonly treated; and therefore it has been propoſed to mix it with an equal quantity of the flour of rye. But this method of uſing the flour of rice is a very uncertain remedy in caſe of want; ſince we can have no rice-bread if we have not rye. We are taught, however, in the *Journal des Sciences*, *des Lettres*, *et des Arts*, how to make excellent bread from rice alone, by a method which the author of the memoir ſays he learned from the natives of America.

According to this method of making the wiſhed-for bread, the firſt thing to be done to the rice is, to reduce it to flour, by grinding it in a mill, or, if we have not a mill, it may be done in the following manner:

Let a certain quantity of water be heated in a ſauce-pan or caldron ; when the water is near boiling, let the rice we mean to reduce into flour be thrown into it : the veſſel is then to be taken off the fire, and the rice left to ſoak till the next morning. It will then be found at the bottom of the water, which is to be poured off, and the rice put to drain upon a table placed in an inclined poſition. When it is dry, it muſt be beat to powder, and paſſed through the fineſt ſieve that can be procured.

When we have brought the rice into flour, we muſt take as much of it as may be thought neceſſary, and put it into the kneading trough in which bread is generally made. At the ſame time we muſt heat ſome water in a ſaucepan or other veſſel, and, having thrown into it ſome handfuls of rice, we muſt let them boil together for ſome time : the quantity of rice muſt be ſuch as to render the water very thick and glutinous. When this glutinous matter is a little cooled, it muſt be poured upon the rice-flour, and the whole muſt be well kneaded together, adding thereto a little ſalt, and a proper quantity of leaven. We are then to cover the dough with warm cloths, and to let it ſtand that it may riſe. During the fermentation, this paſte (which, when kneaded, muſt have ſuch a proportion of flour as to render it pretty firm) becomes ſo ſoft and liquid that it ſeems impoſſible it ſhould be formed into bread. It is now to be treated as follows :

While the dough is riſing, the oven muſt be heated ; and, when it is of a proper degree of heat, we muſt take a ſtewpan of tin, or copper tinned, to which is fixed a handle of ſufficient length to reach to the end of the oven. A little water muſt be put into this ſtewpan, which muſt then be filled with the fermented paſte, and covered with cabbage or any other large leaves, or with a ſheet of paper. When this is done, the ſtewpan is to be put into the oven, and puſhed forward to the part where it is intended the bread ſhall be baked; it muſt then be quickly turned upſide down. The heat of the oven acts upon the paſte in ſuch a way as to prevent its ſpreading, and keeps it in the form the ſtewpan has given it.

In this manner pure rice-bread may be made ; it comes out of the oven of a fine yellow colour, like paſtry which has yolk of eggs over it. It is as agreeable to the taſte as to the ſight ; and may be made uſe of, like wheat-bread, to put into broth, &c. It muſt, however, be obſerved, that it loſes its goodneſs very much as it becomes ſtale.

It may be here remarked, that the manner in which Indian corn is uſed in ſome countries, for making bread, can only produce (and does in fact produce) very bad dough, and of courſe very bad bread. To employ it advantageouſly, it ſhould be treated like rice ; and it may then be uſed, not only for making bread, but alſo for paſtry.

BREWING is an art of vaſt importance, and has accordingly been explained in the Encyclopædia Britannica. A few improvements, however, have been made in the art, which, though not noticed in that Work, ſeem to be worthy of general attention, and, therefore, to deſerve a place in this Supplement. The firſt, of which we ſhall give an account, is an invention of Mr William Ker of *Kerfield*, in the county of Tweedale, for the ſaving of hops, and, at the ſame time, giving to the liquor, whether ale, beer, or porter, a ſuperior flavour and quality.

The ſteam which ariſes from the boiling copper is known to be ſtrongly impregnated with the eſſential oil of the hops, in which their flavour conſiſts. Inſtead, therefore, of allowing it to eſcape and evaporate, as it does in the common mode of brewing, Mr Ker contrives to preſerve and condenſe it, by means of a winding-pipe fixed to the copper, ſimilar to the worm of a ſtill, or by a ſtraight pipe paſſing through cold water, or any other cooling medium. The oil and water, thus obtained, are returned into the worts when boiled, or the oil, after being ſeparated from the water, along with which it had been exhaled, is returned into the worts after they are boiled ; and the watery part, which, after the oil is ſeparated, ſtill continues impregnated with the aromatic taſte and bitter of the hop, is returned into the next copper or boiling-veſſel ; and ſo on from one copper or boiling-veſſel into another. By this proceſs a conſiderable part of the hop and flavour, which is loſt in the ordinary mode of brewing, is preſerved : the flavour of the liquor is improved by the preſervation of the finer parts of the aromatic oil : and the ale and beer are better ſecured from any tendency to acidity or putrefaction, and therefore muſt be fitter for home conſumption and exportation. For this invention, which is certainly ſimple, and we think rational, Mr Ker obtained a patent, dated March 4 1788.

On the 4th of June 1790, Mr John Long of *Longville*, in the county of *Dublin*, Ireland, obtained a patent for an improvement in brewing, reſembling, in one particular, this invention of Mr Ker's. To his invention, however, he gives the name of *an entire new method*, in *all the eſſential parts*, of brewing good malt liquor ; and therefore, as it comprehends the whole proceſs of brewing, we ſhall lay it before our readers in the words of its author.

" 1. For the better extracting from malt, place near a maſh-tun a ſhallow copper or other veſſel that will readily heat ; the curb of which to be on a level with the tun, and to contain from two to ſix hogſheads, according to the dimenſion of the tun, more or leſs; and, at the lower end of the copper, have a cock from two to five inches diameter, more or leſs, to conduct the heated liquor from the copper into a tube which paſſes down the external part of the tun, and enters it through an aperture about ſix inches from the bottom; then forming two revolutions, more or leſs, through the body of the tun, and communicating its heat to the wort as it paſſes through the tube; and then, at a convenient diſtance from the place it firſt entered, it runs from the tun into a ciſtern or tub, ſituate as near as convenient to the copper or heating-veſſel. In the tub or ciſtern is to be placed a pump, for the purpoſe of conveying the cooler liquor back to the copper or heating-veſſel again ; there to receive the heat of 208 degrees, more or leſs (which it will require after the firſt half-hour), and then convey it through the maſhing-tun as before, and in the ſame manner, as long as the working brewer or diſtiller may think neceſſary, to raiſe the maſhing-tun to any degree of heat required. By adhering to the foregoing proceſs, the firſt liquor may, with the greateſt ſafety, be let upon the malt from 20 to 30 degrees lower than the preſent practice ; by which means it operates with gentleneſs, opens and expands the malt and raw corn, and prepares it for the reception of ſharper or warmer liquor, ſo as to extract the whole of the ſaccharine quality from the malt and raw corn. By the foregoing method, the maſhing-tun, inſtead of loſing its firſt heat (which it does by the preſent practice), continues to increaſe in heat every moment, by conveying the heated liquor through the tube into the tun; by which means, at the end of two hours, the working brewer or diſtiller can have the tun brought to any degree of heat he ſhall think beſt ſuited to the different qualities of the malt or raw corn. Perſons who would wiſh to ſave expence, may heat their maſhing-tun at the ſide or bottom by a large piece of metallic ſubſtance made fire proof, and fixed therein; which, in ſome degree, will anſwer the end propoſed, but with great trouble and delay.

"2. To prevent the wort from receiving a diſagreeable flavour while in the under-back, a tube muſt be placed at the cock of the maſhing-tun, to receive the wort as it comes off, and convey it to a great ciſtern or refrigeratory, which is ſupplied with a ſtream of water. The wort, paſſing through that medium in a ſpiral tube, ſoon loſes that heat which ſo often proves prejudicial to the brewer and diſtiller in warm weather: then paſs it from the tube into a veſſel in which pumps are placed, to return the worts into the copper for the purpoſe of boiling off. All veſſels for receiving the cold wort muſt be placed lower than the ſource whence the wort comes.

"3. As the great object of long boiling the wort is remedied, by my invention of taking the extract from the hops in a ſeparate manner from the worts, I boil my worts no longer than from 15 to 20 minutes; and, by purſuing that method, I ſave much time and fuel, and regulate my lengths accordingly.

"4. I ſteep my hops, the preceding day to which they are to be uſed, in a copper or other veſſel, with as much fluid, blood-warm, as will cover the hops, where it is to remain over a ſlow fire at leaſt 14 hours, cloſe covered; the copper at the tenth hour not to be of a greater heat than 175 degrees, continuing ſlow until the laſt hour. Then I bring the copper gradually to a ſimmer or ſlow boil; in which ſtate I let it remain about 10 minutes, and then run off the fluid; and this I do at the ſame time the firſt wort is boiled off, that they may both paſs together through the refrigeratory into the fermentation or working tun. After the foregoing operation, I cover the hops again with other liquor, and bring the copper to boil as ſoon as convenient, and let it remain in that ſtate a conſiderable time, until the ſecond worts are boiled off. Then I paſs the hop-fluid with the wort, the ſame as in the firſt inſtance; and, if there is a third wort, I boil my hops a third time with ſmall worts, and paſs it off as before; by which means I gradually obtain the whole of the eſſential oil and pleaſing bitter from the hops, which is effectually preſerved in the beer.

"5. To cool worts. When the wort is boiled off, it is conducted from the cock of the copper or boiler into a tube of a proper dimenſion, which paſſes the wort from the cock to the large ciſtern or refrigeratory, and there performs ſeveral revolutions, in a ſpiral manner, through the ſame tube; which is immerſed in conſtant ſupply of cold water, where it loſes the greateſt part of its heat in a ſhort time, and thence continues a ſtraight courſe through the tube, a little elevated and of a ſuitable length, placed in brick-work, until it meets a ſmall refrigeratory, ſupplied with colder water from a reſervoir made for that purpoſe at the head of the works; whence a continual ſtream runs on the ſurface of the tube down to the great refrigeratory, cooling the wort as it paſſes, in order to enable the working brewer or diſtiller to ſend it into the backs or working-tuns at whatever degree of heat he ſhall think proper. There is no other difference between brewer and diſtiller in this proceſs, but that the diſtiller immediately paſſes the ſtrong wort from the maſhing-tun to the back, thro' the ſame machinery above inſerted, and the tubes may be made of lead, or any other metallic ſubſtance.

"6. To enable me to brew in the warm ſummer months, I ſink my backs or working-tuns at leaſt to a level with the ground, but if deeper the better, and cover them cloſely by an arch made of bricks, or other materials, that will totally exclude the atmoſpheric air from them. I place them as near as poſſible to a ſpring or ſand-drain, as their depth will naturally draw the water thence, which muſt be ſo contrived as to paſs or flow round the backs or tuns. I then introduce a large tube, which paſſes through the tuns, and keeps the wort ſeveral degrees lower than can poſſibly be done by the preſent practice; by which means I can produce a complete fermentation even in the dog-days.

"7. In cold or froſty weather, if the tun and backs ſhould loſe the firſt heat, intended to carry it through the proceſs by the foregoing method, you may convey a ſupply of warm or boiling water by the tube, which paſſes through the body of the backs or tun, communicating its heat, which riſes to any degree the working brewer ſhall think proper: by purſuing this method, in the coldeſt ſeaſon, I never want a fermentation."

We regret that we cannot with propriety ſtate to our readers, under this article, a ſummary of Mr Richardſon of Hull's *Philoſophical Principles of Brewing*; for as the author has a new edition of his work in the preſs, it is our duty rather to refer to it, than to quote from a former edition, which contains not his laſt improvements. See FERMENTATION and MALT, in this Supplement.

BRIDEALE. See SCOTALE in this Supplement.

BRIDGE. See that article *(Encycl.)*, and ARCH in this Supplement. A *wooden*-bridge, of large ſpan, ſhould be conſtructed on the principles explained under the title ROOF (*Encycl.*) See alſo CENTRE (*Suppl.*)

BRINDLEY (James), was born at Tunſted, in the pariſh of Wormhill, Derbyſhire, in 1716. His father was a ſmall freeholder, who diſſipated his property in company and field amuſements, and neglected his family. In conſequence, young Brindley was left deſtitute of even the common rudiments of education, and till the age of 17 was caſually employed in ruſtic labours. At that period he bound himſelf apprentice to one Bennet, a mill-wright at Macclesfield, in Cheſhire, where his mechanical genius preſently developed itſelf. The maſter being frequently abſent, the apprentice was often left for weeks together to finiſh pieces of works concerning which he had received no inſtruction; and Bennet, on his return, was often greatly aſtoniſhed to ſee improvements in various parts of mechaniſm, of which he had no previous conception. It was not long before the millers diſcovered Brindley's merits, and preferred

ferred him in the execution of their orders to the maſter or any other workman. At the expiration of his ſervitude, Bennet being grown into years, he took the management of the buſineſs upon himſelf, and by his ſkill and induſtry contributed to ſupport his old maſter and his family in a comfortable manner.

In proceſs of time Brindley ſet up as a mill-wright on his own account; and by a number of new and ingenious contrivances greatly improved that branch of mechanics, and acquired a high reputation in the neighbourhood. His fame extending to a wider circle, he was employed, in 1752, to erect a water-engine at Clifton, in Lancaſhire, for the purpoſe of draining ſome coal mines. Here he gave an eſſay of his abilities in a kind of work for which he was afterwards ſo much diſtinguiſhed, driving a tunnel under ground through a rock nearly 600 yards in length, by which water was brought out of the Irwell for the purpoſe of turning a wheel fixed 30 feet below the ſurface of the earth. In 1755 he was employed to execute the larger wheels for a ſilk mill at Congleton: and another perſon, who was engaged to make other parts of the machinery, and to ſuperintend the whole, proving incapable of completing the work, the buſineſs was entirely committed to Brindley; who not only executed the original plan in a maſterly manner, but made the addition of many curious and valuable improvements, as well in the conſtruction of the engine itſelf, as in the method of making the wheels and pinions belonging to it. About this time, too, the mills for grinding flints in the Staffordſhire potteries received various uſeful improvements from his ingenuity.

In the year 1756 he undertook to erect a ſteam engine, upon a new plan, at Newcaſtle-under-Line; and he was, for a time, very intent upon a variety of contrivances for improving this uſeful piece of mechaniſm. But from theſe deſigns he was, happily for the public, called away to take the lead in what the event has proved to be a national concern of capital importance—the projecting the ſyſtem of canal navigation. The Duke of Bridgewater, who had formed his deſign of carrying a canal from his coal-works at Worſley to Mancheſter, was induced by the reputation of Mr Brindley to conſult him on the execution of it; and having the ſagacity to perceive, and ſtrength of mind to confide in, the original and commanding abilities of this ſelf-taught genius, he committed to him the management of the arduous undertaking. The nature of this enterpriſe has already been deſcribed (*Encycl.* vol. IV. p. 8c.); it is enough here to mention, that Mr Brindley, from the very firſt, adopted thoſe leading principles, in the projecting of theſe works, which he ever after adhered to, and in which he has been imitated by all ſucceeding artiſts. To preſerve as much as poſſible the level of his canals, and to avoid the mixture and interference of all natural ſtreams, were objects at which he conſtantly aimed. To accompliſh theſe, no labour or expence was ſpared; and his genius ſeemed to delight in overcoming all obſtacles by the diſcovery of new and extraordinary contrivances.

The moſt experienced engineers upon former ſyſtems were amazed and confounded at his projects of aqueduct bridges over navigable rivers, mounds acroſs deep valleys, and ſubterraneous tunnels; nor could they believe in the practicability of ſome of theſe ſchemes till they ſaw them effected. In the execution, the ideas he followed were all his own; and the minuteſt, as well as the greateſt, of the expedients he employed, bore the ſtamp of originality. Every man of genius is an enthuſiaſt. Mr Brindley was an enthuſiaſt in favour of the ſuperiority of canal navigations above thoſe of rivers; and this triumph of art over nature led him to view with a ſort of contempt the winding ſtream, in which the lover of rural beauty ſo much delights. This ſentiment he is ſaid to have expreſſed in a ſtriking manner at an examination before a committee of the Houſe of Commons, when, on being aſked, after having made ſome contemptuous remarks relative to rivers, what he conceived they were created for? he anſwered, "to feed navigable canals." A direct rivalry with the navigation of the Irwell and Merſey was the bold enterprize of his firſt great canal; and ſince the ſucceſs of that deſign, it has become common, all over the kingdom, to ſee canals accompanying, with inſulting parallel, the courſe of navigable rivers.

After the ſucceſsful execution of the Duke of Bridgewater's canal to the Merſey, Mr Brindley was employed in the revived deſign of carrying a canal from that river to the Trent, through the counties of Cheſter and Stafford. This undertaking commenced in the year 1766; and from the great ideas it opened to the mind of its conductor, of a ſcheme of inland navigation which ſhould connect all the internal parts of England with each other, and with the principal ſea-ports, by means of branches from this main ſtem, he gave it the emphatical name of the *grand trunk*. In executing this, he was called upon to employ all the reſources of his invention, on account of the inequality and various nature of the ground to be cut through: in particular, the hill of Harecaſtle, which was only to be paſſed by a tunnel of great length, bored through ſtrata of different conſiſtency, and ſome of them mere quickſand, proved to be a moſt difficult, as well as expenſive, obſtacle, which, however, he completely ſurmounted. While this was carrying on, a branch from the grand trunk, to join the Severn near Bewdly, was committed to his management, and was finiſhed in 1772. He alſo executed a canal from Droitwich to the Severn; and he planned the Coventry canal, and for ſome time ſuperintended its execution; but on account of ſome difference in opinion, he reſigned that office. The Cheſterfield canal was the laſt undertaking of the kind which he conducted, but he only lived to finiſh ſome miles of it. There was, however, ſcarcely any deſign of canal-navigation ſet on foot in the kingdom, during the latter years of his life, in which he was not conſulted, and the plan of which he did not either entirely form, or reviſe and improve. All theſe it is needleſs to enumerate; but, as an inſtance of the vaſtneſs of his ideas, it may be mentioned, that on planning a canal from Liverpool to join that of the Duke of Bridgewater at Runcorn, it was part of his intention to carry it, by an aqueduct bridge, acroſs the Merſey, at Runcorn Gap, a place where a tide, ſometimes riſing fourteen feet, ruſhes with great rapidity through a ſudden contraction of the channel. As a mechanic and engineer, he was likewiſe conſulted on other occaſions; as with reſpect to the draining of the low lands in different parts of Lincolnſhire and the Iſle of Ely, and to the cleanſing of the docks of Liverpool from mud. He pointed out a method, which has been ſucceſsfully practiſed, of building ſea-walls without mortar; and he was the author of a very ingenious improvement of the machine for drawing water out of mines by the contrivance of a loſing and a gaining bucket.

The intenſity of application which all his various and complicated employments required, probably ſhortened his days; as the number of his undertakings, in ſome degree, impaired his uſefulneſs. He fell into a kind of chronic fever, which, after continuing ſome years, with little intermiſſion, at length wore out his frame. and put a period to his life on September 27. 1772, in the 56th year of his age. He died at Tunhurſt, in Staffordſhire, and was buried at New Chapel in the ſame county.

In appearance and manners, as well as in acquirement, Mr Brindley was a mere peaſant. Unlettered, and rude of ſpeech, it was eaſier for him to deviſe means for executing a deſign than to communicate his ideas concerning it to others. Formed by nature for the profeſſion he aſſumed, it was there alone that he was in his proper element; and ſo occupied was his mind with his buſineſs, that he was incapable of relaxing in any of the common amuſements of life. As he had not the ideas of other men to aſſiſt him, whenever a point of difficulty in contrivance occurred, it was his cuſtom to retire to his bed, where, in perfect ſolitude, he would lie for one, two, or three days, pondering the matter in his mind till the requiſite expedient had preſented itſelf. This is that true inſpiration which poets have almoſt excluſively arrogated to themſelves, but which men of original genius in every walk are actuated by, when, from the operation of the mind acting upon itſelf, without the intruſion of foreign notions, they create and invent.

A remarkably retentive memory was one of the eſſential qualities which Mr Brindley brought to his mental operations. This enabled him to execute all the parts of the moſt complex machine in due order, without any help of models or drawings, provided he had once accurately ſettled the whole plan in his mind. In his calculations of the powers of machines, he followed a plan peculiar to himſelf; but, indeed, the only one he could follow without inſtruction in the rules of art. He would work the queſtion ſome time in his head, and then ſet down the reſult in figures. Then taking it up in this ſtage, he would again proceed by a mental operation to another reſult; and thus he would go on by ſtages till the whole was finiſhed, only making uſe of figures to mark the ſeveral reſults of his operations. But though, by the wonderful powers of native genius, he was thus enabled to get over his want of artificial method to a certain degree; yet there is no doubt that when his concerns became extremely complicated, with accounts of various kinds to keep, and calculations of all ſorts to form, he could not avoid that perplexity and embarraſſment which a readineſs in the proceſſes carried on by pen and paper can alone obviate. His eſtimates of expence have generally proved wide of reality; and he ſeems to have been better qualified to be the contriver, than the manager of a great deſign. His moral qualities were, however, highly reſpectable. He was far above envy and jealouſy, and freely communicated his improvements to perſons capable of receiving and executing them; taking a liberal ſatisfaction in forming a new generation of engineers able to proceed with the great plans in the ſucceſs of which he was ſo deeply intereſted. His integrity and regard to the advantage of his employers were unimpeachable. In fine, the name of Brindley will ever keep a place among that ſmall number of mankind who form eras in the art or ſcience to which they devote themſelves, by a large and durable extenſion of its limits.

BRISSOT (J. P.), acted ſo conſpicuous a part in the French revolution, that a fair detail of the principal events of his life would undoubtedly be acceptable to all our readers. A fair detail, however, of ſuch a life, we believe it impoſſible at preſent to give; for characters like Briſſot's are almoſt always miſrepreſented both by their friends and by their enemies; and till the troubles which they have excited, or in which they have been engaged, have long ſubſided, the impartial truth is nowhere to be found.

In a fulſome panegyric, under the denomination of *The Life of J. P. Briſſot*, ſaid to be written by himſelf, we are told, that he was born January 14. 1754; and that his father was a *traiteur*, or "the keeper of an eating-houſe," but in what place we are not informed. Our author, however, aſſures us that the old man was in eaſy circumſtances, and that he employed all the means reſulting from them to give to his numerous family a good education. The ſubject of this memoir was intended for the bar; but not reliſhing the ſtudies neceſſary to fit him for the profeſſion of the law, or, if we chooſe to believe him, having a mind too *pure* and *upright* for the ſtudy of *chicane*, he relinquiſhed the purſuit after five years of drudgery!

To relieve his wearineſs and diſguſt, he applied himſelf, he ſays, to literature and the ſciences. The ſtudy of the languages was above all others his favourite purſuit. Chance brought him acquainted with two Engliſhmen on their travels through France: he learned their language; and this circumſtance, he tells us, decided his fate.

"It was at the commencement of my paſſion for that language (continues he) that I made the metamorphoſis of a diphthong in my name which has ſince been imputed to me as ſo heinous a crime. Born the thirteenth child of my family, and the ſecond of my brothers in it, I bore, for the ſake of diſtinction, according to the cuſtom of Beauce, the name of a village in which my father poſſeſſed ſome landed property. This village was called *Ouarville*, and Ouarville became the name by which I was known in my own country. A fancy ſtruck me that I would caſt an Engliſh air upon my name; and accordingly I ſubſtituted, in the place of the French diphthong *ou*, the *w* of the Engliſh, which has preciſely the ſame ſound." For this puerile affectation, which was certainly not criminal, he juſtifies himſelf by the example of the literati of the 16th and 17th centuries, who made no ſcruple of Greciſing and Latiniſing their appellatives.

Having proſecuted his ſtudies for two years, he had an application from the Engliſh proprietor of a paper then much in circulation, and intitled *Le Courier de l' Europe*. This man having drawn upon himſelf an attack from government, felt and yielded to the neceſſity of printing his paper at Boulogne-ſur-mer. It was his wiſh to render it intereſting to the French in the department of miſcellaneous intelligence; which he therefore wiſhed to ſubmit to the ſuperintendency and arrangement of Briſſot, who repreſents himſelf as for ſome moments heſitating. The profeſſion of a journaliſt, ſubject to a licenſer, was repugnant to his principles; yet it ſecured his independence, and put into his power the means of proſecuting an inveſtigation of conſtitutions and of the ſciences. After ſome ridiculous reaſoning from the original ſtations of *Bayle*, *Poſtel*, and *Rouſſeau*, he at laſt accepted of the employment, and became enamoured of it, "becauſe (ſays he) it enabled me to ſerve talents and virtue, and, as it were, to inoculate the French with the principles of the Engliſh conſtitution.

This employment, however, did not laſt for any length of time. The plan of the proprietor of the *Courier* was overthrown by adminiſtration, and Briſſot quitted Boulogne to return to his firſt ſtudies. Having informed us of this fact, he makes an extravagant pretence to unſullied virtue, and calls upon the inhabitants of the city which he had left to bear witneſs, not only that he had *no vices*, but that he had not even the *ſeeds* of any one of the vices which his adverſaries, it ſeems, had laid to his charge.

"Doubtleſs (ſays he), too eager to publiſh my ideas, I conceived that the proper moment had arrived, and I felt an inclination to commence with an important work. Revolting, from the very inſtant of my beginning to reflect, againſt religious and political tyranny, I ſolemnly proteſted, that thenceforward I would conſecrate my whole life to their extirpation. Religious tyranny had fallen under the redoubled ſtrokes of Rouſſeau, of Voltaire, of Diderot, and of D'Alembert. It became neceſſary to attack the ſecond;" and this was a taſk which the vanity of Briſſot led him to conſider as reſerved for him.

What Voltaire and his friends meant by religious tyranny, and how they conducted their attacks againſt it, are matters, alas! too well known to all Europe; and as our author choſe theſe philoſophers for his guides, we might infer, without much degree of miſtake, what he underſtood by political tyranny, and by what means he meditated its extirpation. But he has not left us to make this diſcovery by inference.

"It became neceſſary (ſays he) to break in pieces the political idol, which, under the name of *monarchy*, practiſed the moſt violent deſpotiſm; but to attack it openly, was to expoſe the aſſailant without the poſſibility of ſerving mankind. It was by a ſide blow that it was to be wounded moſt effectually;" and therefore he reſolved to begin his operations by attacking ſome of thoſe abuſes which might be reformed without apparently ſhaking the authority of the prince.

Our readers, at leaſt the ſober part of them, will probably think that this mode of attack is not peculiar to Briſſot, but that it has been practiſed, or attempted to be put in practice, by aſpiring demagogues in all ages and countries, who have uniformly begun their career of innovation by exciting the public mind againſt thoſe abuſes in government, of which the exiſtence cannot wholly be denied. The ſubject to which our author thought fit to call the attention of his countrymen, was the criminal juriſprudence: a ſubject, ſays he, which, with the exception of ſome particulars that had been ſucceſsfully inveſtigated by Beccaria and Servan, no writer had thoroughly conſidered in a philoſophical point of view. Thinking himſelf fully equal to this taſk, he drew up a general plan; and in the year 1780 publiſhed his Theory of Criminal Laws, in two vols 8vo. This work, favourably received by foreigners, applauded by ſome journaliſts, and pulled to pieces by others, procured him the friendſhip of the warmeſt advocates for human liberty, in whoſe opinion the defects of his plan were highly pardonable, on account of the energy conſpicuous in his remarks. This publication was ſoon followed by two diſcourſes which gained the prize in 1782 at the academy of Chalons-ſur-Marne; the one upon the reform of the criminal laws, and the other on the reparation due to innocent perſons unjuſtly accuſed.

It is natural to ſuppoſe that the government beheld with an evil eye theſe writings, which, under pretext of dragging into light the abuſes of the criminal laws, inſinuated dangerous principles on the nature of government in general.

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

But the ſtudy of legiſlation and politics had not entirely drawn him off from that of other ſciences; ſuch as chemiſtry, phyſics, anatomy, theology, &c. Theſe he conſtantly cultivated with ardour; but acknowledges that in each he met with obſcurities, and that in every quarter truth eſcaped from his reſearches. He therefore ſat down to inveſtigate the nature of truth, and the proper method of attaining to it in every department of reſearch; and the reſult of his labours was a kind of *novum organum*, by which he ſeems to have expected that Bacon's work would be buried in oblivion; and to this important volume he gave the title of *Concerning Truth; or, Thoughts on the Means of attaining Truth in all the Branches of Human Knowledge.* This volume was meant as nothing more than the introduction to a greater work, in which he propoſed to inveſtigate what is *certain* in knowledge and what *doultful*, and then to ſtrike the balance of the account.

He was prevented, however, from completing his plan, which he regrets exceedingly; for, as he affirms, with *becoming modeſty*, his work would certainly have amended its readers! But the French government happened to think otherwiſe; his aim, which, he ſays, was to lead mankind to reflect on their rights, was perceived, and he was accuſed to the miniſter as a ſeditious writer. The career of genius was ſtopped by the dread of the Baſtile; and he was obliged to take refuge in London. There it was his wiſh to create *a univerſal confederation of the friends of liberty and truth*, and to eſtabliſh a *centre of correſpondence and union* with the learned and the politicians of Europe. This dark deſign, however, was fruſtrated by the treachery, as it would appear, of his aſſociates, who had bound themſelves, he ſays, by the moſt *ſacred oaths*, to aſſiſt him, and had offered to ſign articles *even with their own blood*.

Finding himſelf unable to proceed directly to the object which he had in view, he reſolved to *enlighten his* countrymen gradually, and to begin with exciting their love and admiration of the Engliſh conſtitution. That conſtitution, which he had inveſtigated on the ſpot, appeared to him a model for thoſe ſocieties which were deſirous of changing their form of government. It was but little known, he ſays, in France (the work of *De Lolme* being at that time only in the hands of the learned);

ed); and to make it known was to make it beloved, was to render it deſired. But the French miniſters ſtood upon their guard, and it became neceſſary to *deceive* them. He reſolved therefore to bring forward a journal written actually in London, and profeſſing to contain only a *deſcription of the ſciences and arts of England*, whilſt the greater part of it was to be occupied in reality by an inveſtigation of the *Engliſh conſtitution*.

After many difficulties, the miniſtry granted a privilege for this journal, being publiſhed in London, to be reprinted in Paris; and it firſt appeared in 1784. "In the twelve numbers which have been publiſhed (ſays the author), the friends of liberty muſt have perceived, that if, on the one ſide, I endeavoured to inculcate more juſt ideas than had hitherto been entertained concerning this celebrated iſland; ſo, on the other, I reſolutely made my advances toward that important end which has perpetually preſided over all my labours, *the univerſal emancipation of men*."

His affairs calling him at this time to Paris, he was arreſted and conveyed to the Baſtile on the 12th of July 1784. In this conduct of the government we cannot perceive any thing very tyrannical or arbitrary, ſince he confeſſes, that, in the 16th page of the firſt number of his Journal, he had ſuffered the *ſecret and favourite aim*, which always guided his pen, to become diſcernible. He was, however, diſcharged from priſon on the 5th of September, and returned with increaſed zeal to his former employments.

"This perſecution (ſays he), far from extinguiſhing the ardour of my wiſhes to inculcate the principles of freedom, ſerved only to inflame it the more." Accordingly, in 1785, he publiſhed two letters to the Emperor Joſeph II. *concerning the right of emigration, and the right of people to revolt*. The firſt of theſe letters, which, though well known in Germany, were in France ſuppreſſed by the *police*, was occaſioned by what the author calls the ridiculous and barbarous edict againſt emigration; and the ſecond by the puniſhment of *Horiah* the chief of the *Walachian* inſurgents. In this laſt letter he lays it down as a maxim, that all people under ſuch a government as that of the *Walachians*, have from nature a ſacred *right* to revolt, a right which they can and ought to exerciſe. In the ſame ſpirit he brought out, in 1786, his Philoſophical Letters on the Hiſtory of England, in 2 vols, and A Critical Examination of the Travels of the Marquis de Chatelleux in North America.

The French revolution appearing to him extremely diſtant, notwithſtanding all his efforts to haſten it, he reſolved to leave France for the purpoſe of ſettling in America. His project received the approbation of ſeveral, whoſe ſentiments were congenial with his own. But as it was thought imprudent to tranſport numerous families to a country ſo far off, without thoroughly knowing it, Briſſot was engaged to proceed thither, to examine the different places, to obſerve the inhabitants, and to diſcover where and in what manner the eſtabliſhment they had propoſed might be moſt advantageouſly fixed. He had ſome time before inſtituted a ſociety at Paris for accompliſhing the abolition of the negro trade, and for ſoftening the condition of the ſlaves. At the period of his departure, this ſociety conſiſted of a conſiderable number of diſtinguiſhed members, and he was commiſſioned to carry the firſt fruits of their labours to America. His ſtay there, however, was not ſo long as he was deſirous of making it. In the beginning of 1789 he was recalled by the news of the French revolution, which he conceived might probably produce a change in his own meaſures and in thoſe of his friends. This idea, added to other circumſtances, accelerated his return. The fire had blazed forth in his native country. "Hope (ſays he) animated every heart; the moſt diſtinguiſhed champions had engaged in the conteſt; I too became deſirous to break a lance, and I publiſhed my *Plan of Conduct for the Deputies of the People*."

This, and other works of a ſimilar kind, of which he loudly boaſts the merits, raiſed him high in the favour of the republican part of the nation, and he became preſident of his diſtrict; where he acted, according to his own account, with great uprightneſs in the municipality, in the firſt committee of inquiries, and as an elector. At laſt he became a member, firſt of the *National Aſſembly*, and, after its diſſolution, of the *Sanguinary Convention*; and by ſome means or other got to be the leader of a party called ſometimes the *Girondiſts*, and ſometimes the *Briſſotines*. From that period the principal events of his life were involved with the public tranſactions of the nation, of which we have given an account in the *Encyclopædia* under the title REVOLUTION (ſee that article, n° 101—182.) The Girondiſt faction was denounced by the Mountain, and Briſſot ſuffered by the guillotine on the 30th of November 1793. He fell indeed by a very unjuſt ſentence; but his fall was the natural conſequence of that anarchical tyranny under which no man had contributed more than he to ſubject his native country.

BROWN (Dr John), author of the *Elementa Medicinæ*, &c. was born in the village of Dunſe, or, as ſome ſay, Lintlaws, in the county of Berwick, in the year 1735-6. His parents were of mean condition, but much reſpected in the neighbourhood for the integrity of their lives. His father gained his livelihood in the humble capacity of a day-labourer; while his mother contributed her ſhare towards the ſupport of the family by the profits ariſing from a milch cow.

Such were the perſons who, in an obſcure part of the country, gave birth to a ſon deſtined, at a future period, to make a diſtinguiſhed figure in the republic of letters; and from whom originated a ſyſtem of the animal economy, which, whatever be its real merits, has undoubtedly produced a conſiderable revolution in the practice of medicine.

At the age of three or four years, young Brown was put to a reading ſchool in Dunſe, which he himſelf commemorates as the place rather of his education than of his nativity. Here, under the tuition of an old woman, he very early began to exhibit marks of that ſtrength of mind for which he was afterwards ſo eminently diſtinguiſhed. In the ſhort period of a year he became able to read with facility any part of the Bible, and acquired over his claſs-fellows that ſuperiority which he ever after maintained both at ſchool and college.

It was almoſt immediately after his entrance into this ſchool, that his inſatiable deſire of reading commenced; and ſo unremitting was his application, that he is ſaid never to have been found, even at thoſe hours which children much more advanced in life devote to amuſement, without a book in his hand.

While he was making this rapid progreſs in the rudiments

diments of literature, he ſuffered what muſt have appeared to be a very heavy loſs in the death of his father; but his mother ſoon afterwards married a worthy man of the ſame name, whoſe care and attention ſupplied the place of a father to her ſon. This man being a weaver, deſigned to educate his ſon-in-law to the ſame buſineſs, and began to inſtruct him in his art when he was about nine years of age: but the taſte which young Brown had already acquired for letters, made him look with diſguſt on the inſipid employment of a weaver. His ſtep-father was no tyrant, and his mother was affectionate. They were both proud of the talents which at ſo early a period of life had appeared in their ſon, and they felt no inclination to ſtruggle with the invincible averſion which he expreſſed to the buſineſs for which they intended him.

Another circumſtance, however, contributed in no ſmall degree to make them recal their original reſolution. They were both of that ſect of religioniſts which in Scotland are called Seceders (ſee SECEDERS, *Encycl.*); and it was ſuggeſted to them by ſome perſons of their own perſuaſion, who had remarked the uncommon abilities of the boy, that he might one day prove an able ſupport and promoter of their tenets as a preacher. He was accordingly, much to his ſatisfaction, taken away from the buſineſs to which he had conceived ſuch a diſtaſte, and ſent to the grammar-ſchool of Dunſe, which was taught at that time by a gentleman of the name of Cruickſhank, eminent for his grammatical knowledge. Here he appears to have ſpent ſome years with uncommon advantage and happineſs; during which he was eſteemed by all the country round as a kind of prodigy. Like Johnſon, and many other men of the higheſt celebrity, he united in the ſame perſon uncommon powers of mind, with no leſs ſtrength of body, as indeed his appearance indicated; and in his youth he enſured his own perſonal importance among his ſchool-fellows, by excelling them not leſs in athletic exerciſes than in the taſks preſcribed by their maſter. He was particularly fond, when a boy, of practiſing the pugiliſtic art; and indeed until the laſt period of his life he was obſerved by his friends always to view an exhibition of that kind with peculiar reliſh. He alſo prided himſelf much in being a ſtout walker; and mentions his having in one day accompliſhed, when but fifteen years of age, a journey of fifty miles between Berwick-upon-Tweed and Morpeth in Northumberland. When farther advanced in life, he travelled on foot from four in the afternoon of one day to two in the afternoon of next day, with the ſhort interval of one hour's reſt! But as one of his biographers very juſtly obſerves, "we have ſeen that he could make a more rational uſe of his ſtrength than merely to ſtake it againſt time and ſpace *."

* Dr Bed- s.

His early years while at ſchool were marked by the moſt rigid attachment to his ſect. So ſtrict indeed were his religious ſentiments, if a boy of ten or eleven can be ſaid to have any ſentiments deſerving to be called religious, that he would have conceived the holding of any communion with the eſtabliſhed church as a kind of profanation. An event, however, happened, ſome time between the eleventh and thirteenth years of his age, which produced a total and unexpected revolution in his religious opinions. At a meeting of the provincial ſynod of Merſe and Tiviotdale, he was prevailed upon, though not without manifeſting much reluctance, to accompany a party of his ſchool-fellows to the pariſh church of Dunſe. The conſequence of this tranſgreſſion, as he had dreaded, was an immediate ſummons to appear before the ſeſſion of the Seceding congregation; to which, through pride, not chooſing to attend, in order to preclude a formal expulſion, he voluntarily abjured their tenets, and openly avowed his apoſtacy to the eſtabliſhment.

All changes in religion which are not the conſequence of candid inveſtigation are dangerous. He who leaves one ſect he knows not why, will quickly abandon, with as little reaſon, that to which in a fit of paſſion he had haſtily joined himſelf. From the moment of his quitting the communion of the Seceders, Brown's religious ardour ſuffered a gradual abatement; and though, to pleaſe his mother, he continued to proſecute his ſtudies with a view to the office of a clergyman in the church of Scotland, his opinions became daily more and more lax, and his life of courſe leſs and leſs regular. It was, however, a conſiderable time before he admitted, in their full extent, thoſe principles of irreligion which he afterwards avowed; for upon his firſt peruſing the Eſſays of Mr Hume, though his own zeal was then much cooled, he expreſſed great indignation at their dangerous tendency.

At the age of twelve years he had been employed by Mr Cruickſhank as a kind of uſher in the ſchool of Dunſe; and that gentleman having declared that his knowledge of the Latin language was equal to his own, his fame as a ſcholar was ſo ſpread over the country, that at the age of thirteen he was intruſted with the education of a gentleman's ſon in the neighbourhood, when he quitted the ſchool and his beloved maſter. In his new ſituation, however, he remained not long. Dr Beddoes conjectures, that to the ſtiffneſs of pedantry he added the ſourneſs of a bigot, and was therefore a diſagreeable inmate of the family. That a boy of thirteen, proud of his talents, and prouder of his learning, ſhould have the ſtiffneſs of a pedant, is indeed extremely probable; it was the natural conſequence of the praiſe with which he had been honoured by Mr Cruickſhank: but there is reaſon to believe that of his original bigotry few traces now remained. The real cauſe of his diſmiſſion from the family, we are aſſured, was his pride; and as it muſt have been the pride of parts, it confirms the firſt part of Dr Beddoes's conjecture.

It ſeems he was much diſpleaſed that, when company were at dinner, he was not deſired to remain after the cloth was removed; and yet if he was then only thirteen years of age, it is not eaſy to conceive for what purpoſe he ſhould have ſtaid. He could not poſſibly know much of the world, or of any thing likely to employ the converſation of country gentlemen; and we cannot help thinking, that the maſter of the houſe would have treated his gueſts with rudeneſs, had he detained among them a raw boy to liſten to every unguarded expreſſion which might eſcape them over their wine. It would appear, however, that he was not unwilling to give the tutor of his ſon an opportunity of diſplaying his abilities, when ſuch ſubjects were introduced as he knew him to have ſtudied; for a diſpute having ariſen, one day after Brown had retired to his own room, concerning the decrees of Providence, he ſent to requeſt his opinions on that abſtruſe ſubject. By the meſſenger Brown returned a verbal anſwer, that "the decrees of Providence are very unjuſt, for having made blockheads lairds."

Mr Cruickſhank had ſome time before requeſted him to return to the ſituation which he had formerly held in the ſchool of Dunſe; and we cannot wonder that, immediately after making this inſolent anſwer, he found it convenient to comply with his requeſt. He was now about fifteen, and he continued in the ſchool till the 20th year of his age; during which time, from the conſtant habit of teaching the Latin and Greek languages, he acquired a wonderful facility in reading both theſe languages, and in writing the former, though he wrote not with taſte.

About this time it occurred to him that he might turn his claſſical acquirements to more account, by becoming a private teacher of languages in Edinburgh. To that city he accordingly repaired, where, while he obtained a livelihood as a teacher, he propoſed at the ſame time to purſue his theological ſtudies at the univerſity. But an accident happened to him here which made him altogether change the plan he had come upon; and the death of his mother, after a reſidence of ſome time in Edinburgh, abſolved him, as he thought, from the promiſe which he had made to her of appearing one day in the pulpit. Shortly after an unſucceſsful competition for one of the chairs then vacant in the high-ſchool, an application was made to a friend of his for a proper perſon to turn a medical theſis into Latin. Brown was recommended. He was limited to a certain time; within which it appeared ſcarce practicable to perform the taſk. He accompliſhed it, however, and in ſuch a ſtyle of grammatical correctneſs and purity as far exceeded the general run of ſuch productions. On this being remarked to him by his friends, he obſerved, "that he now knew his ſtrength, and was ambitious of riding in his carriage as a phyſician." He therefore determined to apply himſelf with ardour to the ſtudy of medicine, to which this accidental circumſtance alone directed his attention. Accordingly, at the commencement of the next winter ſeſſion, he addreſſed a Latin letter to each of the medical profeſſors, and by them was preſented with tickets of admittance to their ſeveral claſſes.

From ſuch a favourable beginning, being of a very ſanguine diſpoſition, he conceived the moſt flattering expectations of his future ſucceſs; and indeed for ſome time he ſeems to have lived in affluent circumſtances. His attainments were ſo various, and in ſuch requeſt in Edinburgh, that as a ſingle man he could ſcarcely fail to gain a competent living; for during the laſt five years of his reſidence under Mr Cruickſhank, to a thorough acquaintance with ancient hiſtory, he had added a very conſiderable knowledge of mathematics; in which, among other branches of ſcience, he never had any objection to give inſtructions. In the acquiſition of that variety of knowledge which he poſſeſſed, he was greatly aſſiſted by a moſt tenacious memory; to the retentiveneſs of which an old ſchool-fellow bears teſtimony, by affirming, that "after once reading over the leſſon, conſiſting of two octavo pages in Latin, he would lay aſide the book, and prelect the whole over without miſtaking a ſingle word."

Brown, already in eaſy circumſtances for an individual, ſaw, or thought he ſaw, in the eſtabliſhment of a boarding-houſe for ſtudents a reſource which would enable him to maintain a family; and in expectation of realiſing this proſpect, he married, in 1765, the daughter of a reſpectable tradeſman in Edinburgh. The diſtinguiſhed attention at that time paid him by Dr Cullen, in whoſe family he had become a neceſſary perſon, contributed in all probability to ſtrengthen his hopes that his houſe would be filled with proper boarders through the Doctor's recommendation. His ſucceſs in this way for ſome time anſwered his moſt ſanguine expectations; and his circumſtances at one period were ſo flouriſhing, that he is ſaid to have kept a one-horſe chaiſe.

It was, perhaps, the greateſt misfortune that could have befallen Brown, that he poſſeſſed, in a high degree, thoſe talents which make a man's company ſought after by the gay and the diſſipated: He was capable of "ſetting the table in a roar." We need not therefore wonder at his frequently neglecting more neceſſary purſuits to enjoy the conviviality of the numerous friends who courted his company; or that drinking and diſſipation became habitual to him. He was as deficient in point of prudence as he excelled in genius. His houſe was filled with reſpectable boarders; but as he lived too ſplendidly for an income at beſt but precarious, he became gradually involved in debt, and his affairs were ſtill more embarraſſed by the burden of a numerous family. Soon after he began to be involved in theſe difficulties, he ſuffered an additional loſs in being deprived of the patronage of Dr Cullen, in conſequence of a diſagreement that had taken place between them. This enmity, which had for ſome time before ſecretly ſubſiſted, probably from mutual jealouſy, was at length excited into an open rupture; firſt, by Dr Cullen's not exerting his intereſt in procuring for Brown the theoretical chair of medicine, then vacant in conſequence either of the death or reſignation of Dr Alexander Monro Drummond; and, ſecondly, by his rejecting, ſome time after, Brown's petition for admittance into the Edinburgh Philoſophical Society.

In 1776 Brown was elected preſident of the Medical Society; and the ſame honour was again conferred on him in 1780. He was led on, in the gradual manner he himſelf deſcribes in his maſterly preface to the *Elementa Medicinæ*, to the diſcovery of his new doctrine; which, on dropping all correſpondence with his former friend and benefactor, he now, for the firſt time, began to illuſtrate in a courſe of public lectures; and in theſe he diſplayed equal ingenuity and philoſophical profundity. Much about the time of which we now ſpeak, he publiſhed the firſt edition of the *Elementa Medicinæ*; a work which certainly proves its author to have been a man of uncommon genius and originality of thought. The circumſtances in which this work was compoſed reflect great honour on his abilities. He never retired to his ſtudy; but, totally abſorbed in his own ideas, wrote with the greateſt tranquillity amidſt the noiſe of ten children, occaſionally ſettling their childiſh differences.

In the year 1779, though he had ſtudied medicine ten or twelve years at the univerſity of Edinburgh, he was prevailed upon by his friends to take a degree at St Andrews, where he gave a conſpicuous proof of his facility in Latin compoſition. He wrote a theſis, or inaugural diſſertation, in the tavern while the cloth was laying for dinner; and one of his companions, who was ſinging beſide him, having uttered a falſe note, or ſung out of time, Mr Brown, in the middle of his writing, ſtopped to ſhew him how the ſong ought to be ſung, and then inſtantly proceeded in his theſis.

His family having now become ſo numerous as to render keeping a boarding-houſe inconvenient, he had already for ſome time given it up, and depended for ſupport entirely on his practice as a phyſician and his public lectures. At this time the diſputes between the Cullenians and the Brunonians (as the young men now ſtyled themſelves) were carried on with ſuch acrimony on both ſides, in the different ſocieties, that it was not unuſual for them to terminate in duels; and there exiſts at this day, on the records of the Medical Society, a law which it was thought expedient to enact, by which a member who challenges another for any thing ſaid in public debate incurs the penalty of expulſion.

Obſerving the ſtudents of medicine frequently to ſeek initiation into the myſteries of free-maſonry, Dr Brown thought their youthful curioſity afforded him a chance of proſelytes. In 1784, he inſtituted a meeting of that fraternity, and intitled it *the Lodge of the Roman Eagle.* The buſineſs was conducted in the Latin language, which he ſpoke with the ſame fluency as Scotch; and he diſplayed much ingenuity in turning into Latin all the terms uſed in maſonry.

As the terms on which he lived with his brethren of the faculty were ſuch that he obſtinately avoided meeting them even in conſultation, we may conclude that his own private practice was but limited. His friends affirmed, perhaps without ſufficient proof, that cabals were formed againſt him, and every advantage taken of the errors he was led to commit by his own imprudence. After a long ſeries of ſtruggles, therefore, hoping to meet with that encouragement among the Engliſh of which he had been diſappointed in his own country, he put in practice a plan upon which he had long meditated, and removed in 1786 with part of his family to London. Immediately on his arrival, an incident befel him, which Dr Beddoes ſays he has heard the late Mr Murray, bookſeller in Fleet-ſtreet, relate as a proof of his ſimplicity. The peculiarity of his appearance as he moved along (a ſhort ſquare figure, with an air of dignity, in a black ſuit, which heightened the ſcarlet of his cheeks and noſe) fixed the attention of ſome *gentlemen* in the ſtreet. They addreſſed him in the dialect of his country. His heart, heavy as it muſt have been, from the precariouſneſs of his ſituation, and diſtance from his accuſtomed haunts, expanded at theſe agreeable ſounds. A converſation enſued; and the parties, by common conſent, adjourned to a tavern. Here the ſtranger was kindly welcomed to town; and, after the glaſs had circulated for a time, ſomething was propoſed by way of ſober amuſement—a game at cards, or whatever the Doctor might prefer. The Doctor had been too civilly treated to demur; but his purſe was ſcantily furniſhed, and it was neceſſary to quit his new friends in ſearch of a ſupply. Mr Murray was the perſon to whom he had recourſe: the reader will not wonder that his interference ſhould have ſpoiled the adventure.

A London ſharper, of another denomination, afterwards tried to make advantage by the Doctor. This was an ingenious ſpeculator in public medicines. He thought a compoſition of the moſt powerful ſtimulants might have a run, under the title of *Dr Brown's exciting pill*; and, for the privilege of his name, offered him a ſum in hand by no means contemptible, as well as a ſhare of the contingent profits. Poor Brown, needy as he was, ſpurned at the propoſal.

After this period, his life affords little variety of incident. Like Avicenna, his time ſeems to have been ſpent between his literary purſuits and his pleaſures. A ſplendid manner of living, without an income to ſupport it, had become habitual to him: The conſequence was, that, from inability to diſcharge certain debts he had contracted, he was thrown into the king's bench priſon; from which, however, he was, not long afterwards, releaſed by the exertions of a few firm friends, particularly Mr Maddiſon of Charing-croſs, a gentleman univerſally reſpected for his well-known benevolence. As a proof of the activity he was ſtill capable of exerting, it will be ſufficient to mention, that he accompliſhed the tranſlation of his *Elementa*, with the addition of the ſupplementary notes, within 23 days, having been informed that a tranſlation of the ſame was about to be publiſhed by another perſon.

Shortly before his death, the ambaſſador of the king of Pruſſia, in the name of his maſter, made Dr Brown an offer of a ſettlement in the court of Berlin; during the negociation of which he was unexpectedly cut off by an apoplexy early in the morning of the 7th of October 1788, the day ſucceeding that on which he had delivered to a company of thirteen gentlemen the greater part of the introductory lecture to his ſecond courſe. At his death, he was between 52 and 53 years of age. His remains were interred in the church-yard of St James's Picadilly; and the only monument left behind him to tranſmit his name to poſterity is his own works; which, when perſonal prejudice no longer ſhall prevail againſt their ingenious author, cannot fail to procure him all that deſerved celebrity which they have already, in part, obtained in the different countries of Europe.

In 1787, he publiſhed his "Obſervations," without his name, which he afterwards, however, refers to in the Elements as his own. The "Enquiry," ſaid to be written by Dr Jones, and which was compoſed in as ſhort a time as the generality of men would tranſcribe a work of its extent, we can affirm, from undoubted authority, to be his production.

This ſketch of the life of the unfortunate Dr Brown would be of very little value if not followed by a view of his ſyſtem; but to give a complete view of that ſyſtem would far exceed the limits within which, in a work like this, ſuch articles muſt be confined. We truſt, therefore, that our readers will be ſatisfied with an abſtract; and as we are neither the partiſans nor opponents of the Doctor, and not very partial to any medical *ſyſtem* whatever, we ſhall content ourſelves with inſerting, in this place, the view which Dr Beddoes has given of Dr Brown's fundamental propoſitions in the valuable obſervations which he has prefixed to his edition of the Elements of Medicine.

"The varied ſtructure of organized beings (ſays Dr Beddoes), it is the buſineſs of anatomy to explain. Conſciouſneſs, aſſiſted by common obſervation, will diſtinguiſh animated from inanimate bodies with preciſion more than ſufficient for all the ends of medicine. The cauſe of gravitation has been left unexplored by all prudent philoſophers; and Brown, avoiding all uſeleſs diſquiſition concerning the cauſe of vitality, confines himſelf to the phenomena which this great moving principle in nature may be obſerved to produce. His moſt general propoſitions are eaſy of comprehenſion.

" 1. To every animated being is allotted a certain portion only of the quality or principle on which the phenomena of life depend. This principle is denominated *excitability*.

" 2. The excitability varies in different animals, and in the ſame animal at different times. As it is more intenſe, the animal is more vivacious or more ſuſceptible of the action of exciting powers.

" 3. Exciting powers may be referred to two claſſes. 1. External; as heat, food, wine, poiſons, contagions, the blood, ſecreted fluids, and air. 2. Internal; as the functions of the body itſelf, muſcular exertion, thinking, emotion, and paſſion.

" 4. Life is a forced ſtate; if the exciting powers are withdrawn, death enſues as certainly as when the excitability is gone.

" 5. The excitement may be too great, too ſmall, or in juſt meaſure.

" 6. By too great excitement, weakneſs is induced, becauſe the excitability becomes defective; this is *indirect debility*: when the exciting powers and ſtimulants are withheld, weakneſs is induced; and this is *direct debility*. Here the excitability is in exceſs.

" 7. Every power that acts on the living frame is ſtimulant, or produces excitement by expending excitability. Thus, although a perſon accuſtomed to animal food may grow weak if he lives upon vegetables, ſtill the vegetable diet can only be conſidered as producing an effect, the ſame in kind with animals, though inferior in degree. Whatever powers, therefore, we imagine, and however they vary from ſuch as are habitually applied to produce due excitement, they can only weaken the ſyſtem by urging it into too much motion, or ſuffering it to ſink into langour.

" 8. Excitability is ſeated in the medullary portion of the nerves, and in the muſcles. As ſoon as it is anywhere affected, it is immediately affected everywhere; nor is the excitement ever increaſed in a part, while it is generally diminiſhed in the ſyſtem; in other words, different parts can never be in oppoſite ſtates of excitement.

" I have already ſpoken of an illuſtration, drawn up by Mr Chriſtie from a familiar operation, to facilitate the conception of Brown's fundamental poſitions. I introduce it here as more likely to anſwer its purpoſe than if ſeparately placed at the end of my preliminary obſervations. ' Suppoſe a fire to be made in a grate, filled with a kind of fuel not very combuſtible, and which could only be kept burning by means of a machine containing ſeveral tubes, placed before it, and conſtantly pouring ſtreams of air into it. Suppoſe alſo a pipe to be fixed in the back of the chimney, through which a conſtant ſupply of freſh fuel was gradually let down into the grate, to repair the waſte occaſioned by the flame, kept up by the air machine.

' The grate will repreſent the human frame; the fuel in it, the matter of life—the excitability of Dr Brown, and the ſenſorial power of Dr Darwin; the tube behind, ſupplying freſh fuel, will denote the power of all living ſyſtems, conſtantly to regenerate or reproduce excitability; while the air machine, of ſeveral tubes, denotes the various ſtimuli applied to the excitability of the body; and the flame drawn forth in conſequence of that application repreſents life, the product of the exciting powers acting upon the excitability.

' As Dr Brown has defined life to be *a forced ſtate*, it is fitly repreſented by a flame forcibly drawn forth from fuel little diſpoſed to combuſtion, by the conſtant application of ſtreams of air poured into it from the different tubes of a machine. If ſome of theſe tubes are ſuppoſed to convey pure or dephlogiſticated air, they will denote the higheſt claſs of exciting powers, opium, muſk, camphor, ſpirits, wine, tobacco, &c. the diffuſible ſtimuli of Dr Brown, which bring forth for a time a greater quantity of life than uſual, as the blowing in of pure air into a fire will temporarily draw forth an uncommon quantity of flame. If others of the tubes be ſuppoſed to convey common or atmoſpheric air, they will repreſent the ordinary exciting powers, or ſtimuli, applied to the human frame, ſuch as heat, light, air, food, drink, &c. while ſuch as convey impure and inflammable air may be uſed to denote what have formerly been termed ſedative powers, ſuch as poiſons, contagious miaſmata, foul air, &c.

' The reader will now probably be at no loſs to underſtand the ſeeming paradox of the Brunonian ſyſtem; that food, drink, and all the powers applied to the body, though they ſupport life, yet conſume it; for he will ſee that the application of theſe powers, though it brings forth life, yet at the ſame time it waſtes the excitability or matter of life, juſt as the air blown into the fire brings forth more flame, but waſtes the fuel or matter of fire. This is conformable to the common ſaying, " the more a ſpark is blown, the brighter it burns, and the ſooner it is ſpent." A Roman poet has given us, without intending it, an excellent illuſtration of the Brunonian ſyſtem, when he ſays,

" *Balnea, vina, Venus, conſumunt corpora noſtra;*
" *Sed vitam faciunt balnea, vina, Venus.*

" Wine, warmth, and love, our vigour drain;
" Yet wine, warmth, love, our life ſuſtain."

Or to tranſlate it more literally,

" Baths, women, wine, exhauſt our frame;
" But life itſelf is drawn from them."

' Equally eaſy will it be to illuſtrate the two kinds of debility, termed *direct* and *indirect*, which, according to Brown, are the cauſe of all diſeaſes. If the quantity of ſtimulus or exciting power is proportioned to the quantity of excitability, that is, if no more excitement is drawn forth than is equal to the quantity of excitability produced, the human frame will be in a ſtate of health, juſt as the fire will be in a vigorous ſtate when no more air is blown in than is ſufficient to conſume the freſh ſupply of fuel conſtantly poured down by the tube behind. If a ſufficient quantity of ſtimulus is not applied, or air not blown in, the excitability in the man, and the fuel in the fire, will accumulate, producing direct debility; for the man will become weak, and the fire low. Carried to a certain degree, they will occaſion death to the firſt, and extinction to the laſt. If, again, an over proportion of ſtimulus be applied, or too much air blown in, the excitability will ſoon be waſted, and the matter of fuel almoſt ſpent. Hence will ariſe indirect debility, producing the ſame weakneſs in the man, and lowneſs in the fire, as before, and equally terminating, when carried to a certain degree, in death and extinction.

‘ As all the diſeaſes of the body, according to Dr Brown, are occaſioned by direct or indirect debility, in conſequence of too much or too little ſtimuli, ſo all the defects of the fire muſt ariſe from direct or indirect lowneſs, in conſequence of too much or too little air blown into it. As Brown taught that one debility was never to be cured by another, but both by the more judicious application of ſtimuli, ſo will be found the caſe in treating the defects of the fire. If the fire has become low, or the man weak, by the want of the needful quantity of ſtimulus, more muſt be applied, but very gently at firſt, and increaſed by degrees, leſt a ſtrong ſtimulus applied to the accumulated excitability ſhould produce death ; as in the caſe of a limb benumbed with cold (that is, weakened by the accumulation of its excitability in conſequence of the abſtraction of the uſual ſtimulus of heat), and ſuddenly held to the fire, which we know from experience is in danger of mortification ; or as in the caſe of the fire becoming very low by the accumulation of the matter of fuel, when the feeble flame, aſſailed by a ſudden and ſtrong blaſt of air, would be overpowered and put out, inſtead of being nouriſhed and increaſed. Again, if the man or the fire have been rendered indirectly weak, by the application of too much ſtimulus, we are not ſuddenly to withdraw the whole, or even a great quantity of the exciting powers or air, for then the weakened life and diminiſhed flame might ſink entirely ; but we are by little and little to diminiſh the overplus of ſtimulus, ſo as to enable the excitability, or matter of fuel, gradually to recover its proper proportion. Thus a man who has injured his conſtitution by the abuſe of ſpirituous liquors is not ſuddenly to be reduced to water alone, as is the practice of ſome phyſicians, but he is to be treated as the judicious Dr Pitcairn of Edinburgh is ſaid to have treated a Highland chieftian, who applied to him for advice in this ſituation. The Doctor gave him no medicines, and only exacted a promiſe of him, that he would every day put in as much wax into the wooden *queich*, out of which he drank his whiſky, as would receive the impreſſion of his arms. The wax thus gradually accumulating, diminiſhed daily the quantity of the whiſky, till the whole *queich* was filled with wax ; and the chieftain was thus gradually, and without injury to his conſtitution, cured of the habit of drinking ſpirits.

‘ Theſe analogies might be purſued farther ; but my object is ſolely to furniſh ſome general ideas, to prepare the reader for entering more eaſily into the Brunonian theory, which I think he will be enabled to do after peruſing what I have ſaid. The great excellence of that theory, as applied, not only to the practice of phyſic, but to the general conduct of the health, is, that it impreſſes on the mind a ſenſe of the impropriety and danger of going from one extreme to another. The human frame is capable of enduring great varieties, if time be given it to accommodate itſelf to different ſtates. All the miſchief is done in the tranſition from one ſtate to another. In a ſtate of low excitement, we are not raſhly to induce a ſtate of high excitement ; nor when elevated to the latter, are we ſuddenly to deſcend to the former, but ſtep by ſtep, and as one who from the top of a high tower deſcends to the ground. From haſty and violent changes the human frame always ſuffers ; its particles are torn aſunder, its organs injured, the vital principle impaired, and diſeaſe, often death, is the inevitable conſequence.

‘ I have only to add, that though in this illuſtration of the Brunonian ſyſtem (written ſeveral years ago), I have ſpoken of a tube conſtantly pouring in freſh fuel, becauſe I could not otherwiſe convey to the reader a familiar idea of the power poſſeſſed by all living ſyſtems, to renew their excitability when exhauſted ; yet it may be proper to inform the ſtudent, that Dr Brown ſuppoſed every living ſyſtem to have received at the beginning its determinate portion of excitability ; and, therefore, although he ſpoke of the exhauſtion, augmentation, and even renewal of excitability, I do not think it was his intention to induce his pupils to think of it as a kind of fluid ſubſtance exiſting in the animal, and ſubject to the law by which ſuch ſubſtances are governed. According to him, excitability was an unknown *ſomewhat*, ſubject to peculiar laws of its own, and whoſe different ſtates we were obliged to deſcribe (though inaccurately) by terms borrowed from the qualities of material ſubſtances.’

“ The Brunonian ſyſtem has frequently been charged with promoting intemperance. The objection is ſerious ; but the view already given of its principles ſhews it to be groundleſs. No writer had inſiſted ſo much upon the dependence of life on external cauſes, or ſo ſtrongly ſtated the inevitable conſequences of exceſs. And there are no means of promoting morality upon which we can rely, except the knowledge of the true relations between man and other beings or bodies. For by this knowledge we are directly led to ſhun what is hurtful, and purſue what is ſalutary. And in what elſe does moral conduct, as far it regards the individual, conſiſt ? It may be ſaid that the author's life diſproves the juſtneſs of this repreſentation : his life, however, only ſhews the ſuperior power of other cauſes, and of bad habits in particular ; and I am ready to acknowledge the little efficacy of inſtruction when bad habits are formed. Its great uſe conſiſts in preventing their formation ; for which reaſon popular inſtruction in medicine would contribute more to the happineſs of the human ſpecies, than the complete knowledge of every thing which is attempted to be taught in education, as it is conducted at preſent. But though the principles of the ſyſtem in queſtion did not correct the propenſities of its inventor, it does not follow that they tend to produce the ſame propenſities in others.”

BRUCE (James, Eſq; F. R. S.), the celebrated Abyſſinian traveller, was born, 1730, at Kinnaird houſe, in the pariſh of Larbert and county of Stirling. His deſcent by both parents was ancient and honourable ; and of that deſcent he was, perhaps, too proud. His grandfather was —— Hay, Eſq; of Woodcockdale, in the county of Linlithgow, who, marrying Miſs Bruce, the heireſs of Kinnaird, gave the name of *Bruce* to all his deſcendants.

Perhaps this change of name may have taken place in obedience to the deed by which the eſtate of Kinnaird was ſettled on Mrs Hay's children ; but it is a change which, in a country like Scotland, where antiquity of deſcent is highly valued, any man would voluntarily have adopted, who had married the heireſs of ſuch

ſuch a family. The Bruces of Kinnaird had been in poſſeſſion of that eſtate for three centuries: they were deſcended from a younger ſon of Robert de Bruce, the competitor with Baliol for the crown of Scotland. It would readily occur, that the knowledge of ſuch a deſcent would be beſt preſerved by continuing the name of their great anceſtor; and we have reaſon to believe, that the ſubject of this memoir was not much delighted when put in mind, as he frequently was, that, though the heir of the line, he was not the *male* heir of that branch of the illuſtrious family.

As he was allied to royalty by his father and grandmother, through his mother he was related to ſome of the moſt reſpectable families in the kingdom. She was the daughter of James Graham, Eſq; of Airth, dean of the faculty of advocates, and judge of the high court of admiralty in Scotland, by Marion, daughter of James Hamilton Eſq; of Pencaitland; and to a man of our traveller's turn of mind, there can be no doubt but that it muſt have afforded much ſatisfaction to think, that no family ranks higher in Scotland than thoſe of Bruce, Graham, and Hamilton. In him, however, it was weakneſs to be proud, if indeed he was proud, of family; for the talents beſtowed upon him by nature, or, to ſpeak more properly, by nature's God, would have made him great though he had been born on a dunghill. He would indeed have been, in all probability, much greater than he was, had he not been in poſſeſſion of the phantom of birth to gratify much of his ambition; for the facility with which he maſtered every ſtudy in which he engaged, would have carried him quickly to the top of the moſt honourable profeſſion.

Mr Bruce was inſtructed in grammatical learning at the ſchool of Harrow on the Hill, in the county of Middleſex, where he gave the moſt unequivocal proofs of genius, and acquired a very conſiderable knowledge of the Greek and Latin languages. It was cuſtomary with him to perform, not only his own exerciſes, but alſo the exerciſes of ſuch of his companions as were not equal to the taſk themſelves. Among theſe was his maternal uncle, who was frequently indebted to his aſſiſtance, and, on one occaſion, produced a copy of verſes of his compoſition, which excited, not only the applauſe, but the admiration of their maſter. Mr Graham, who was but a few months older than Mr Bruce, had, for ſome tranſgreſſion (we know not what), been puniſhed, as boys in the great ſchools in England are often puniſhed, by having a taſk ſet him, which he ſoon found himſelf unable to perform. His nephew deſired him to be under no uneaſineſs, promiſing to furniſh him with the verſes before the time at which they were to be given in. He was as good as his word; but the maſter of the ſchool ſoon diſcovering that they were not the performance of Mr Graham, exclaimed, that the author of theſe verſes, whoever he was, might apply to himſelf the words of Horace,

—— *Sublimi feriam ſidera vertice.*

While Mr Bruce was at Harrow, and for a year or two after he had left it, he was of a very delicate frame, and appeared to his friends to be threatened with a conſumption. The truth is, that he was uncommonly tall for his age, and felt all the feebleneſs of joints and other bodily weakneſſes to which overgrown boys are generally ſubject. His father intended him for the profeſſion of the law; and, upon his return from Harrow, he was entered into the univerſity of Edinburgh, where he went through a regular courſe of ſtudy to fit him for being enrolled in the body of advocates: but for ſome reaſon, which we do not perfectly know, he relinquiſhed the ſtudy of law for the purſuits of trade; and, going to London, entered into partnerſhip with a wine merchant of the name of Allen, whoſe daughter he married.

That lady falling into a bad ſtate of health, Mr Bruce took her abroad, in hopes that travelling would be attended with beneficial effects; but in theſe he was diſappointed, as ſhe died within a year after her marriage. He was induced, in order to diſpel his grief, to continue his travels; during which his father dying (at Edinburgh, 4th May 1758), the inheritance of his anceſtors devolved upon him, and he returned to Britain. Some of his ſubſequent tranſactions ſhall now be related in his own words.

" Every one will remember that period, ſo glorious to Britain, the latter end of the miniſtry of the late earl of Chatham. I was then returned from a tour through the greateſt part of Europe, particularly through the whole of Spain and Portugal, between whom there was then the appearance of an approaching war.

" I was about to retire to a ſmall patrimony I had received from my anceſtors, in order to embrace a life of ſtudy and reflection, nothing more active appearing within my power, when chance threw me unexpectedly into a very ſhort and very deſultory converſation with Lord Chatham.

" It was a few days after this that Mr Wood, then under-ſecretary of ſtate, my zealous and ſincere friend, informed me that Lord Chatham intended to employ me upon a particular ſervice; that, however, I might go down for a few weeks to my own country to ſettle my affairs, but, by all means, to be ready upon a call. Nothing could be more flattering to me than ſuch an offer, when ſo young; to be thought worthy by Lord Chatham of any employment, was doubly a preference. No time was loſt on my ſide; but juſt after receiving orders to return to London, his lordſhip had gone to Bath, and reſigned his office.

" This diſappointment, which was the more ſenſible to me that it was the firſt I had met with in public life, was promiſed to be made up to me by Lord Egremont and Mr George Grenville. The former had been long my friend; but unhappily he was then far gone in a lethargic indiſpoſition, which threatened, and did very ſoon put a period to his exiſtence. With Lord Egremont's death my expectations vaniſhed. Further particulars are unneceſſary; but I hope that, at leaſt in part, they remain in that breaſt where they naturally ought to be, and where I ſhall ever think, not to be long forgotten, is to be rewarded.

" Seven or eight months were paſſed in an expenſive and fruitleſs attendance in London, when Lord Halifax was pleaſed, not only to propoſe, but to plan for me a journey of conſiderable importance, and which was to take up ſeveral years. His lordſhip ſaid, that nothing could be more ignoble than, at ſuch a time of life, at the height of my reading, health, and activity, I ſhould, as it were, turn peaſant, and voluntarily bury myſelf in obſcurity and idleneſs; that though war was now drawing faſt to an end, full as honourable a competition remained

mained among men of ſpirit, which ſhould acquit themſelves beſt in the dangerous line of uſeful adventure and diſcovery.

"He obſerved, that the coaſt of Barbary, which might be ſaid to be juſt at our door, was yet but partially explored by Dr Shaw, who had only illuſtrated (very judiciouſly indeed) the geographical labours of Sanſon; that neither Dr Shaw nor Sanſon had been, or pretended to be, capable of giving the public any detail of the large and magnificent remains of ruined architecture, which they both vouch to have ſeen in great quantities, and of exquiſite elegance and perfection, all over the country. Such had not been their ſtudy, yet ſuch was really the taſte that was required in the preſent times. He wiſhed, therefore, that I ſhould be the firſt, in the reign juſt now beginning, to ſet an example of making large additions to the royal collection; and he pledged himſelf to be my ſupport and patron, and to make good to me, upon this additional merit, the promiſes which had been held forth to me by former miniſters for other ſervices.

"The diſcovery of the ſource of the Nile was alſo a ſubject of theſe converſations, but it was always mentioned to me with a kind of diffidence, as if to be expected from a more experienced traveller. Whether this was but another way of exciting me to the attempt I ſhall not ſay; but my heart, in that inſtant, did me juſtice to ſuggeſt, that this too was either to be atchieved by me, or to remain as it had done for theſe laſt 2000 years, a defiance to all travellers, and an opprobrium to geography.

"Fortune ſeemed to enter into this ſcheme. At the very inſtant, Mr Aſpinwall, very cruelly and ignominiouſly treated by the dey of Algiers, had reſigned his conſulſhip, and Mr Ford a merchant, formerly the dey's acquaintance, was named in his place. Mr Ford was appointed, and, dying a few days after, the conſulſhip became vacant. Lord Halifax preſſed me to accept of this as containing all ſorts of conveniences for making the propoſed expedition.

"This favourable event finally determined me. I had all my life applied unweariedly, perhaps with more love than talent, to drawing, the practice of mathematics, and eſpecially that part neceſſary to aſtronomy. The tranſit of Venus was at hand. It was certainly known that it would be viſible once at Algiers, and there was great reaſon to expect it might be twice. I had furniſhed myſelf with a large apparatus of inſtruments, the completeſt of their kind, for the obſervation. In the choice of theſe, I had been aſſiſted by my friend Admiral Campbell, and Mr Ruſſel ſecretary to the Turkey Company: every other neceſſary had been provided in proportion. It was a pleaſure now to know that it was not from a rock or a wood, but from my own houſe at Algiers, I could deliberately take meaſures to place myſelf in the liſt of men of ſcience of all nations, who were then preparing for the ſame ſcientific purpoſe.

"Thus prepared, I ſet out for Italy, through France; and though it was in time of war, and ſome ſtrong objections had been made to particular paſſports, ſolicited by our government from the French ſecretary of ſtate, Monſieur de Choiſeul moſt obligingly waved all ſuch exceptions with regard to me, and moſt politely aſſured me, in a letter accompanying my paſſport, that thoſe difficulties did not in any ſhape regard me, but that I was perfectly at liberty to paſs through, or remain in, France with thoſe that accompanied me, without limiting their number, as ſhort or as long a time as ſhould be agreeable to me.

"On my arrival at Rome, I received orders to proceed to Naples, there to await his majeſty's further commands. Sir Charles Saunders, then with a fleet before Cadiz, had orders to viſit Malta before he returned to England. It was ſaid that the grand-maſter of that order had behaved ſo improperly to Mr Harvey (afterwards Lord Briſtol) in the beginning of the war, and ſo partially and unjuſtly between the two nations in the courſe of it, that an explanation on our part was become neceſſary. The grand-maſter no ſooner heard of my arrival at Naples, than, gueſſing the errand, he ſent off Chevalier Mazzini to London, where he at once made his peace and his compliments to his majeſty upon his acceſſion to the throne.

"Nothing remained now but to take poſſeſſion of my conſulſhip. I returned, without loſs of time, to Rome, and from thence to Leghorn, where, having embarked on board the Montreal man of war, I proceeded to Algiers.

"While at Naples, I received from ſlaves, redeemed from the province of Conſtantine, accounts of magnificent ruins they had ſeen while traverſing that country with their maſter the Bey. I ſaw the abſolute neceſſity there was for aſſiſtance, without which it was impoſſible for any one man, however diligent and qualified, to do any thing but bewilder himſelf. All my endeavours, however, had hitherto been unſucceſsful to perſuade any Italian to put himſelf wilfully into the hands of a people conſtantly looked upon by them in no better light than pirates. At laſt Mr Lumiſden, by accident, heard of a young man who was then ſtudying architecture at Rome, a native of Bologna, whoſe name was Luigi Balugani. I can appeal to Mr Lumiſden as to the extent of this perſon's practice and knowledge, and that he knew very little when firſt ſent to me. In the twenty months which he ſtaid with me at Algiers, by aſſiduous application to proper ſubjects under my inſtruction, he became a very conſiderable help to me, and was the only one that ever I made uſe of, or that attended me for a moment, or ever touched one repreſentation of architecture in any part of my journey."

Our traveller, when in Spain, had endeavoured to find acceſs to that immenſe collection of Arabic manuſcripts which were periſhing in the duſt of the eſcurial; but in vain. "All my ſucceſs (ſays he) in Europe terminated in the acquiſition of thoſe few printed Arabic books that I had found in Holland; and theſe were rather biographers than general hiſtorians, and contained little in point of general information. The ſtudy of theſe, however, and of Maracci's Koran, had made me a very tolerable Arab; a great field was opening before me in Africa to complete a collection of manuſcripts, an opportunity which I did not neglect.

"After a year ſpent at Algiers, conſtant converſation with the natives while abroad, and with my manuſcripts within doors, had qualified me to appear in any part of the continent without the help of an interpreter. Ludolf had aſſured his readers, that the knowledge of any oriental language would ſoon enable them to acquire the Ethiopic; and I needed only the ſame number of books to have made my knowledge of that language

guage go hand in hand with my attainments in the Arabic. My immediate proſpect of ſetting out on my journey to the inland parts of Africa had made me double my diligence; night and day there was no relaxation from theſe ſtudies, although the acquiring any ſingle language had never been with me either an object of time or difficulty."

At Algiers Mr Bruce was detained longer than he expected, in conſequence of a diſpute with the Dey concerning Mediterranean paſſes. This being adjuſted, he proceeded to Mahon, and from Mahon to Carthage. He next viſited Tunis and Tripoli, and travelled over the interior parts of theſe ſtates. At Bengazi, a ſmall town on the Mediterranean, he ſuffered ſhipwreck, and with extreme difficulty ſaved his life, though with the loſs of all his baggage. He afterwards ſailed to the iſles of Rhodes and Cyprus, and proceeding to Aſia Minor, travelled through a conſiderable part of Syria and Paleſtine, viſiting Haſſia, Latikea, Aleppo, and Tripoli; near which laſt city he was again in imminent danger of periſhing in a river. The ruins of Palmyra and Baalbec were next carefully ſurveyed and ſketched by him; and his drawings of theſe places are depoſited in the king's library at Kew; " the moſt magnificent preſent in that line," to uſe his own words, " ever made by a ſubject to his ſovereign."

It is much to be regretted that Mr Bruce publiſhed no particular account of theſe various journeys; from the nature of the places viſited, and the abilities of the man, much curious and uſeful information might have been expected. Some manuſcript accounts of different parts of them are ſaid to have been left by him, but whether in ſuch a ſtate as to be fit for publication, we have not learned.

In theſe various travels ſome years were paſſed; and Mr Bruce now prepared for the grand expedition, the accompliſhment of which had ever been neareſt his heart, the diſcovery of the ſources of the Nile. In the proſecution of that dangerous object, he left Sidon on the 15th of June 1768, and arrived at Alexandria on the 20th of that month. He proceeded from thence to Cairo, where he continued to the 12th of December following, when he embarked on the Nile; and in a very extraordinary boat, called a *canja*, of which he ſays the main-ſail yard was about 200 feet in length, he ſailed up that river as far as Syene, viſiting in the courſe of his voyage the ruins of Thebes, and the place where Memphis once ſtood, now known by the name of *Metrahenny*. Leaving Kenne on the Nile, 16th February 1769, he croſſed the deſert of the Thebaid to Coſſeir on the Red Sea, and arrived at Jidda on the 3d of May. In Arabia Felix he remained, not without making ſeveral excurſions, till the 3d of September, when he ſailed from Loheia, and arrived on the 19th at Maſuah, where he was detained near two months by the treachery and avarice of the Naybe of that place. It was not till the 15th of November that he was allowed to quit Arkeeko, near Maſua; and he arrived on the 15th of February 1770 at Gondar, the capital of Abyſſinia, where he ingratiated himſelf with the moſt conſiderable perſons of both ſexes belonging to the court. This he accompliſhed by being a phyſician in the city, a ſoldier in the field, a courtier every where, demeaning himſelf as conſcious that he was not unworthy of being a companion to the firſt of their nobility, and the king's gueſt, which is there a character, as it was with eaſtern nations of old, to which a certain ſort of conſideration is due. " To this I may add (ſays he), that, being in the prime of life, of no ungracious figure, having an accidental knack, which is not a trifle, of putting on the dreſs, and ſpeaking the language eaſily and gracefully, I cultivated, with the utmoſt aſſiduity, the friendſhip of the fair ſex, by the moſt modeſt and reſpectful diſtant attendance and obſequiouſneſs in public, abating juſt as much of that in private as ſuited their humours and inclination;" and jealouſy being a paſſion unknown in Abyſſinia, he thus acquired from the ladies great ſupport at court.

Several months were employed in attendance on the king, and in an unſucceſsful expedition round the lake of Dambea. Towards the end of October Mr Bruce ſet out for the ſources of the Nile; at which long deſired ſpot he arrived on the 14th of November; and his feelings on the accompliſhment of his wiſhes cannot better be expreſſed than in his own words:

" It is eaſier to gueſs than to deſcribe the ſituation of my mind at that moment; ſtanding in that ſpot which had baffled the genius, induſtry, and inquiry, of ancients and moderns for the courſe of near 3000 years. Kings had attempted this diſcovery at the head of armies, and each expedition was diſtinguiſhed from the laſt only by the difference of the numbers which had periſhed, and agreed alone in the diſappointment which had uniformly, and without exception, followed them all. Fame, riches, and honour, had been held out for a ſeries of ages to every individual of thoſe myriads thoſe princes commanded, without having produced one man capable of gratifying the curioſity of his ſovereign, or wiping off this ſtain upon the enterpriſe and abilities of mankind, or adding this deſideratum for the encouragement of geography. Though a mere private Briton, I triumphed here in my own mind over kings and their armies; and every compariſon was leading nearer and nearer to the preſumption, when the place itſelf where I ſtood, the object of my vain glory, ſuggeſted what depreſſed my ſhort-lived triumphs."

If theſe triumphs were ſhort-lived, they were equally ill-founded: for if the ſource of the Nile was ſeen by Mr Bruce, there can be no doubt of its having been likewiſe ſeen by the Portugueſe jeſuits. Of this we have elſewhere brought forward ſufficient proof; and the candid reader, who ſhall take the trouble to compare the extract printed at the bottom of this page (A), with our traveller's account of theſe coy fountains, as it ſtands

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(A) " In the eaſtern part of this kingdom, on the declivity of a mountain, whoſe deſcent is ſo eaſy that it ſeems a beautiful plain, is that ſource of the Nile which has been ſought after at ſo much expence of labour, and about which ſuch a variety of conjectures hath been formed without ſucceſs. This ſpring, or rather theſe two ſprings, are two holes, each about two feet diameter, a ſtone's caſt diſtant from each other. The one is about five feet and an half in depth, at leaſt we could not get our plummet farther, perhaps becauſe it was ſtopped by roots, ſtands in his own book or in our article Nile (*Encycl.*), will be convinced that it was ridiculous in Mr Bruce, and is equally ridiculous in his friends, to pretend that he *diſcovered* what had baffled the genius of inquiry for the courſe of near 3000 years.

It was not, however, the conſciouſneſs of having been anticipated by the jeſuits (for theſe he without ceremony calls a ſet of liars), but the proſpect of danger to be encountered on his return to Europe, that caſt ſuch a damp on his preſent enjoyment. "I was but a few minutes (ſays he) arrived at the ſource of the Nile, through numberleſs dangers and ſufferings, the leaſt of which would have overwhelmed me, but for the continual goodneſs and protection of Providence; I was, however, but then half through my journey, and all thoſe dangers which I had already paſſed awaited me again on my return. I found a deſpondency gaining ground faſt upon me, which blaſted the crown of laurels I had too raſhly woven for myſelf."

When he returned to reſt the night of that diſcovery, repoſe was ſought for in vain. "Melancholy reflections upon my preſent ſtate, the doubtfulneſs of my return in ſafety, were I permitted to make the attempt, and the fears that even this would be refuſed, according to the rule obſerved in Abyſſinia with all travellers who have once entered the kingdom; the conſciouſneſs of the pain that I was then occaſioning to many worthy individuals, expecting daily that information concerning my ſituation which it was not in my power to give them: ſome other thoughts, perhaps ſtill nearer the heart than thoſe, crowded upon my mind, and forbade all approach of ſleep.

"I was, at that very moment, in poſſeſſion of what had for many years been the principal object of my ambition and wiſhes; indifference which, from the uſual infirmity of human nature, follows, at leaſt for a time, complete enjoyment, had taken place of it. The marſh, and the fountains, upon compariſon with the riſe of many of our rivers, became now a trifling object in my ſight. I remembered that magnificent ſcene in my own native country, where the Tweed, Clyde, and Annan, riſe in one hill; three rivers I now thought not inferior to the Nile in beauty, preferable to it in the cultivation of thoſe countries through which they flow; ſuperior, vaſtly ſuperior, to it in the virtues and qualities of the inhabitants, and in the beauty of its flocks, crowding its paſtures in peace, without fear or violence from man or beaſt. I had ſeen the riſe of the Rhine and Rhone, and the more magnificent ſources of the Soane; I began, in my ſorrow, to treat the inquiry about the ſource of the Nile as a violent effort of a diſtempered fancy.

'What's Hecuba to him, or he to Hecuba,
'That he ſhould weep for her?'

Grief and deſpondency now rolling upon me like a torrent, relaxed, not refreſhed, by unquiet and imperfect ſleep, I ſtarted from my bed in the utmoſt agony; I went to the door of my tent, every thing was ſtill; the Nile, at whoſe head I ſtood, was not capable either to promote or to interrupt my ſlumbers, but the coolneſs and ſerenity of the night braced my nerves, and chaſed away thoſe phantoms that while in bed had oppreſſed and tormented me.

"It was true that numerous dangers, hardſhips, and ſorrows, had beſet me through this half of my excurſion; but it was ſtill as true, that another Guide, more powerful than my own courage, health, or underſtanding, if any of them can be called man's own, had uniformly protected me in all that tedious half. I found my confidence not abated, that ſtill the ſame Guide was able to conduct me to my wiſhed-for-home. I immediately reſumed my former fortitude, conſidered the Nile as indeed no more than riſing from ſprings as all other rivers do, but widely differing in this, that it was the palm for 3000 years held out to all the nations of the world as a *detur digniſſimo*, which in my cool hours I had thought was worth the attempting at the riſk of my life, which I had long either reſolved to loſe, or lay this diſcovery a trophy in which I could have no competitor, for the honour of my country, at the feet of my ſovereign, whoſe ſervant I was."

How unworthy is this ranting reflection of the greatneſs of mind which Mr Bruce on other occaſions unqueſtionably diſplayed! Had he indeed been the firſt European who diſcovered thoſe pitiful holes from which the Nile is ſaid to flow, his merit would not have conſiſted in travelling from Gondar to the village Geeſh, and viewing the fountains which are at that village the objects of idolatrous adoration, but in the addreſs with which he contrived to make himſelf the favourite of all the factions which agitated a barbarous and almoſt inhuman nation. In managing thoſe factions, he was indeed great; but he ſeems to have valued himſelf more upon looking at three ſprings, of which it is far from being certain that they are the ſources of the Nile (ſee Nile in this *Suppl.*), and of which two had certainly been examined more than a century before he was born, by different miſſionaries from the kingdom of Portugal! This, however, he calls the object of his wiſhes; and

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roots, for the whole place is full of trees: of the other, which is ſomewhat leſs, with a line of ten feet, we could find no bottom, and were aſſured by the inhabitants that none ever had been found. It is believed here that theſe ſprings are the vents of a great ſubterraneous lake; and they have this circumſtance to favour their opinion, that the ground is always moiſt, and ſo ſoft that the water boils up under foot as one walks upon it. Such is the ground round about theſe fountains. At a little diſtance to the ſouth is a village named *Guix* (the *Geeſh* of Mr Bruce), through which the way lies to the top of the mountain, whence the traveller diſcovers a vaſt extent of land, which appears like a deep valley, though the mountain riſes ſo imperceptibly, that thoſe who go up or down it are ſcarce ſenſible of any declivity."—*Johnſon's Tranſlation of Father Lobo's Voyage to Abyſſinia*, Chap. X.

The only difference between Lobo's and Bruce's account of theſe fountains worthy of notice is, that the former found but *two*, while the latter found *three* holes; but Bruce ſays expreſsly, that the holes are partly artificial; and Lobo's deſcription of them indicates the ſame thing. It is therefore not improbable that there may now be four or five holes.

and having now accompliſhed it, he bent his thoughts on his return to his native country.

He arrived at Gondar on the 19th November 1770; but found, after repeated ſolicitations, that it was by no means an eaſy taſk to obtain permiſſion to quit Abyſſinia. A civil war in the mean time breaking out (no uncommon occurrence in that barbarous country), ſeveral engagements took place between the king's forces and the troops of the rebels, particularly three actions at a place called Serbraxos on the 19th, 20th, and 23d of May 1771. In each of them Mr Bruce acted a conſiderable part; and for his valiant conduct in the ſecond received, as a reward from the king, a chain of gold, of 184 links, each link weighing $3\frac{1}{11}$ dwts. or ſomewhat more than $2\frac{1}{4}$ lbs. troy in all. At Gondar, after theſe engagements, he again preferred the moſt earneſt entreaties to be allowed to return home, entreaties which were long reſiſted; but his health at laſt giving way, from the anxiety of his mind, the king conſented to his departure, on condition of his engaging by oath (B) to return to him in the event of his recovery, with as many of his kindred as he could engage to accompany him.

After a reſidence of nearly two years in that wretched country, Mr Bruce left Gondar on the 16th of December 1771, taking the dangerous way of the deſert of Nubia, in place of the more eaſy road of Maſuah, by which he entered Abyſſinia. He was induced to take this route from his knowledge and former experience of the cruel and ſavage temper of the Naybe of Maſuah. Arriving at Teawa the 21ſt March 1772, he had the misfortune to find the Shekh Fidele of Atbara, the counterpart of the Naybe of Maſuah in every bad quality: by his intrepidity and prudence, however, and by making good uſe of his foreknowledge of an eclipſe of the moon, which happened on the 17th of April, he was permitted to depart next day, and he arrived at Sennaar on the 29th of the ſame month.

Mr Bruce was detained upwards of four months at that miſerable and inhoſpitable place; the inhabitants of which he deſcribes in theſe expreſſive words: "War and treaſon ſeem to be the only employment of theſe horrid people, whom heaven has ſeparated by almoſt impaſſable deſerts from the reſt of mankind, confining them to an accurſed ſpot, ſeemingly to give them an earneſt in time of the only other worſe which he has reſerved to them for an eternal hereafter." This delay was occaſioned by the villany of thoſe who had undertaken to ſupply him with money; but at laſt, by diſpoſing of 178 links of his gold chain, the well-earned trophy of Serbraxos, he was enabled to make preparation for his dangerous journey through the deſerts of Nubia.

He left Sennaar on the 5th of September, and arrived on the 3d of October at Chendi, which he quitted on the 20th, and travelled through the deſert of Gooz, to which village he came on the 26th of October. On the 9th of November he left Gooz, and entered upon the moſt dreadful and dangerous part of his journey; the perils attending which he has related with a power of pencil not unworthy of the greateſt maſters. All his camels having periſhed, Mr Bruce was under the neceſſity of abandoning his baggage in the deſert, and with the greateſt difficulty reached Aſſouan upon the Nile on the 29th of November.

After ſome days reſt, having procured freſh camels, he returned into the deſert, and recovered his baggage, among which is particularly to be remarked a quadrant (of three feet radius) ſupplied by Louis XV. from the Military Academy at Marſeilles; by means of which noble inſtrument, now depoſited in the Muſeum at Kinnaird, Mr Bruce was enabled with preciſion and accuracy to fix the relative ſituations of the ſeveral remote places he viſited.

On the 10th of January 1773, after more than four years abſence, he arrived at Cairo, where, by his manly and generous behaviour, he ſo won the heart of Mahomet Bey, that he obtained a firman, permitting the commanders of Engliſh veſſels belonging to Bombay and Bengal to bring their ſhips and merchandiſe to Suez, a place far preferable in all reſpects to Jidda, to which they were formerly confined. Of this permiſſion, which no European nation could ever before acquire, many Engliſh veſſels have ſince availed themſelves; and it has proved peculiarly uſeful both in public and private diſpatches. Such was the worthy concluſion of his memorable journey through the deſert; a journey which, after many hardſhips and dangers, terminated in obtaining this great national benefit.

At Cairo Mr Bruce's earthly career had nearly been concluded by a diſorder in his leg, occaſioned by a worm in the fleſh. This accident kept him five weeks in extreme agony; and his health was not re-eſtabliſhed till a twelvemonth afterwards, at the baths of Porretta in Italy. On his return to Europe, Mr Bruce was received with all the admiration due to ſo exalted a character. After paſſing ſome conſiderable time in France, particularly at Montbard, with his friend the Comte de Buffon, by whom he was received with much hoſpitality, and is mentioned with great applauſe, he at laſt reviſited his native country, from which he had been upwards of twelve years abſent.

It was now expected that he would take the earlieſt opportunity of giving to the world a narrative of his travels, in which the public curioſity could not but be deeply intereſted. But ſeveral circumſtances contributed to delay the publication; and what theſe were will be beſt related in his own words:

"My friends at home gave me up for dead; and as my death muſt have happened in circumſtances difficult to have been proved, my property became as it were a *hæreditas jacens*, without an owner, abandoned in common to thoſe whoſe original title extended no further than temporary poſſeſſion.

"A number of law-ſuits were the inevitable conſequences of this upon my return. To theſe diſagreeable avocations, which took up much time, were added others ſtill more unfortunate. The relentleſs ague, caught at Bengazi,

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(B) With regard to this oath, Mr Bruce ſays, that he hopes the difficulty of performing it extinguiſhed the ſin of breaking it; and that, at any rate, it being merely perſonal, his engagement to return ceaſed with the death of the king, of which he received intelligence during his ſtay at Sennaar.

Bengazi, maintained its ground, at times, for a ſpace of more than 16 years, though every remedy had been uſed, but in vain; and what was worſt of all, a lingering diſtemper had ſeriouſly threatened the life of a moſt near relation (his ſecond wife), which, after nine years conſtant alarm, where every duty bound me to attention and attendance, conducted her at laſt, in very early life, to her grave."

Amidſt the anxiety and the diſtreſs thus occaſioned, Mr Bruce was by no means neglectful of his private affairs. He conſiderably improved his landed property, encloſing and cultivating the waſte grounds, and he highly embelliſhed his paternal ſeat, making many additions to the houſe, one in particular of a noble muſeum, filled with the moſt precious ſtores of oriental literature, large collections of drawings made, and curious articles obtained, during his far extended peregrinations. An excellent ſtratum of coal at Kinnaird drew much of his attention: he erected ſteam engines of the moſt approved conſtruction, and placed his coalery on ſuch a footing that, at the period of his deceaſe, it produced about 2000l. a-year.

The termination of ſome law-ſuits, and of other buſineſs, which had occupied much of his time, having at length afforded leiſure to Mr Bruce to put his materials in order, his greatly deſired and long expected work made its appearance in 1790, in five large quarto volumes, embelliſhed with plates and charts. It is unneceſſary, and might be tedious, to enter at preſent into any critic or analyſis of this celebrated work. It is univerſally allowed to be replete with much curious and uſeful information; and to abound in narratives which at once excite our admiration and intereſt our feelings. The very ſingular and extraordinary picture which it gives of Abyſſinian manners, ſtartled the belief of ſome; but theſe manners, though ſtrange in the ſight of an European, are little more than might be expected in ſuch a barbarous country; and had an enlightened philoſopher viſited Scotland in the times of our earlieſt monarchs, he might perhaps have witneſſed and related ſcenes, different indeed from what Mr Bruce ſaw in Abyſſinia, but which to us would have ſeemed equally ſtrange.

A more ſerious objection to the truth of Mr Bruce's narrative was ſtarted by an anonymous, but able, critic *, in an Edinburgh newſpaper, ſoon after the publication, from the account of two aſtronomical phenomena, which *could not poſſibly have happened*, as Mr Bruce aſſerts. The firſt of theſe is the appearance of the new moon at Furſhout, during Mr Bruce's ſtay in that place, which he mentions to have been from 25th December 1768 to the 7th of January 1769; and on a particular day in that interval aſſerts, that the new moon was ſeen by a fakir, and was found by the ephemerides to be three days old; whereas it is certain that the moon changed on the 8th of January 1769. The other phenomenon appears equally impoſſible. At Teawa Mr Bruce ſays he terrified the Shekh by foretelling that an eclipſe of the moon was to take place at four afternoon of the 17th of April 1772; that accordingly, ſoon after that hour, he ſaw the eclipſe was begun; and when the ſhadow was half over, told the Shekh that in a little time the moon would be totally darkened. Now, by calculation, it is certain that at Teawa this eclipſe muſt have begun at 36 minutes paſt four, and the moon have been totally covered at 33 minutes paſt five; while the ſun ſet there a few minutes paſt ſix, before which time the moon, then in oppoſition, could not have riſen: ſo that as the moon roſe totally eclipſed, Mr Bruce could not ſee the ſhadow half over the diſk, nor point it out to the Shekh. To theſe objections, which appear unſurmountable, Mr Bruce made no reply, though in converſation he ſaid he would do it in the ſecond edition of his book.

Theſe are miſtakes which can hardly be accounted for by attributing them to the inaccuracy of his notes, or indeed to any cauſe which we are inclined to name; and perhaps he has fallen into a miſtake of the ſame kind in his account of the enormous main-ſail yard of the *canja*, in which he ſailed up the river Nile. To every man who has but dipped into the ſcience of mechanics, it is known that a beam of wood 100 feet in length, muſt be of proportional thickneſs, or it would fall in pieces by its own weight. This thickneſs muſt be greatly increaſed, to enable it to bear the ſtrain occaſioned by a prodigious ſail filled with wind; and thoſe only who have been at the Nile, and have ſeen the canjas, can ſay, whether theſe veſſels, or indeed any veſſels which can be employed on that river, would not be overſet by yards,

——To equal which, the talleſt pine
Hewn on Norwegian hills, to be the maſt
Of ſome great admiral, were but a wand.

The language of the work is in general harſh and unpoliſhed, though ſometimes animated. Too great a diſplay of vanity runs through the whole, and the apparent facility with which the traveller gained the moſt familiar acceſs to the courts, and even to the harams of the ſovereigns of the countries through which he paſſed, is apt to create in readers ſome doubts of the accuracy of the narration. Yet there appears upon the whole ſuch an air of manly veracity, and circumſtances are mentioned with a minuteneſs ſo unlike deceit, that theſe doubts are overcome by the general impreſſion of truth, which the whole detail irreſiſtibly faſtens upon the mind. The character of Ras Michael has often ſtruck us, as containing very ſtrong internal evidence of its having been taken from nature; for it is ſuch a character, at once extraordinary and conſiſtent, as neither Mr Bruce, nor perhaps any writer ſince Shakeſpeare, had genius to feign.

The firſt impreſſion of the book being almoſt diſpoſed of, Mr Bruce had ſtipulated with an eminent bookſeller in London for a ſecond edition to be publiſhed, we think in octavo; and he was buſy in preparing that edition for the preſs when death removed him from this tranſitory ſtage. On the 26th of April 1794 he entertained ſome company at Kinnaird-houſe with his uſual hoſpitality and elegance. About eight o'clock in the evening, when his gueſts were ready to depart, he was handing one of the ladies down ſtairs, when, having reached the ſeventh or eighth ſtep from the bottom, his foot ſlipped, and he fell down headlong. He was taken up ſpeechleſs; his face, particularly the forehead and temples, being ſeverely cut and bruiſed, and the bones of his hands broken. He continued in a ſtate of apparent inſenſibility for eight or nine hours, and expired on Sunday the 27th, in the 64th year of his age.

Mr Bruce's ſecond wife, whom he married on the 20th

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* Suppoſed o be Dr Rotheram. rofeſſor of naturalphi-oſophy in he univerity of St Andrew's.

20th May 1776, was Mary, eldeſt daughter of Thomas Dundas, Eſq; of Carron-hall, by Lady Janet Maitland, daughter of Charles ſixth Earl of Lauderdale. By that lady, who, after a ſevere and lingering indiſpoſition, died in 1784, he had three children, of whom one ſon and one daughter ſurvive him.

Mr Bruce's perſon was large, his height exceeding ſix feet, his bulk being in proportion to his height; and at the period when he entered on his dangerous expedition, he was equally remarkable for ſtrength and for agility. To thoſe who never beheld him, the engraved medallion in the title pages of the firſt and third volumes of his Travels will convey ſome idea of his features. He excelled in all manly accompliſhments, being trained to exerciſe and fatigue of every kind. He was a hardy, practiſed, and indefatigable ſwimmer; and his long reſidence among the Arabs had given him a more than ordinary facility in managing the horſe. In the uſe of fire-arms he was ſo unerring, that in innumerable inſtances he never failed to hit the mark; and his dexterity in handling the ſpear and lance on horſeback was alſo uncommonly great. He was maſter of moſt languages; and was ſo well ſkilled in oriental literature, that he reviſed the New Teſtament in the Ethiopic, Samaritan, Hebrew, and Syriac, making many uſeful notes and remarks on difficult paſſages. He had applied from early youth to mathematics, drawing, and aſtronomy, and had acquired ſome knowledge of phyſic and ſurgery. His memory was aſtoniſhingly retentive, and his mind vigorous. He was dexterous in negociation, a maſter of public buſineſs, and animated with the warmeſt zeal for the glory of his king and country. Such, at leaſt, is *his own* repreſentation of his character; and though an impartial judge would probably make conſiderable abatement for the natural bias of a man drawing his own portrait, yet it cannot be denied, that in perſonal accompliſhments Mr Bruce equalled, if not exceeded, moſt of his contemporaries.

Thus accompliſhed, he could not but be eminently fitted for an attempt ſo full of difficulty and danger as what he called the diſcovery of the ſources of the Nile: no one who peruſes his account of the expedition, can fail to pay an unfeigned tribute of admiration to his intrepidity, manlineſs, and uncommon dexterity, in extricating himſelf out of ſituations the moſt dangerous and alarming, in the courſe of his long and hazardous journey; not to mention his conduct during his reſidence in Abyſſinia, his behaviour at Maſuah, Teawa, and Sennaar, evinces the uncommon vigour of his mind: but it was chiefly during his paſſage through the Nubian deſert, that his fortitude, courage, and prudence, appeared to the greateſt advantage. Of his learning and ſagacity, his delineation of the courſe of Solomon's fleet from Tarſhiſh to Ophir, his account of the cauſe of the inundations of the Nile, and his comprehenſive view of the Abyſſinian hiſtory, afford ample proofs. It muſt indeed be confeſſed, that in his account of the inundations of the Nile, as well as in his delineation of the courſe of Solomon's fleet, he has not the merit of originality; but on both theſe occaſions he has ſtated the hypotheſis which he maintains with greater clearneſs, and ſupported it with more plauſible arguments, than any other author whoſe writings have fallen into our hands; and it was ſurely to his honour, that as ſoon as he learned that his hypotheſis reſpecting Ophir and Tarſhiſh had been controverted by Dr Doig of Stirling, he earneſtly courted the acquaintance of that eminent ſcholar.

After his return to his own country, he reſided moſtly at Kinnaird; and till he became corpulent, ſpent much of his time in the various ſports of the field, in which he engaged with great ardour. Though ſtudious in youth, and at all times a ſtranger to intemperance and diſſipation, he read but little in his later years; and ſeemed to find his chief pleaſure in converſation, eſpecially the converſation of well-informed ladies. In his friendſhips he ſometimes appeared to be capricious, attaching himſelf to men in whoſe heads and hearts no other perſon could perceive a charm for a mind like his. Though in his own dealings he was always juſt and honourable, he was too ready to apprehend unfairneſs in others, and to expreſs ſuch apprehenſions with undue warmth. To ſtrangers he was often arrogant, and ſometimes inſolent; but in his own family he was an affectionate huſband, a kind father, an agreeable entertainer, and to his ſervants a maſter perhaps too indulgent. In converſation, as well as in his writings, he embraced every opportunity of expreſſing a deep and lively ſenſe of the care of a ſuperintending Providence, without which he was convinced that there could be no ſafety in human ſtrength or human foreſight. His belief of the Chriſtian religion reſted on the ſureſt grounds; and ſuch was his veneration for the ſacred writings, that for ſome years before his death they ſeemed to occupy all the time which he gave to ſtudy. He read no ſermons, however elegant; and diſſuaded others from ſuch reading. "Read the Bible (ſaid he), and you will ſoon perceive the emptineſs of the moſt applauded ſermons."

BUCK-WHEAT, a ſpecies of POLYGANUM (ſee that article *Encycl.*), was firſt introduced into Europe about the end of the 15th or the beginning of the 16th century. According to ſome botaniſts, who lived at that period, its native country is the northern parts of Aſia, whence it was brought to Germany and France, where, about the year 1587, it was the common food of the poor.

A new ſpecies of this grain, or, to ſpeak perhaps more properly, a variety of this ſpecies, has been for ſome time known under the name of *Siberian* buck-wheat, which appears to have conſiderable advantages over the former. It was ſent from Tartary to St Peterſburgh by the German botaniſts, who travelled thro' that country in the beginning of the preſent century; and it has thence been diſperſed over all Europe. Linnæus received the firſt ſeeds of it in 1737 from Garber the botaniſt, and deſcribed the plant in his *Hortus Cliffertionus*. After this it was mentioned by Ammann in 1739: but it muſt have been earlier known in Germany; for in 1733 it was growing in the garden of Dr Ehrhart at Memmingen. In Siberia this plant ſows itſelf for four or five years by the grains that drop; but at the end of that period the land becomes ſo full of tares that it is choked, and muſt be ſown afreſh. Even in the economical gardens of Germany, it is propagated in the ſame manner; and in that country it is in ſome places found growing wild, though it is nowhere cultivated in the neighbourhood. It is not, however, indigenous, otherwiſe Ehrhart might have raiſed it from German ſeed, which it ſeems he could not find in 1733.

See much curious information concerning this plant in Profeſſor Beckmann's *Hiſtory of Inventions and Diſcoveries*.

BULAM, or BULAMA, as it is more uſually called, forms part of the Archipelago, or cluſter of iſlands, lying on the weſtern or windward coaſt of Africa, and known by the name of the *Biſſaos* or *Biſſagos*, which are ſuppoſed to have been celebrated by the ancients under the appellation of the *Heſperides*. It is ſituated at the mouth of the Rio Grande, in 11° N. Lat. and 15° W. Long. from the meridian of London; and is between ſeventeen and eighteen leagues long, and from four to five broad.

This iſland has become an intereſting object to the inhabitants of Great Britain, in conſequence of its having been purchaſed in the year 1792 by a ſociety inſtituted for the ſame humane purpoſes with thoſe which gave riſe to the Sierra-Leona company (ſee SIERRA-*Leona*, Encycl.) The Bulam aſſociation was formed towards the latter end of the year 1791; and they were induced to pitch upon that iſland as the moſt eligible tract for their intended colony, in conſequence of the flattering deſcription given of its climate, ſoil, and harbours, by M. Brue, formerly director-general of the French African companies.

The gentlemen originally appointed as truſtees for managing the concerns of the aſſociation at home were, *Paul Le Meſurier*, M. P.; *James Kirkpatrick*, Eſq; *George Hartwell*, Eſq; *Moſes Ximenes*, Eſq; *Sir John Riggs Miller*, Bart. and *David Scott*, Eſq. M. P.; and for eſtabliſhing the colony, and conducting the affairs of the ſociety abroad, the following gentlemen were nominated, viz. *Meſſrs H. H. Dalrymple*, *John Young*, *Sir William Halton*, Bart. *John King*, *Philip Beaver*, *Peter Clutterbuck*, *Nicholas Bayly*, *Francis Brodie*, *Charles Drake*, *John Paiba*, *Richard Hancorne*, *Robert Dobbins*, and *Iſaac Ximenes*.

A ſum of L. 9000 being quickly ſubſcribed for the eſtabliſhment of the intended colony, this committee ſailed from Spithead in three ſhips on the 11th of April 1792; and landing in due time at Bulama, they purchaſed that iſland from the kings of Canabac, who claimed it as their property. They purchaſed likewiſe from the kings of Ghinala the neighbouring iſland Arcas, and the adjacent land on the continent; and theſe ſeveral purchaſes being taken poſſeſſion of in the uſual form, a body of ſettlers, conſiſting of 49 men, 13 women, and 25 children, were left at Bulama under the ſuperintendence of Mr Beaver, with a temporary ſupply of proviſions, ſtores, plantation-tools, and merchandiſe, for trading with the neighbouring natives. It is from the diſpatches of theſe ſettlers, after having lived ſome time in Bulama, that the following account of the iſland was drawn up by Mr Johanſen.

"The climate, on the whole, may be deemed ſalubrious, and will become more ſo in proportion to the increaſe of cultivation. The mornings and evenings are temperate and pleaſant; the middle of the day is hot, but the fine ſea breeze which then ſets in tends greatly to cool and refreſh the air. The heat of the ſun is not either ſo exceſſive or intolerable as has been generally ſuppoſed: indeed nature has moſt admirably adapted our mechanical and phyſical qualities to the exigencies of different regions; and man, who is the inhabitant of every climate, may, in ſome meaſure, render himſelf indigenous to every ſoil. Here the only danger ariſes from too ſudden an expoſure to the operation of the vertical rays of the ſun, or an exceſs of labour; both of which the firſt ſettlers ought moſt ſtudiouſly to avoid.

"It appears from Mr Beaver's obſervations at noon, between the 20th of July 1792, and the 28th of April 1793, that the thermometer, when loweſt, was at 74; the medium heat 85; and that it never exceeded 96, except at one time when it roſe to 100, during a calm that occurred in the interval between the north-eaſt breeze in the morning and the ſouth-weſt in the evening of the 19th of February 1793. The difference between the heat of noon and that of the morning and evening is from 20 to 30 degrees. On the 23d of October 1792, hail of the ſize of a pin's head fell during two minutes, although not a cloud was to be ſeen during this phenomenon. The mercury in the thermometer then ſtood at 85; the wind was at north-eaſt in the morning and ſouth-weſt in the evening.

"Immediately after ſun-ſet a dew conſtantly begins to fall, which induces ſome to light a fire in their houſes; they at the ſame time put on warmer clothing. There is little or no twilight; and night and day are nearly equal: the earth has therefore time to cool during twelve hours abſence of the ſun.

"None of thoſe terrible and deſtructive hurricanes ſo frequently experienced in the Weſt Indies are to be met with here. The *tornadoes*, which ariſe chiefly from the eaſtern point of the compaſs, are but of ſhort duration, ſeldom laſting above an hour, and may be readily foreſeen ſome time previouſly to their commencement. They occur at the beginning and cloſe of the wet ſeaſon, and are highly beneficial, as they purify the air, and diſpel the noxious vapours with which it would otherwiſe abound.

"The rains ſet in about the latter end of May or the beginning of June, and diſcontinue in October or November. They do not fall every day, for there is often a conſiderable interval of clear weather, during which the atmoſphere is beautifully ſerene; the ſhowers in the firſt and laſt month occur but ſeldom, and are far from being violent; while, on the other hand, they ſometimes reſemble torrents, more eſpecially towards the middle of the ſeaſon. During the whole of this period, Europeans ſhould, if poſſible, confine themſelves to their habitations, as the rains prove injurious to health, more eſpecially if thoſe expoſed to them neglect to wipe their bodies dry, and to change their clothes immediately on their return home. It is deemed prudent alſo not to dig the earth until the expiration of a month after the return of fair weather, as this is conſidered to be unhealthy.

"During the continuance of the dry ſeaſon, a dew falls during the night, in ſufficient quantity to anſwer all the purpoſes of vegetation.

"Every ſtranger is generally here, as well as in the Weſt Indies, ſubject to a fever or *ſeaſoning* on his arrival. This is not infectious; it proceeds perhaps from an increaſed perſpiration and a ſudden extenſion of the pores of the human body, in conſequence of the heat, by which means it is rendered more liable to imbibe the abundant exhalations that ariſe from the animal, vegetable, and mineral kingdoms; but even this, ſlight as it is, might doubtleſs be avoided by means of a proper regimen, and a ſhort ſeclusion from the full action of the open air, more eſpecially at noon, and during the evening, until the climate has been rendered familiar.

“ Bulama is admirably adapted for all the purpoſes of an extenſive commerce, being not only happily ſituated at the mouth of the Rio Grande, but in the vicinity of ſeveral other navigable rivers ; ſo that a trade with the internal parts of Africa is thereby greatly facilitated. The landing is remarkably eaſy and ſafe, there being no ſurge ; the ebb and flow is regular, and there is an increaſe of 16 feet of water at ſpring tide. The bay oppoſite the Great Bulama is adorned with a number of iſlands, covered with trees, and forms a moſt excellent harbour, ſufficiently capacious to contain the whole navy of Great Britain, which might ride there in ſafety. The ſettlement in general is well ſupplied with water. A number of ſprings have been lately diſcovered in different places ; and beſides a draw-well in the fort, which was erected for the defence of the colony, there is a ſmall ſtream, which runs into Elewſis Bay, near the new ſettlement called Heſper Elewſis : this is admirably ſituated for the ſupply of ſhipping.

“ The iſland is beautifully ſurrounded, and interſperſed with woods : lofty fruit and foreſt trees, moſtly free from underwood and brambles, form a verdant belt, in ſome places two or three miles broad, which entirely encircles it, in ſuch a manner as to repreſent a plantation artificially formed around a park. Within this the fields are regularly divided by trees, ſo as to reſemble the hedge-rows in England. The beach has in ſome places the appearance of gravel walks ; it is fringed with mangrove trees, which forming a line with the high-water mark, dip their branches into the ſea, and thus afford nouriſhment to the oyſters that often adhere to their extremities.

“ Several parts of Bulama have been occaſionally cultivated by the neighbouring blacks, though they did not conſtantly reſide on it.

“ The land in general riſes gradually towards the middle of the iſland, where the higheſt ſpot is from 60 to 100 feet above the level of the ſea. The ſmall hill on which the fort is ſituated is nearly of the ſame altitude.

“ The ſoil is abundantly rich and deep ; ſtones do not here impede the labours of the farmer ; and indeed none have hitherto been diſcovered, but a ſmall ſort, reſembling pieces of ore, which are to be met with on the ſhore. There are many *ſavannahs* or natural meadows, ſo extenſive that the eye can ſcarcely deſcry their boundaries. Theſe are admirably adapted for the rearing of ſtock and feeding of cattle of every kind.

“ Cotton, indigo, rice, and coffee, grow ſpontaneouſly on this coaſt ; the ſugar-cane is indigenous to many parts of Africa, and might be cultivated here by the labour of freemen, in equal perfection, and to much greater advantage, than in the exhauſted iſlands of the Weſt Indies. All kinds of tropical productions, ſuch as pine-apples, limes, oranges, grapes, plums, caſſada, guava, Indian wheat, the papaw, water-melon, muſk-melon, the pumpkin, tamarind, banana, and numbers of other delicious fruits, alſo flouriſh here. The adjoining territories produce many valuable ſorts of ſpices, gums, and materials for dyeing : all of which it is but fair to ſuppoſe, might be readily cultivated in a kindred climate and a congenial ſoil.

“ The neighbouring ſeas abound with a variety of fiſh, highly agreeable to the palate. The lion, tyger, jackall, &c. are natives of the continent ; but in Bulama no animals have been diſcovered, the wolf, ſome buffaloes, a few elephants, and a ſpecies of the deer, excepted.

“ The woods abound with doves, guinea-fowls, and a variety of birds, celebrated for the beauty of their plumage.

“ The natives of this part of Africa, like all ſavages, are entirely under the dominion of their paſſions : hence the violence of their attachment to their friends, and the exceſs of their reſentment againſt their enemies. Their notions of property are very obſcure and confuſed : they have no idea of any right ariſing from occupancy or improvement. What they want, they either receive or take wherever they may happen to meet with it, and they permit others to do the ſame. They have been taught by experience that the Europeans will not agree to this : againſt them therefore they employ every artifice that it is in the power of cunning to ſuggeſt.

“ The coloniſts need not fear any attack on the part of the negroes, provided their own conduct be juſt and peaceable : for Mr Beaver, who was indeed admirably calculated by nature and habit for the ſtation he occupied, could enſure both ſafety and reſpect when the ſettlers under him were reduced to four white men, although the neighbouring nations knew that he was in poſſeſſion of commodities, for the acquiſition of which many of them had become day-labourers. He often kept from twenty to forty gromittos, or black cultivators in pay, at that very period, at about four or five bars (A) each per month. Theſe are eaſy to be procured, to almoſt any number that can poſſibly be wanted.

“ Until a ſufficient quantity of ſtock and proviſions can be raiſed in the company's ſettlements, the adjacent iſlands will furniſh abundance of cattle, hogs, fowls, &c. at a very cheap rate. A horſe may be purchaſed at Goree for 1l. 10s. a bullock may be had from 12s. to 18s. ſterling : proviſions of all kinds are equally reaſonable. Honey is alſo to be procured in great plenty, and bees-wax may be rendered an advantageous object of commercial ſpeculation.

“ In ſhort, the acquiſition of Bulama, Arcas, and the adjacent territories, preſents the faireſt opportunity of furniſhing Europe with many valuable articles that have hitherto been brought from more remote countries, with much greater hazard, and at an increaſed expence. The intercourſe with England is eaſy, ſafe, and expeditious ; for the voyage may be performed in the ſpace of three or four weeks : and by the terms of the firſt ſubſcription, a ſettler on Bulama might purchaſe 500 acres of land for L. 30 Sterling ; by the terms of the ſecond, which we ſuppoſe are the terms at preſent, he might purchaſe on the iſlands of Bulama and Arcas, or on that part of the adjacent coaſt which was ceded to the ſociety by the kings of Ghinala, 200 acres for L. 50 ſterling.

(A) A bar is about the value of three ſhillings and ſixpence.

“ The colonization of Africa opens a noble and extenſive field to nations and to individuals. To people thoſe fertile territories, deſpoiled of their inhabitants by the ſlave-trade; to rear the productions of the climes between the tropics, by the aſſiſtance of free men; to give ample ſcope to the induſtry and exertions of thoſe who may be inclined to remove from Great Britain; and to extend the commerce and the manufactures of our native country—theſe are ſubjects which have excited the attention of the Bulama aſſociation, and now claim the aſſiſtance of the ingenious, the ſupport of the rich, and the concurrence and good wiſhes of all.”

BUNTING, is a bird which has been deſcribed under its generic name EMBERIZA (*Encycl.*); but there is one ſpecies, the *orange ſhouldered bunting* of Latham, of which M. Vaillant relates ſome particulars certainly not unworthy of notice in this place.

“ The female of this beautiful bird (ſays he) has the ſimple colours of the ſky-lark, and a ſhort horizontal tail, like that of almoſt all other birds: the male, on the contrary, is wholly black except at the ſhoulder of the wing, where there is a large red patch; and his tail is long, ample, and vertical, like that of the common cock. But this brilliant plumage and fine vertical tail ſubſiſt only during the ſeaſon of love, which continues ſix months. This period over, he lays aſide his ſplendid habiliments, and aſſumes the more modeſt dreſs of his mate. The moſt extraordinary circumſtance is, that the vertical tail alſo changes to a horizontal one, and the male ſo exactly reſembles the female, that it is not poſſible to diſtinguiſh them from each other.

“ The female has her turn. When ſhe reaches a certain age, and has loſt the faculty of propagating the ſpecies, ſhe clothes herſelf for the remainder of her days in the garb which the male had temporarily aſſumed; her tail, like his at that period, grows long, and, like his alſo, from horizontal becomes vertical.

“ The birds of this ſpecies aſſociate together, live in a ſort of republic, and build their neſts near to each other. The ſociety uſually conſiſts of about fourſcore females; but, whether by a particular law of nature, more females are produced than males, or for any other reaſon of which I am ignorant, there are never more than twelve or fifteen males to this number of females, who have them in common.”

According to our author, this tranſmutation is by no means confined to this particular ſpecies of bunting. Many females of the feathered creation, when they grow ſo old as to ceaſe laying eggs, aſſume the more ſplendid colours of the male, which they retain during the remainder of their lives. This fact is ſtrikingly perceptible in thoſe ſpecies in which the male and female very much differ in colour, as the golden pheaſant of China, for inſtance. In ſome ſpecies, and thoſe not a few, the male alone regularly changes his colour, and aſſumes once in a year the plumage of the female; ſo that at a certain period all the birds of that ſpecies appear females. “ I have in my poſſeſſion (ſays our author) ſpecimens of more than fifty of thoſe changing ſpecies, in all their tranſitions from one hue to another; and the change is ſometimes ſo great, that a perſon would ſuppoſe himſelf to ſee individuals totally different. A cloſet-naturaliſt, for inſtance, ſhewed me four birds as ſo many different ſpecies, and even as not belonging to the ſame genus, with which I was well acquainted, and which I knew to be the ſame bird, only of different ages.”

Such changes as theſe, could they be proved to take place occaſionally among domeſtic fowls, would in ſome meaſure account for ſtrange ſtories of cocks laying eggs, which we have heard related by perſons whoſe general veracity was never queſtioned.

BURKE (Edmund), was born in the city of Dublin on the 1ſt of January 1730. His father was an attorney of conſiderable knowledge in his profeſſion, and of extenſive practice; and the family from which he ſprung was ancient and honourable. He received the rudiments of his claſſical education under Abraham Shackleton, a Quaker, who kept a private ſchool or academy, as it has been called, at Bellytore, near Carlow, and is ſaid to have been a very ſkilful and ſucceſsful teacher.

Under the tuition of this maſter, Burke devoted himſelf with great ardour, induſtry, and perſeverance, to his ſtudies; and manifeſted, even from his boyiſh days, a diſtinguiſhed ſuperiority over his contemporaries. He was the pride of his preceptor, who prognoſticated every thing great from his genius, and who was, in return, treated by his illuſtrious pupil, for forty years, with reſpect and gratitude.

From ſchool Burke was ſent to Trinity-college, Dublin, where it was aſſerted by Goldſmith and others his contemporaries, that he diſplayed no particular eminence in the performance of his exerciſes. Like Swift, he deſpiſed the logic of the ſchools; and like him too, he devoted his time and his talents to more uſeful purſuits. Johnſon, though proud of being an Oxonian, did not much employ himſelf in academical exerciſes; and Dryden and Milton, who ſtudied at Cambridge, were neither of them ambitious of college diſtinctions. Let not, however, the example of a Burke, a Johnſon, a Dryden, or a Milton, ſeduce into by-paths the ordinary ſtudent; for though great genius either finds or makes its own way, common minds muſt be content to purſue the beaten track. Shakeſpeare, with very little learning, was the greateſt dramatic poet that ever wrote; but how abſurd would it be to infer from this fact, that every illiterate man may excel in dramatic poetry?

Whilſt at college Burke applied himſelf with ſufficient diligence to thoſe branches of mathematical and phyſical ſcience which are moſt ſubſervient to the purpoſes of life; and though he neglected the ſyllogiſtic logic of Ariſtotle, he cultivated the method of induction pointed out by Bacon. Pneumatology, likewiſe, and ethics, occupied a conſiderable portion of his attention; and whilſt attending to the acquiſition of knowledge, he did not neglect the means of communicating it. He ſtudied rhetoric and the art of compoſition, as well as logic, phyſics, hiſtory, and moral philoſophy; and had at an early period of his life, ſays Dr Biſſet, planned a confutation of the metaphyſical theories of Berkeley and Hume.

For ſuch a taſk as this, we do not think that nature intended him. Through the ever-active mind of Burke ideas ſeem to have flowed with too great rapidity to permit him to give that patient attention to minute diſtinctions, without which it is vain to attempt a confutation of the ſubtleties of Berkeley and Hume. The ableſt antagoniſt of theſe two philoſophers was remarkable for patient thinking, and even *apparent* ſlowneſs of apprehenſion;

apprehenſion ; and we have not a doubt, but that if he had poſſeſſed the rapidity of thought which characteriſed Burke, his confutation of Hume and Berkeley would have been far from concluſive. It might have been equal to the *Eſſay on the Nature and Immutability of Truth*, but would not have been what we find it in *The Inquiry into the Human Mind on the Principles of Common Senſe*, and in *The Eſſays on the Intellectual and Active Powers of Man.*

A taſk much better ſuited to Burke's talents than the writing of metaphyſical diſquiſitions on the ſubſtratum of body, preſented itſelf to him in the year 1749, and a taſk which was likewiſe more immediately uſeful. At that period one Lucas, a democratic apothecary, wrote a number of very daring papers againſt government, and acquired by them as great popularity at Dublin as Mr Wilkes afterwards obtained by his North Briton in London. Burke, though a boy, perceived, almoſt intuitively, the pernicious tendency of ſuch levelling doctrines, and reſolved to counteract it. He wrote ſeveral eſſays in the ſtyle of Lucas, imitating it ſo exactly as to deceive the public ; purſuing his principles to conſequences neceſſarily reſulting from them, and ſhewing at the ſame time their abſurdity and their danger. Thus was his firſt literary effort, like his laſt, calculated to guard his country againſt anarchical innovations.

Whilſt employed in treaſuring up knowledge, which at a future period was to command the admiration of liſtening ſenates, he did not neglect the means neceſſary to render himſelf agreeable in the varied intercourſe of private life. To the learning of a ſcholar he added the manners of a gentleman. His company was ſought among the gay and the faſhionable, for his pleaſing converſation and eaſy deportment ; as much as among the learned, for the force and brilliancy of his genius, and the extent and depth of his knowledge. But though the object of very general regard in his native country, he had hardly any proſpect of obtaining in it an independent ſettlement. He therefore applied, ſome time after the publication of his letters expoſing the doctrines of Lucas, for the profeſſorſhip of logic, which had then become vacant in the univerſity of Glaſgow : but whether that application was made too late, or that the univerſity was unwilling to receive a ſtranger, certain it is that the vacant chair was filled by another, and that Burke was diſappointed of an office in which he was eminently qualified to excel. For many years very little attention has been paid in the univerſities of Scotland, perhaps even too little, to the Ariſtotelian logic ; and the profeſſors, inſtead of employing their time in the analyſing of ſyllogiſms, deliver lectures on rhetoric and the principles of compoſition—lectures which no man was more capable of giving than the unſucceſsful candidate for the profeſſorſhip in Glaſgow.

Diſappointment of early views has frequently been the means of future advancement. Had Johnſon become maſter of the Staffordſhire ſchool, talents might have been conſumed in the tuition of boys which Providence formed for the inſtruction of men ; and had Burke obtained the profeſſorſhip of logic in Glaſgow, he would have been the moſt eloquent lecturer in that univerſity, inſtead of the moſt brilliant ſpeaker in the Britiſh ſenate : but whether his talents might not have been as uſefully employed in the univerſity as in the ſenate, may perhaps be a queſtion, though there can be no queſtion whether they would have inveſted himſelf with an equal blaze of ſplendour.

Diſappointed in Glaſgow, he went to London, where he immediately entered himſelf of the Temple ; and as there is reaſon to believe that he was in ſtraitened circumſtances, he ſubmitted to the drudgery of regularly writing for daily, weekly, and monthly publications, eſſays on general literature and particular politics. The profits ariſing from ſuch writings were at firſt ſmall ; but they were ſo neceſſary to their author, that the intenſe application which they required gradually impaired his health, till at laſt a dangerous illneſs enſued, when he reſorted for medical advice to Dr Nugent, a phyſician whoſe ſkill in his profeſſion was equalled only by the benevolence of his heart. The Doctor, conſidering that the noiſe, and various diſturbances incidental to chambers, muſt retard the recovery of his patient, furniſhed him with apartments in his own houſe, where the attention of every member of the family contributed more than medicines to the reſtoration of his health. It was during this period that the amiable manners of Miſs Nugent, the Doctor's daughter, made a deep impreſſion on the heart of Burke ; and as ſhe could not be inſenſible to ſuch merit as his, they felt for each other a mutual attachment, and were married ſoon after his recovery.

Hitherto his mental powers and acquirements were known in their full extent only to his friends and more intimate companions ; but they were now made public in his firſt acknowledged work, intitled, *A Vindication of Natural Society.* The object of this performance was to expoſe the dangerous tendency of Lord Bolingbroke's philoſophy. By the admirers of that nobleman, his principles were deemed inimical only to revealed religion and national churches, which they would have been glad to ſee overturned, provided our civil eſtabliſhment had been preſerved; and to the civil eſtabliſhment they perceived no danger in the writings of the author of *The Patriot King.* Mr Burke thought very differently ; and endeavoured to convince them, that if his Lordſhip's philoſophy ſhould become general, it would ultimately deſtroy their rank, their conſequence, and their property, and involve the church and ſtate in one common ruin. In his ironical attack upon artificial ſociety, he makes uſe of the ſame common place mode of unfair reaſoning which his noble antagoniſt had employed againſt religion and religious eſtabliſhments. He argues, from the incidental abuſes of political ſociety, that political ſociety muſt itſelf be evil ; he goes over every form of civil polity, pointing out its defects in the moſt forcible language; and, in perfect imitation of the ſceptical philoſophy, he pulls them all down, one after another, without propoſing any thing in their ſtead. So complete is the irony, that to many not acquainted with ſuch diſquiſitions, he would appear to be ſeriouſly inveighing againſt civil government ; and we have actually heard ſome of the advocates for modern innovation mention this work as a proof how different Mr Burke's opinions in politics once were from what they appear to have been when he wrote his *Reflections on the French Revolution.*

The truth, however, is, that there is no inconſiſtency between *The Vindication of Natural Society* and the lateſt publications of its illuſtrious author. At the period

riod when that work was publiſhed, infidelity had infected only the higher orders of men, and ſuch of the lower as had got the rudiments of a liberal education. Of theſe we believe a ſingle individual was not then to be found, who ſuppoſed that ſociety could ſubſiſt both without government and without religion; and therefore while they laboured to overturn the church, and to prove that Chriſtianity itſelf is an impoſture, they all pretended to be zealouſly attached to our civil government as eſtabliſhed in king, lords, and commons. Except the clergy of the eſtabliſhed church, there was no order of men whom they indiſcriminately reviled. Hence it was that not Burke only, but Warburton, and almoſt every other opponent of Lord Bolingbroke, began their defences of revelation, by ſhewing the indiſſoluble connection between our civil and eccleſiaſtical eſtabliſhments; and all the difference was, that he did, through the medium of the moſt refined irony, the very ſame thing which they had done by ſerious reaſoning.

Soon after his *Vindication of Natural Society*, Burke publiſhed *A Philoſophical Enquiry into the Origin of our Ideas of the Sublime and Beautiful;* a work which ſoon made its author univerſally known and admired, and which has been ſtudied by every Engliſh reader of taſte. It is therefore needleſs for us to hazard any opinion either of its general merit or its particular defects. In one of the literary journals of that day, Mr Murphy urged objections againſt ſome of its fundamental principles, which, in our opinion, it would be very difficult to anſwer; whilſt Johnſon, who was certainly a ſevere judge, conſidered it as a model of philoſophical criticiſm. "We have (ſaid he) an example of true criticiſm in Burke's Eſſay on the Sublime and Beautiful. There is no great merit in ſhewing how many plays have ghoſts in them, or how this ghoſt is better than that; you muſt ſhew how terror is impreſſed on the mind."

In conſequence of this manifeſtation of Burke's intellectual powers, his acquaintance was courted by men of diſtinguiſhed talents, and, among others, by Johnſon and Sir Joſhua Reynolds. The literary club which has been mentioned (*Encycl.*) in the life of JOHNSON, was inſtituted for their entertainment and inſtruction, and conſiſted at firſt of Johnſon, Burke, Reynolds, Goldſmith, Dr Nugent, Mr Topham, Beauclerk, Sir John Hawkins, Mr Chamier, and Mr Bennet Langton, who were all men of letters and general information, though far above the reſt ſtood Burke and Johnſon. Of Burke indeed Johnſon declared, upon all occaſions, that he was the greateſt man living; whilſt Burke, on a very ſolemn occaſion, ſaid of Johnſon, "He has made a chaſm, which not only nothing can fill up, but which nothing has a tendency to fill up. Johnſon is dead. Let us go to the next beſt—There is nobody—No man can be ſaid to put you in mind of Johnſon." Nor was the opinion which theſe two illuſtrious men held of each other's powers peculiar to themſelves alone: all the members of the club obſerved, that in colloquial talents they were nearly matched, and that Johnſon never diſcourſed with ſuch animation and energy as when his powers were called forth by thoſe of Burke.

Some years before the inſtitution of this club, Burke, who had devoted much of his time to the ſtudy of hiſtory and politics, propoſed to Mr Dodſley, an eminent bookſeller, a plan of an ANNUAL REGISTER of the civil, political, and literary tranſactions of the times; and the propoſal being acceded to, the work was begun and carried on for many years, either by Burke himſelf, or under his immediate inſpection. It bears indeed internal marks of his genius, his learning, and his candour, being by much the moſt elegant and impartial periodical hiſtory which has perhaps appeared in any age or nation. Even when the heat of oppoſition made him, in his ſpeeches, ſometimes miſrepreſent the conduct of adminiſtration, the Annual Regiſter, under his management, continued to render juſtice to all parties.

He ſtill continued to write occaſionally political eſſays for other publications than the Annual Regiſter; and ſome of theſe eſſays in the *Public Advertiſer* having attracted the notice of the Marquis of Rockingham, that nobleman ſought the acquaintance of their author. It was in the year 1765 that the firſt interview took place between them; and the Marquis, who was then at the head of the treaſury, offering to make Burke his own ſecretary, the offer was readily accepted. On this occaſion he gave a remarkable proof of diſintereſtedneſs and delicate integrity. Through the influence of Mr Hamilton, known by the appellation of *Single Speech* Hamilton, and long ſuſpected to be the author of *Junius's Letters*, he had ſome time before obtained a penſion of L.300 a-year on the Iriſh eſtabliſhment; but this penſion he now thought it incumbent upon him to reſign, becauſe he had connected himſelf with a party oppoſite in many things to the party whoſe meaſures were ſupported by his friend.

During the Rockingham adminiſtration he was choſen member of Parliament for the borough of Wendover in the county of Bucks; and he prepared himſelf for becoming a public ſpeaker, by ſtudying, ſtill more cloſely than he had yet done, hiſtory, poetry, and philoſophy; and by ſtoring his mind with facts, images, reaſonings, and ſentiments. He paid great attention likewiſe to parliamentary uſage; and was at much pains to become acquainted with old records, patents, and precedents, ſo as to render himſelf complete maſter of the buſineſs of office. That he might communicate without embarraſſment the knowledge which he had thus laboriouſly acquired, he frequented, with many other men of eminence, the Robin Hood Society, where he practiſed the replies and contentions of eloquence; and to acquire a graceful action, with the proper management of his voice, he was a very diligent obſerver of Garrick in Drury-Lane theatre. He procured his ſeat in 1765, and in the enſuing ſeſſion delivered his maiden ſpeech; which was ſuch a diſplay of eloquence as excited the admiration of the Houſe, and drew very high praiſe from its moſt diſtinguiſhed member Mr Pitt, afterwards Earl of Chatham.

The principal objects which engaged the attention of the Rockingham adminiſtration were the ferments in America, which was then in a ſtate little ſhort of rebellion, on account of the famous ſtamp-act. Parliament was divided in opinion reſpecting that meaſure. Whilſt Mr Grenville and his party (under whoſe auſpices the ſtamp-act had paſſed into a law) were for enforcing obedience to it by coercive meaſures, Mr Pitt and his followers denied that the parliament of Great Britain had a right to tax the Americans; and the marquis of Rockingham, who was hardly able to carry any meaſure in oppoſition to both theſe parties, had to conſider,

ſider, on this occaſion, whoſe ſentiments he would adopt. By the advice, it is ſaid, of Mr Burke, he choſe a middle courſe between the two oppoſite extremes. To gratify the Americans, he repealed the ſtamp-act; and to vindicate the honour of Britain, he got a law paſſed declaratory of her right to legiſlate for America in taxation as in every other caſe.

This meaſure, whoever was its author, was certainly not the offspring either of wiſdom or vigour. If the mother-country had a right to legiſlate in all caſes for America, obedience to the ſtamp-act ſhould certainly have been enforced; and the miniſtry which relinquiſhed an acknowledged right, to gratify the factious diſpoſition of diſtant colonies, was obviouſly unfit to guide the helm of a great empire. Lord Rockingham and his friends were accordingly diſmiſſed from office; and a new adminiſtration was formed under the auſpices of Mr Pitt, now created earl of Chatham.

Burke, in the mean time, wrote in defence of the party with which he was connected; and aſſumed great credit to it for compoſing the diſtractions of the Britiſh empire by the repeal of the American ſtamp-act, whilſt the conſtitutional ſuperiority of Great Britain was preſerved by the act for ſecuring the dependence of the colonies. After defending his friends, he proceeds to attack thoſe who had ſucceeded them in office. Of Lord Chatham he ſays—" He has once more deigned to take the reins of government into his own hand, and will, no doubt, drive with his wonted ſpeed, and raiſe a deal of duſt around him. His horſes are all matched to his mind; but as ſome of them are young and ſkittiſh, it is ſaid he has adopted the new contrivance lately exhibited by Sir Francis Delaval on Weſtminſter bridge: whenever they begin to ſnort and toſs up their heads, he touches the ſpring, throws them looſe, and away they go, leaving his lordſhip ſafe and ſnug, and as much at his eaſe as if he ſat on a woolpack."

The letter, of which this is an extract, was printed in the Public Advertiſer; and is ſaid to have contributed, in no ſmall degree, to leſſen the popularity of the illuſtrious ſtateſman againſt whom it was written. The miniſtry, indeed, which he had formed, conſiſted of very heterogeneous materials, and was not heartily approved of by the nation. It therefore ſoon fell in pieces by its own diſcord, and Lord Chatham retired in diſguſt.

The parliament being diſſolved in 1768, Burke was re-elected for Wendover, and took his ſeat, when the houſe met, in November. The duke of Grafton was now prime miniſter, and was oppoſed by two powerful parties in parliament; that of the marquis of Rockingham, and that of which Mr Grenville was conſidered as the leader. Theſe two parties, however, differed widely between themſelves. Mr Grenville had publiſhed a pamphlet, intitled, *The Preſent State of the Nation;* in which he very ably vindicated his own meaſures, and of courſe condemned the meaſures of thoſe who had ſucceeded him; and Burke replied to him, with greater eloquence, but perhaps with leſs of argument, in a tract, intitled, *Obſervations on the Preſent State of the Nation*, in which he makes a very high panegyric on his own patron, and the connections of the party, and animadverts with cutting ſeverity on their ſucceſſors in office.

About this period commenced the national frenzy which was excited by the expulſion of Wilkes from the houſe of commons, *for having printed and publiſhed a ſeditious libel, and three obſcene and impious libels.* In the controverſy to which this tranſaction gave riſe, Burke and Johnſon took oppoſite ſides. Johnſon, in his *Falſe Alarm*, contends, with great ability, that the expulſion of a member from the houſe of commons for the commiſſion of a crime, amounts to a diſqualification of that member from ſitting in the parliament from which he is expelled; whilſt Burke, though he diſapproved of the conduct of Wilkes as much as his friend, laboured to prove, that nothing but an act of the legiſlature can diſqualify any perſon from ſitting in parliament who is regularly choſen, by a majority of electors, to fill a vacant ſeat. It does not appear that this difference of opinion produced the ſmalleſt abatement of mutual regard between him and Johnſon. They both attended the weekly club, and were as much pleaſed with each other as formerly.

The proceedings of the Grafton adminiſtration, reſpecting Wilkes and other ſubjects, gave riſe to the celebrated *Letters of Junius.* That thoſe compoſitions were, in clearneſs, neatneſs, and preciſion of ſtyle, infinitely ſuperior to perhaps every other ſeries of newſpaper invectives, has never been controverted; and that they diſplay a vaſt extent of hiſtorical and political information, is known to all who are not themſelves ſtrangers to the hiſtory of this kingdom. Unclaimed by any author, and ſuperior to the productions of moſt authors, they have been given to Burke, to his brother Richard, a man likewiſe of very bright talents, to Mr Hamilton, and to Lord George Germaine. We ſhould hardly heſitate to adopt the opinion of thoſe who aſcribe them to Burke, had he not diſavowed them to his friend Johnſon. " I ſhould have believed Burke to be Junius (ſaid Johnſon), becauſe I know no man but Burke who is capable of writing theſe letters; but Burke *ſpontaneouſly* denied it to me. The caſe would have been different had I *aſked* him if he was the author. A man may think he has a right to deny when ſo queſtioned as to an anonymous publication." The difference between the ſtyle of theſe letters and that of Burke's acknowledged writings, would have had no weight with us; becauſe ſuch was his command of language, that he could aſſume, and occaſionally did aſſume, any ſtyle which he choſe to imitate. He had already ſo cloſely imitated the very different ſtyles of Lucas and Bolingbroke as to deceive the public; and what was to hinder him from imitating the ſtyle of Lord George Germaine, which certainly has a ſtrong reſemblance to that of Junius? We think, however, with Johnſon, that his *ſpontaneous diſavowal* of theſe letters ought to be held as ſufficient proof that he was not their author.

Burke had now gotten a very pleaſant villa near Beaconsfield in Buckinghamſhire; and being one of the freeholders of the county, he drew up a petition to the king, complaining of the conduct of the houſe of commons reſpecting the Middleſex election, and praying for a diſſolution of the parliament. The petition, though explicit and firm, was temperate and decorous, and as unlike to one on the ſame ſubject from the livery of London, as the principles of a moderate Whig are to thoſe of a turbulent democrate.

About

About this period he ſtated very clearly his own political principles in a pamphlet intitled, "Thoughts on the Cauſes of the Preſent Diſcontents;" and his plan for removing theſe diſcontents had not a grain of democracy in its compoſition. He propoſed to place the government in the hands of an open ariſtocracy of talents, virtue, property, and rank, combined together on avowed principles, and ſupported by the approbation and confidence of the people; and the ariſtocracy which he thought fitteſt for this great truſt, was a combination of thoſe Whig families which had moſt powerfully ſupported the revolution and conſequent eſtabliſhments. He expreſſed, in ſtrong terms, his diſapprobation of any change in the conſtitution and duration of parliament; and declared himſelf as averſe from an adminiſtration which ſhould have no other ſupport than popular favour, as from one brought forward merely by the influence of the court.

In this plan there is not that wiſdom or liberality which might have been expected from a man of Burke's cultivated mind and extenſive reading. The Whigs, when in power, had been as venal as the Tories; and the impriſonment of Lord Oxford, the baniſhment of Atterbury biſhop of Rocheſter, and the reſolution of the houſe of commons to ſit for ſeven years, when it had been choſen by its conſtituents for no more than three, were certainly greater violations of the conſtitution than the diſqualification of Wilkes, or any other meaſure that had been carried by the court during the adminiſtrations of Grenville and the duke of Grafton. Burke ſhewed himſelf in this publication to be indeed no republican; but every ſentence of it breathed the ſpirit of party.

Lord North was now prime miniſter; and in order to tranquillize America, he propoſed, in the beginning of his adminiſtration, to repeal the obnoxious laws of his predeceſſors in office, and to reſerve the duty on tea merely to maintain the authority of parliament. The conſequences of this conduct we have detailed elſewhere (ſee Britain, *Encycl.*); and they are too well known to all our readers. The part which Burke acted during his adminiſtration will not, in our opinion, admit of any plauſible defence. It was not indeed the part of a democrate, but of a man determined to oppoſe every meaſure of thoſe in power. In the beginning of the conteſt, he certainly diſplayed more wiſdom and patriotiſm than the miniſter; for, without entering directly into the queſtion, Whether the mother country had or had not a right to tax the colonies? he contented himſelf with warning the houſe againſt dangerous innovations. "The Americans (ſaid he) have been very ſerviceable to Britain under the old ſyſtem: do not, therefore, let us enter raſhly upon new meaſures. Our commercial intereſts have been hitherto greatly promoted by our friendly intercourſe with the colonies; do not let us endanger poſſeſſion for contingency; do not let us ſubſtitute untried theories for a ſyſtem experimentally aſcertained to be uſeful."

This was undoubtedly ſound reaſoning, and everyway becoming a lover of his country: but his continued oppoſition to government, after all Europe had leagued againſt Great Britain, was a conduct which will admit of no vindication, and for which the only poſſible apology muſt be found in that ardour of temper which made his friend Hamilton ſay, on another occaſion, "Whatever opinion Burke, from any motive, ſupports, ſo ductile is his imagination, that he ſoon conceives it to be right." In his moſt violent oppoſition, however, though his expreſſions were often extravagant and indecent, he never for a moment gave his ſupport to the metaphyſical doctrine of the *impreſcriptible rights of man*, or to the actual innovations which ſome meant to introduce on the baſis of that doctrine. His upright mind was indeed ſufficiently guarded againſt theſe novelties by what he had obſerved in France during the year 1772. Whilſt he remained in that country, his literary and political eminence made him courted by all the anti-monarchical and infidel philoſophers of the time; and in the religious ſcepticiſm and political theories of Voltaire, Helvetius, Rouſſeau, and D'Alembert, he ſaw, even at that period, the probable overthrow of religion and government. His ſentiments on this ſubject he took occaſion, immediately on his return, to communicate to the houſe of commons; and to point out the conſpiracy of atheiſm to the watchful policy of every government. He profeſſed that he was not over-fond of calling in the aid of the ſecular arm to ſuppreſs doctrines and opinions; but he recommended a grand alliance among all believers againſt thoſe miniſters of rebellious darkneſs, who were endeavouring to ſhake all the works of God eſtabliſhed in beauty and in order.

The American war proving unſucceſsful, though Great Britain never made a more glorious ſtand, Lord North and his friends retired from office; and, in February 1782, a new miniſtry was formed, at the head of which was placed the marquis of Rockingham; Lord Shelburne and Mr Fox were the ſecretaries of ſtate; and Mr Burke, who was appointed pay-maſter to the forces, exulted, rather childiſhly, in the houſe of commons, on the happineſs which was to accrue, both to the king and to the people, from the able and upright conduct of the new miniſters. The time in which the greater part of them continued in office was too ſhort to permit them to do either much good or much evil.

On the 1ſt of July the marquis of Rockingham died; and the earl of Shelburne being placed at the head of the treaſury, Fox and Burke reſigned in diſguſt, and, to the aſtoniſhment of the nation, formed the famous coalition with Lord North, whoſe meaſures they had ſo long, and ſo vehemently oppoſed. In the coalition of North and Burke there would have been nothing wonderful. In the intercourſe of private life, theſe two ſtateſmen had always met on terms of friendſhip and mutual regard; they had the ſame ideas of the excellence of the conſtitution, and the ſame averſion to innovation under the name of reform; even their ſtudies and amuſements were very ſimilar, being both men of taſte and claſſical learning; and though Burke oppoſed the taxation of America by the Britiſh parliament, his oppoſition proceeded rather from motives of prudence and expediency than from any ſettled conviction that the meaſure was unconſtitutional. But the political enmity of Fox and North had proceeded, not only to perſonal abuſe, but to profeſſions of mutual abhorrence; and perhaps there was hardly an unprejudiced perſon in the kingdom who entertained not ſuſpicions, that the unexpected union of ſuch enemies was cemented by a principle leſs pure than patriotiſm.

Mr Pitt was now chancellor of the exchequer; and when he announced to the houſe of commons the peace which was concluded in January 1783, he found the terms on which it had been made ſeverely condemned by North, Fox, Burke, and all their friends. The cenſure paſſed on it by Lord North and his followers was perfectly conſiſtent with their former conduct, and with the opinions which they had uniformly maintained; but it was with no good grace that Fox and Burke, who had offered an unconditional peace to the Dutch, and ſo frequently propoſed to recognize the independence of America, condemned the peace which had been concluded by Lord Shelburne. On this, as on many other occaſions, they acted, not as enlightened politicians, but as the rancorous leaders of a party.

In conſequence of a vote of cenſure paſſed by the commons, the miniſters reſigned their employments, and were ſucceeded by the duke of Portland, Lord North, Mr Fox, Mr Burke, and their friends. Burke had his former employment of paymaſter to the forces; Lord North and Mr Fox were ſecretaries of ſtate, and the duke of Portland was firſt lord of the treaſury. To many perſons this miniſtry had the appearance of greater ſtrength than any that had governed the kingdom ſince the time of Sir Robert Walpole; but its duration was not longer than that of the preceding. On the 18th of November, Mr Fox introduced his famous India-bill, into the merits of which it is foreign from our purpoſe to enter: ſuffice it to ſay, that after being ſtrongly ſupported by Burke, and ably oppoſed by Pitt and Dundas, it paſſed the houſe of commons by a very great majority; but was loſt in the houſe of peers, and viewed by the king in ſuch a light, that he determined on an entire change of adminiſtration.

Mr Pitt was now placed at the head of the treaſury, where he has remained ever ſince (1800), notwithſtanding the violent and powerful oppoſition which he met with at firſt from North and Fox and their coaleſced friends: the voice of the nation has been on his ſide; and that voice will always drown the bellowings of patriotiſm.

The principal events in which Burke ſignalized himſelf, ſince the year 1784, were the trial of Haſtings, the deliberations of the houſe on the propoſed regency during the lamented illneſs of the king, and the French revolution; and on each of theſe occaſions he diſplayed talents which aſtoniſhed the nation. He has, indeed, been ſeverely blamed for the pertinacity with which he proſecuted Mr Haſtings, and his conduct has been attributed to very unworthy motives; but of this there is neither proof nor probability. The temperament of his mind was ſuch, that, into whatever meaſure he entered, he entered with a degree of ardour of which cooler heads can hardly form a conception. Burke was but one member of a committee which found, or thought it found, evidences of the guilt of Haſtings; and, in forming his opinion, it is little likely that he ſhould have been biaſſed by intereſt or reſentment, whoſe delicate ſenſe of rectitude would not permit him to retain a penſion when he could no longer ſupport the party of that friend who had obtained it for him.

When the eſtabliſhment of a regency was thought neceſſary, he took the part, as it was called, of the Prince of Wales, in oppoſition to the plan propoſed by Lord Thurlow and the miniſter; and we doubt not but he was actuated by the pureſt principles: but the language which he uſed in the houſe was vehement, and ſome of his expreſſions were highly indecent. Our regard for his memory makes us wiſh to forget them.

Soon after the recovery of the king, the attention of Burke was attracted to the moſt momentous event of modern times;—an event which has convulſed all Europe, and of which, from the very firſt, his ſagacity foreſaw the conſequences. Many of his friends in Parliament, as well as numbers of wiſe and good men out of it, augured, from the meeting of the ſtates-general of France, great benefit to that nation, of which the government was conſidered as deſpotic and oppreſſive; and ſome were ſanguine enough to prognoſticate a new and happy order of things to all the nations connected with France, when its government ſhould become more free. Burke thought very differently: He was well acquainted with the genius of the French people, and with the principles of thoſe philoſophers, as they called themſelves, by whom a total revolution in church and ſtate had long been projected; and from the commencement of their career in the conſtituent aſſembly, when they eſtabliſhed, as the foundation of all legal government, the metaphyſical doctrine of *the rights of man*, he predicted that torrent of anarchy and irreligion which they have ſince attempted to pour over all Europe. Fox and ſome of the other leading men in oppoſition affected to conſider this as a vain fear; and a coolneſs took place between them and Burke, though they ſtill acted together in Parliament. At laſt, perceiving the French doctrines of liberty and equality, and atheiſm, ſpreading through this nation, not only among thoſe who had talents for ſuch diſquiſitions, but in clubs and ſocieties, of which the members could be no judges of metaphyſical reaſonings, he expreſſed his apprehenſion of the conſequences in the houſe of commons. This brought on a violent altercation between him and Fox, who was ſupported by Sheridan; and a rupture took place between theſe old friends which was never healed. He no more attended the meetings of the oppoſition members; and in 1790 he publiſhed his celebrated *Reflections on the French Revolution*.

By the friends of government this work was admired as the moſt ſeaſonable, as well as one of the ableſt, defences of the Britiſh conſtitution that ever was written; whilſt Fox and his friends, with the great body of Engliſh diſſenters, though they admitted it to be the offſpring of uncommon genius, affected to conſider it as declamatory rather than argumentative, and as inconſiſtent with the principles which its author had hitherto uniformly maintained. Many anſwers were written to it; of which the moſt conſpicuous were *Vindiciæ Gallicæ* by Mr Mac Intoſh, and *The Rights of Man* by Thomas Paine. To theſe Burke deigned not to make a direct reply. He vindicated his general principles, as well as ſome of his particular reaſonings, in *A Letter to a Member of the National Aſſembly*; and he very completely evinced the conſiſtency of his principles in his *Appeal from the New to the Old Whigs*.

Of this great work, for great it undoubtedly is, the merits as well as the demerits have been much exaggerated; and ſome have made it a queſtion, Whether it has on the whole been productive of good or harm? By the enemies of the author, it is repreſented as having given riſe to the ſpirit of diſcontent, by exciting ſuch writers as Paine and his adherents, who, but for the provocation given by *The Reflections*, might have remained in ſilence and obſcurity. This was from the firſt a very improbable ſuppoſition; for the ſpirit of democracy has at all times been reſtleſs: but ſince the appearance of Profeſſor Robiſon's *Proofs of a Conſpiracy*, and Barruel's *Hiſtory of Jacobiniſm*, it muſt be known to every reader to be a ſuppoſition contrary to fact. The conſpirators were buſy long before Burke wrote his *Reflections*; and the friends of order and religion are his debtors, for having ſo forcibly rouſed them from their ſlumber, and put them on their guard. With reſpect to compoſition, it is certainly neither ſo energetic nor ſo argumentative as the political tracts of Johnſon, to which ſome have affected to conſider it as ſuperior: but it is more poetical, gives ſcope for a greater diſplay of the knowledge of human nature; and, being written on a more intereſting ſubject, it has had a much greater number of readers than thoſe unrivalled pieces of political controverſy.

Burke being now aſſociated with Mr Pitt, continued to write from time to time memorials and remarks on the ſtate of France, and the alliance that was formed againſt the new order of things in that diſtracted country, of which ſome have been publiſhed ſince his death; and having reſolved to quit the buſtle of public life as ſoon as the trial of Mr Haſtings ſhould be concluded, he vacated his ſeat when that gentleman was acquitted, and retired to his villa at Beaconsfield, where, on the 2d of Auguſt 1794, he met with a heavy domeſtic loſs in the death of his only ſon. In the beginning of the ſame year he had loſt his brother Richard, whom he tenderly loved: but though this reiterated ſtroke of death deeply affected him, it never relaxed the vigour of his mind, nor leſſened the intereſt which he took in the public weal.

In this retreat, while he was labouring for the good of all around him, he was diſturbed by a very unprovoked attack upon his character by ſome diſtinguiſhed ſpeakers in the houſe of Peers. Soon after the death of his ſon the king was graciouſly pleaſed to beſtow a penſion on him and Mrs Burke; and this thoſe noble lords were pleaſed to repreſent as the reward of what they termed the change of his principles and the deſertion of his friends. The injuſtice of this charge muſt be obvious to every impartial mind, ſince the penſion was given after he had retired from parliament, and could not by his eloquence either ſupport the miniſtry or gall the oppoſition. He was not a man to ſubmit tamely to ſuch an inſult. He publiſhed a letter on the occaſion, addreſſed to a noble lord (Earl Fitzwilliam), in which he repels the attack on his character, and retaliates on thoſe by whom it was made, in terms of ſuch eloquent and keen ſarcaſm, as will be read with admiration as long as the language of the letter ſhall be underſtood.

Burke having employed every effort which benevolence and wiſdom could deviſe to ſtimulate civilized governments to unite in oppoſition to the impiety and anarchy of France, laboured likewiſe in private to relieve thoſe who had ſuffered exile and proſcription from the direful ſyſtem. Through his influence a ſchool was eſtabliſhed in his neighbourhood for the education of thoſe whoſe parents, for their adherence to principle, were rendered unable to afford to their children uſeful inſtruction; and that ſchool, which on his deathbed he recommended to Mr Pitt, continues to flouriſh under his powerful protection.

When the appearance of melioration in the principles and government of France induced our ſovereign to make overtures of peace to the French directory, Burke reſumed his pen; and in a ſeries of letters, intitled, *Thoughts on the Proſpect of a Regicide Peace*, diſplayed a force of genius which is certainly not ſurpaſſed, and perhaps not equalled, even in his far-famed *Reflections on the French Revolution*. This was his laſt work, and was conſidered by himſelf as in its nature teſtamentary.

From the beginning of June 1797 his health rapidly declined; but his underſtanding exerted itſelf with undiminiſhed force and uncontracted range; and his diſpoſitions retained all their amiable ſweetneſs. On the 7th of July, when the French revolution was mentioned, he ſpoke with pleaſure of the conſcious rectitude of his own intentions in what he had done and written reſpecting it; entreated thoſe about him to believe, that if any unguarded expreſſion of his on the ſubject had offended any of his former friends, no offence was by him intended; and he declared his unfeigned forgiveneſs of all who had on account of his writings, or for any other cauſe, endeavoured to do him an injury. On the day following he deſired to be carried to another room; and whilſt one of his friends, aſſiſted by ſome ſervants, was complying with his requeſt, Mr Burke faintly uttering, "God bleſs you," fell back and expired in the 68th year of his age.

From this detail, we truſt that our readers are already ſufficiently acquainted with his general character. In genius, variety of knowledge, and readineſs of expreſſion, Johnſon alone of all his contemporaries could be conſidered as his rival; and, like that great man, he took every opportunity, eſpecially during his laſt illneſs, to declare his unſhaken belief of the Chriſtian religion, his veneration for ſincere Chriſtians of all perſuaſions, and his own preference of the church of England. On the worſhip of that church he had indeed through the whole of his life been a regular and devout attendant; and the tears which the poor, in the neighbourhood of his villa, ſhed at his funeral, gave ſufficient evidence that his faith had been productive of charity. In his public conduct, the irritability of his temper, and the ardour of his imagination, ſometimes hurried him into the exceſſes of a mere party-man; but we believe that his great religious and political principles never varied. He has himſelf characteriſed his public conduct in the concluſion of his Reflections on the French Revolution, when he ſays, that "they come from one who has been no tool of power, no flatterer of greatneſs, and who in his laſt acts does not wiſh to belie the tenor of his life; from one who wiſhes to preſerve conſiſtency, but who would preſerve conſiſtency by varying his means to ſecure the unity of his end; and when the equipoiſe of the veſſel in which he ſails may be endangered by overloading it upon one ſide, is deſirous of carrying the ſmall weight of his reaſons to that which may preſerve the equipoiſe."

BURNET (James, Eſq;), better known by the title of *Lord Monboddo*, deſcended from an ancient family in the county of Mearns in Scotland. He was the eldeſt ſon of Arthur Burnet, Eſq; of Monboddo, where he was born in the year 1714. After paſſing through the uſual courſe of ſchool education, he proſecuted his ſtudies at the univerſities of Aberdeen, Edinburgh, and

Leyden, with diſtinguiſhed reputation. He was admitted an advocate in 1737; and on the 12th of February 1767, he was raiſed to the bench, by the title of Lord Monboddo, in the room of Lord Milton, appointed a judge the 4th of June 1742, and who had ſucceeded Sir John Lauder of Fountainhall, admitted November 1. 1689; ſo that he was only the third judge in ſucceſſion ſince the revolution.

Before his promotion to the bench, he had married Miſs Farquharſon, a very amiable woman, by whom he had a ſon and two daughters; whom, without regarding the difference of climate, he reared as the children of ancient Greece were reared.

From early youth Lord Monboddo's application to literary and juridical ſtudies was ſeverely diligent. Between claſſical literature and the law of Scotland, there exiſts a ſtrong connection, ariſing from the adoption of the forms and maxims of the civil law of the Romans, by the ancient legiſlators and judges of Scotland. Accordingly, while Mr Burnet roſe into reputation as a lawyer, he at the ſame time improved into profound erudition that knowledge of the Greek and Roman authors which he had acquired at ſchool and the univerſity; and his partiality to the Greek language could not fail to be ſtrengthened by his frequent converſations with Dr Blackwell, the celebrated profeſſor of that language in the Mariſchal College and Univerſity of Aberdeen.

His favourite ſtudies, however, were not ſuffered to interfere with his duty as a judge. In his native county, his integrity as *Sheriff* will be long remembered; and during the whole time that he was a Lord of Seſſion, he diſcharged the duties of his high office with an aſſiduity, a patience, a clear intelligence, and inflexible rectitude, which did honour to the court of which he was a judge. Like others, he was liable to error; but neither the awe of power, the blandiſhments of flattery, nor even compaſſion for diſtreſs, could turn Lord Monboddo aſide from what he believed to be the courſe of juſtice.

Several of the judges of the court of ſeſſion were at that period ambitious of ſhining among philoſophers and men of taſte; and Lord Kames's *Elements of Criticiſm* is a work which will be long read, and always admired. It was not, however, admired by Lord Monboddo; and he determined to vindicate the ſuperiority of the ancients over the moderns, as well in philoſophy as in belles lettres. With this view he publiſhed, in 1773, the firſt volume of his ORIGIN AND PROGRESS OF LANGUAGE; which was peruſed with mingled ſentiments of reſpect and indignation. It was better received in England than in his own country; and notwithſtanding the ridicule brought upon him by his belief in the exiſtence of *mermen*, and *men with tails*, the author felt himſelf ſufficiently encouraged to complete his plan in five volumes.

Having, as he thought, vindicated *Grecian literature*, he was induced to undertake another great work in defence of *Grecian philoſophy*, againſt the ſtill more arrogant claims, as he deemed them, of Bacon and Newton, with their followers. With this view, he publiſhed, at different times, and in ſix volumes 4to, a work intitled *Ancient Metaphyſics*, fraught, it muſt be confeſſed, with much erudition, much good ſenſe, and, ſtrange as the combination may ſeem, with much abſurdity. In the preface to the firſt volume, he declares open war againſt all modern writers of philoſophy, except Mr Harris, who was an adorer of the ancients like himſelf, Mr Baxter, and Dr Cudworth. He acknowledges Baxter's book on the Immateriality of the Soul to be a truly valuable work; and ſays of Cudworth's *Intellectual Syſtem*, that he agrees with it throughout. There is indeed ſuch a coincidence of notions in the *Intellectual Syſtem* and the *Ancient Metaphyſics*, that an ill-natured critic might be tempted to ſuſpect, that every thing valuable in the latter was borrowed from the former.

The Ancient Metaphyſics had few admirers in Scotland; but it procured for its author, from a ſcholar of Oxford, we think Mr Huntingford, the title of αλλος Αριστοτελης. His Lordſhip continued to cultivate what he called *Greek philoſophy*, and to attend his judicial duties, with indefatigable diligence till within a few days of his death, which happened at his houſe in Edinburgh, on the 26th of May 1799, at the advanced age of 85.

His private life was ſpent in the practice of all the ſocial virtues, and in the enjoyment of much domeſtic felicity. Although rigidly temperate in his habits of life, he, however, delighted much in the convivial ſociety of his friends; and among theſe he could number almoſt all the moſt eminent of thoſe who were diſtinguiſhed in Scotland for virtue, literature, or genuine elegance of converſation and manners. His ſon, a very promiſing boy, in whoſe education he took great delight, was ſnatched away from his affections by a premature death. But when it was too late for ſorrow and anxiety to avail, the afflicted father ſtifled the emotions of nature in his breaſt, and wound up the energies of his ſoul to the firmeſt tone of ſtoical fortitude. He was, in like manner, bereaved of his excellent lady, the object of his deareſt tenderneſs; and he endured the loſs with a ſimilar firmneſs, fitted to do honour either to philoſophy or to religion. In addition to his office as a judge in the court of ſeſſion, an offer was made to him of a ſeat in the court of juſticiary. But though the emoluments of the office would have made a convenient addition to his income, he refuſed to accept it, leſt its buſineſs ſhould too much detach him from the purſuit of his favourite ſtudies.

The vacations of the court of ſeſſion afforded him ſufficient leiſure to retire every year, in ſpring and in autumn, to the country; and he uſed then to dreſs in a ſtyle of ſimplicity, as if he had been only a plain farmer; and to live among the people upon his eſtate with all the kind familiarity and attention of an aged father among his grown-up children. Although the eſtate, from the old leaſes, did not afford an income of more three or four hundred pounds a-year, he would never raiſe the rents upon his old tenants, nor diſplace an old tenant, for the ſake of any augmentation of emolument offered by a richer or more enterpriſing ſtranger In imitation of the rural economy of ſome of the ancients, whom he chiefly admired, he accounted population the true wealth of an eſtate, and was deſirous of no other improvement of his lands, than that of having the number of perſons that ſhould reſide upon them, and be ſuſtained by their produce, ſuperior to that of the population of any equal portion of the lands of his neighbours.

It was at Monboddo that he had the pleaſure of receiving Dr Samuel Johnſon, with his friend James Boſwell, at the time when theſe two gentlemen were

upon

upon their well-known Tour through the Highlands of Scotland. Johnſon admired nothing in literature ſo much as the diſplay of a keen diſcrimination of human character, a juſt apprehenſion of the principles of moral action, and that vigorous common ſenſe which is the moſt happily applicable to the ordinary conduct of life. Monboddo delighted in the refinements, the ſubtleties, the abſtractions, the affectations, of literature; and, in compariſon with theſe, deſpiſed the groſſneſs of modern taſte and of common affairs. Johnſon thought learning and ſcience to be little valuable, except ſo far as they could be made ſubſervient to the purpoſes of living uſefully and happily with the world upon its own terms. Monboddo's favourite ſcience taught him to look down with contempt upon all ſublunary, and eſpecially upon all modern things; and to fit life to literature and philoſophy, not literature and philoſophy to life. James Boſwell, therefore, in carrying Johnſon to viſit Monboddo, probably thought of *pitting* them one againſt another, as two game cocks, and promiſed himſelf much ſport from the colloquial conteſt which he expected to enſue between them. But Monboddo was too hoſpitable and courteous to enter into keen contention with a ſtranger in his own houſe. There was much talk between them, but no angry controverſy, no exaſperation of that diſlike for each other's well-known peculiarities with which they had met. Johnſon, it is true, ſtill continued to think Lord Monboddo what he called *a prig* in literature; and Monboddo to cenſure Johnſon for allowing the moderns, in ſome things, to ſurpaſs the ancients.

Lord Monboddo uſed frequently to viſit London, to which he was allured by the opportunity that great metropolis affords of enjoying the converſation of a vaſt number of men of profound erudition. A journey to the capital became a favourite amuſement of his periods of vacation from the buſineſs of the court to which he belonged; and, for a time, he made this journey once a-year. A carriage, a vehicle that was not in common uſe among the ancients, he conſidered as an engine of effeminacy and ſloth, which it was diſgraceful for a man to make uſe of in travelling. To be dragged at the tail of a horſe, inſtead of mounting upon his back, ſeemed, in his eyes, to be a truly ludicrous degradation of the genuine dignity of human nature. In all his journeys, therefore, between Edinburgh and London, he was wont to ride on horſeback, with a ſingle ſervant attending him. He continued this practice, without finding it too fatiguing for his ſtrength, till he was upwards of eighty years of age. Within a few years of his death, on his return from a laſt viſit, which he made on purpoſe to take leave of all his old friends in London, he became exceedingly ill upon the road, and was unable to proceed; and had he not been overtaken by a Scotch friend, who prevailed upon him to travel the remainder of the way in a carriage, he might perhaps have actually periſhed by the way-ſide, or breathed his laſt in ſome dirty inn.

In London, his viſits were exceedingly acceptable to all his friends, whether of the literary or faſhionable world. He delighted to ſhew himſelf at court; and the king is ſaid to have taken a pleaſure in converſing with the old man with a diſtinguiſhing notice that could not but be very flattering to him. He uſed to mingle, with great ſatisfaction, with the learned and the ingenious, at the houſe of Mrs Montague. However, after the death of his friend Mr Harris, he found a very ſenſible diminution of the pleaſure he had been wont to enjoy in the ſociety of London.

A conſtitution of body, naturally framed to wear well and laſt long, was ſtrengthened to Lord Monboddo by exerciſe, guarded by temperance, and by a tenor of mind too firm to be deeply broken in upon by thoſe paſſions which conſume the principles of life. In the country he always uſed much the exerciſes of walking in the open air and of riding. The cold bath was a means of preſerving the health, to which he had recourſe in all ſeaſons, amid every ſeverity of the weather, and under every inconvenience of indiſpoſition or buſineſs, with a perſeverance invincible. He was accuſtomed, alike in winter and in ſummer, to riſe at a very early hour in the morning, and, without loſs of time, to betake himſelf to ſtudy or wholeſome exerciſe. It is ſaid that he even found the uſe of what he called the air bath, or the practice of occaſionally walking about, for ſome minutes, naked, in a room filled with freſh and cool air, to be highly ſalutary. In a word, if his peculiarities were ſtriking, his virtues, and learning, and talents, were equally ſtriking; and, taken altogether, he muſt be conſidered as a great and a good man.

BURNS (Robert), was a native of Airſhire, one of the weſtern counties of Scotland. He was the ſon of humble parents; and his father paſſed through life in the condition of a hired labourer, or of a ſmall farmer. Even in this ſituation, however, it was not hard for him to ſend his children to the pariſh-ſchool, to receive the ordinary inſtruction in reading, writing, arithmetic, and the principles of religion. By this courſe of education young Robert profited to a degree that might have encouraged his friends to deſtine him to one of the liberal profeſſions, had not his father's poverty made it neceſſary to remove him from ſchool, as ſoon as he had grown up, to earn for himſelf the means of ſupport as a hired ploughboy or ſhepherd.

The expence of education in the pariſh-ſchools of Scotland is ſo ſmall, that hardly any parents who are able to labour want the means of giving to their children at leaſt ſuch education as young Burns received. From the ſpring labours of a ploughboy, from the ſummer employment of a ſhepherd, the peaſant-youth often returns for a few months, eagerly to purſue his education at the pariſh-ſchool.

It was ſo with Burns: he returned from labour to learning, and from learning went again to labour, till his mind began to open to the charms of taſte and knowledge; till he began to feel a paſſion for books, and for the ſubjects of books, which was to give a colour to the whole thread of his future life. On nature he ſoon began to gaze with new diſcernment and with new enthuſiaſm: his mind's eye opened to perceive affecting beauty and ſublimity, where, by the mere groſs peaſant, there was nought to be ſeen but water, earth, and ſky—but animals, plants, and ſoil.

What might perhaps firſt contribute to diſpoſe his mind to poetical efforts, is one particular in the devotional piety of the Scottiſh peaſantry; it is ſtill common for them to make their children get by heart the Pſalms of David, in that verſion of homely rhymes which is uſed in their churches. In the morning and in the evening of every day, or at leaſt on the evening of every Saturday and Sunday, theſe Pſalms are ſung in ſolemn family-devotion, a chapter of the Bible is read, and extemporary prayer is fervently uttered. The whole books of the Sacred Scriptures are thus continually in the hands of almoſt every peaſant. And it is impoſſible that there ſhould not be occaſionally ſome ſouls among them, awakened to the divine emotions of genius by that rich aſſemblage which thoſe books preſent, of almoſt all that is intereſting in incidents, or pictureſque in imagery, or affectingly ſublime or tender in ſentiments and character. It is impoſſible that thoſe rude rhymes, and the ſimple artleſs muſic with which they are accompanied, ſhould not occaſionally excite ſome ear to a fond perception of the melody of verſe. That Burns had felt theſe impulſes, will appear undeniably certain to whoever ſhall carefully peruſe his *Cottar's Saturday's Night;* or ſhall remark, with nice obſervation, the various fragments of Scripture ſentiment, of Scripture imagery, of Scripture language, which are ſcattered throughout his works.

Still more intereſting to the young peaſantry are thoſe ancient ballads of love and war, of which a great number are, in the ſouth of Scotland, yet popularly known, and often ſung by the ruſtic maid or matron at her ſpinning-wheel. They are liſtened to with raviſhed ears by old and young. Their rude melody; that mingled curioſity and awe which are naturally excited by the very idea of their antiquity; the exquiſitely tender and natural complaints ſometimes poured forth in them; the gallant deeds of knightly heroiſm, which they ſometimes celebrate; their wild tales of demons, ghoſts, and fairies, in whoſe exiſtence ſuperſtition alone has believed; the manners which they repreſent; the obſolete, yet pictureſque and expreſſive, language in which they are often clothed—give them wonderful power to tranſport every imagination, and to agitate every heart. To the ſoul of Burns they were like a happy breeze touching the wires of an Æolian harp, and calling forth the moſt raviſhing melody.

Beſide all this, the Gentle Shepherd, and the other poems of Allan Ramſay, have long been highly popular in Scotland. They fell early into the hands of Burns; and while the fond applauſe which they received drew his emulation, they preſented to him likewiſe treaſures of phraſeology and models of verſification. He got acquainted at the ſame time with the poetry of Robert Ferguſon, written chiefly in the Scottiſh dialect, and exhibiting many ſpecimens of uncommon poetical excellence. The Seaſons of Thomſon too, the Grave of Blair, the far-famed Elegy of Gray, the Paradiſe Loſt of Milton, perhaps the Minſtrel of Beattie, were ſo commonly read, even among thoſe with whom Burns would naturally aſſociate, that poetical curioſity, although even leſs ardent than his, could in ſuch circumſtances have little difficulty in procuring them.

With ſuch means to give his imagination a poetical bias, and to favour the culture of his taſte and genius, Burns gradually became a poet. He was not, however, one of thoſe forward children who, from a miſtaken impulſe, begin prematurely to write and to rhyme, and hence never attain to excellence. Converſing familiarly for a long while with the works of thoſe poets who were known to him; contemplating the aſpect of nature in a diſtrict which exhibits an uncommon aſſemblage of the beautiful and the ruggedly grand, of the cultivated and the wild; looking upon human life with an eye quick and keen, to remark as well the ſtronger and leading, as the nicer and ſubordinate, features of character; to diſcriminate the generous, the honourable, the manly, in conduct, from the ridiculous, the baſe, and the mean—he was diſtinguiſhed among his fellows for extraordinary intelligence, good ſenſe, and penetration, long before others, or perhaps even himſelf, ſuſpected him to be capable of writing verſes. His mind was mature, and well ſtored with ſuch knowledge as lay within his ſearch: he had made himſelf maſter of powers of language, ſuperior to thoſe of almoſt any former writer in the Scottiſh dialect, before he conceived the idea of ſurpaſſing Ramſay and Ferguſon.

Hitherto he had converſed intimately only with peaſants on his own level; but having got admiſſion into the fraternity of free maſons, he had the fortune, whether good or bad, to attract in the lodges the notice of gentlemen better qualified than his more youthful companions to call forth the powers of his mind, and to ſhow him that he was indeed a poet. A maſonic ſong, a ſatirical epigram, a rhyming epiſtle to a friend, attempted with ſucceſs, taught him to know his own powers, and gave him confidence to try taſks more arduous, and which ſhould command ſtill higher burſts of applauſe.

The annual celebration of the ſacrament of the Lord's Supper, in the rural pariſhes of Scotland, has much in it of thoſe old popiſh feſtivals, in which ſuperſtition, traffic, and amuſement, uſed to be ſtrangely intermingled. Burns ſaw, and ſeized in it one of the happieſt of all ſubjects, to afford ſcope for the diſplay of that ſtrong and piercing ſagacity by which he could almoſt intuitively diſtinguiſh the reaſonable from the abſurd, and the becoming from the ridiculous; of that pictureſque power of fancy, which enabled him to repreſent ſcenes, and perſons, and groupes, and looks, attitude, and geſtures, in a manner almoſt as lively and impreſſive, even in words, as if all the artifices and energies of the pencil had been employed; of that knowledge which he had neceſſarily acquired of the manners, paſſions, and prejudices of the ruſtics around him, of whatever was ridiculous, no leſs than of whatever was affectingly beautiful in rural life.

A thouſand prejudices of Popiſh, and perhaps too of ruder Pagan ſuperſtition, have from time immemorial been connected in the minds of the Scottiſh peaſantry, with the annual recurrence of the Eve of the Feſtival of all the Saints or Halloween. Theſe were all intimately known to Burns, and had made a powerful impreſſion upon his imagination and feelings. He choſe them for the ſubject of a poem, and produced a piece which is almoſt to frenzy the delight of thoſe who are beſt acquainted with its ſubject; and which will not fail to preſerve the memory of the prejudices and uſages which it deſcribes, when they ſhall perhaps have ceaſed to give one merry evening in the year to the cottage fireſide.

The ſimple joys, the honeſt love, the ſincere friendſhip, the ardent devotion of the cottage; whatever in the more ſolemn part of the ruſtic's life is humble and artleſs, without being mean or unſeemly—or tender and dignified, without aſpiring to ſtilted grandeur—or to unnatural, buſkined pathos, had deeply impreſſed the imagination of the riſing poet; had, in ſome ſort, wrought itſelf into the very texture of the fibres of his ſoul. He tried to expreſs in verſe what he moſt tenderly felt, what he moſt enthuſiaſtically imagined; and produced the *Cottar's Saturday Night*.

Theſe pieces, the true effuſions of genius, informed by reading and obſervation, and prompted by its own native ardour, as well as by friendly applauſe, were ſoon handed about among the moſt diſcerning of Burns's acquaintance; and were by every new reader peruſed, and reperuſed, with an eagerneſs of delight and approbation which would not ſuffer their author long to withhold them from the preſs. A ſubſcription was propoſed, was earneſtly promoted by ſome gentlemen, who were glad to intereſt themſelves in behalf of ſuch ſignal poetical merit; was ſoon crowded with the names of a conſiderable number of the inhabitants of Airſhire, who in the proffered purchaſe ſought not leſs to gratify their own paſſion for Scottiſh poeſy, than to encourage the wonderful ploughman. At Kilmarnock were the poems of Burns for the firſt time printed. The whole edition was quickly diſtributed over the country.

It is hardly poſſible to expreſs with what eager admiration and delight they were everywhere received.— They eminently poſſeſſed all thoſe qualities which the moſt invariably contribute to render any literary work quickly and permanently popular. They were written in a phraſeology, of which all the powers were univerſally felt; and which being at once antique, familiar, and now rarely written, was hence fitted to ſerve all the dignified and pictureſque uſes of poetry, without making it unintelligible. The imagery, the ſentiments, were at once faithfully natural, and irreſiſtibly impreſſive and intereſting. Thoſe topics of ſatire and ſcandal in which the ruſtic delights; that humorous imitation of character, and that witty aſſociation of ideas familiar and ſtriking, yet not naturally allied to one another, which has force to ſhake his ſides with laughter; thoſe fancies of ſuperſtition, at which he ſtill wonders and trembles; thoſe affecting ſentiments and images of true religion, which are at once dear and awful to his heart —were all repreſented by Burns with all a poet's magic power. Old and young, high and low, grave and gay, learned or ignorant, all were alike delighted, agitated, tranſported.

In the mean time, ſome few copies of theſe faſcinating poems found their way to Edinburgh; and having been read to Dr Blacklock, they obtained his warmeſt approbation. In the beginning of the winter 1786-7 Burns went to Edinburgh, where he was received by Dr Blacklock with the moſt flattering kindneſs, and introduced to every man of generoſity and taſte among that good man's friends. Multitudes now vied with each other in patronizing the ruſtic poet. Thoſe who poſſeſſed at once true taſte and ardent philanthropy were ſoon earneſtly united in his praiſe: they who were diſpoſed to favour any good thing belonging to Scotland, purely becauſe it was Scottiſh, gladly joined the cry; thoſe who had hearts and underſtanding to be charmed, without knowing why, when they ſaw their native cuſtoms, manners, and language, made the ſubjects and the materials of poeſy, could not ſuppreſs that voice of feeling which ſtruggled to declare itſelf for Burns: for the diſſipated, the licentious, the malignant wits, and the freethinkers, he was ſo unfortunate as to have ſatire, and obſcenity, and ridicule of things ſacred, ſufficient to captivate their fancies; even for the pious he had paſſages in which the inſpired language of devotion might ſeem to come mended from his pen.

Thus did Burns, ere he had been many weeks in Edinburgh, find himſelf the object of univerſal curioſity, favour, admiration, and fondneſs. He was ſought after, courted with attentions the moſt reſpectful and aſſiduous, feaſted, flattered, careſſed, treated by all ranks as the firſt boaſt of his country, whom it was ſcarcely poſſible to honour and reward to a degree equal to his merits. In compariſon with the general favour which now promiſed to more than crown his moſt ſanguine hopes, it could hardly be called praiſe at all which he had obtained in Airſhire.

In this poſture of our poet's affairs a new edition of his poems was earneſtly called for. He ſold the copyright for one hundred pounds; but his friends at the ſame time ſuggeſted, and actively promoted, a ſubſcription for an edition, to be publiſhed for the benefit of the author, ere the bookſeller's right ſhould commence. Thoſe gentlemen who had formerly entertained the public of Edinburgh with the periodical publication of the papers of the *Mirror*, having again combined their talents in producing the *Lounger*, were at this time about to conclude this laſt ſeries of papers; yet before the Lounger relinquiſhed his pen, he dedicated a number to a commendatory criticiſm of the poems of the Airſhire bard.

The ſubſcription-papers were rapidly filled; and it was ſuppoſed that the poet might derive from the ſubſcription and the ſale of his copy-right a clear profit of at leaſt 700 pounds.

The converſation of even the moſt eminent authors is often found to be ſo unequal to the fame of their writings, that he who reads with admiration can liſten with none but ſentiments of the moſt profound contempt. But the converſation of Burns was, in compariſon with the formal and exterior circumſtances of his education, perhaps even more wonderful than his poetry. He affected no ſoft air or graceful motions of politeneſs, which might have ill accorded with the ruſtic plainneſs of his native manners. Conſcious ſuperiority of mind taught him to aſſociate with the great, the learned, and the gay, without being overawed into any ſuch baſhfulneſs as might have made him confuſed in thought, or heſitating in elocution. He poſſeſſed withal an extraordinary ſhare of plain common ſenſe or mother-wit, which prevented him from obtruding upon perſons, of whatever rank with whom he was admitted to converſe, any of thoſe effuſions of vanity, envy, or ſelf-conceit, in which authors are exceedingly apt to indulge, who have lived remote from the general practice of life, and whoſe minds have been almoſt excluſively confined to contemplate their own ſtudies and their own works. In converſation he diſplayed a ſort of intuitive quickneſs and rectitude of judgment upon every ſubject that aroſe. The ſenſibility of his heart, and the vivacity of his fancy, gave a rich colouring to whatever reaſoning he was diſpoſed to advance; and his language in converſation was not at all leſs happy than in his writings. For theſe reaſons, thoſe who had met and converſed with him once, were pleaſed to meet and to converſe with him again and again.

For ſome time he converſed only with the virtuous, the learned, and the wiſe; and the purity of his morals remained uncontaminated. But, alas! he fell, as others have fallen in ſimilar circumſtances. He ſuffered himſelf to be ſurrounded by a race of miſerable beings, who were proud to tell that they had been in company with Burns, and had ſeen Burns as looſe and as fooliſh as themſelves. He was not yet irrecoverably loſt to temperance and moderation; but he was already almoſt too much captivated with their wanton revels, to be ever more won back to a faithful attachment to their more ſober charms. He now alſo began to contract ſomething of new arrogance in converſation. Accuſtomed to be among his favourite aſſociates what is vulgarly but expreſſively called *the cock of the company*, he could ſcarcely refrain from indulging in ſimilar freedom and dictatorial deciſion of talk, even in the preſence of perſons who could leſs patiently endure his preſumption.

The ſubſcription-edition of his poems, in the mean time, appeared; and although not enlarged beyond that which came from the Kilmarnock preſs by any new pieces of eminent merit, did not fail to give entire ſatisfaction to the ſubſcribers. He was now to cloſe accounts with his bookſeller and his printer, to retire to the country with his profits in his pocket, and to fix upon a plan for his future life. He talked loudly of independence of ſpirit and ſimplicity of manners, and boaſted his reſolution to return to the plough; yet ſtill he lingered in Edinburgh, week after week, and month after month, perhaps expecting that one or other of his noble patrons might procure him ſome permanent and competent annual income, which ſhould ſet him above all neceſſity of future exertions to earn for himſelf the means of ſubſiſtence; perhaps unconſciouſly reluctant to quit the pleaſures of that voluptuous town-life to which he had for ſome time too willingly accuſtomed himſelf. An accidental diſlocation or fracture of an arm or a leg confining him for ſome weeks to his apartment, left him during this time leiſure for ſerious reflection; and he determined to retire from the town without longer delay. None of all his patrons interpoſed to divert him from his purpoſe of returning to the plough, by the offer of any ſmall penſion, or any ſinecure place of moderate emolument, ſuch as might have given him competence without withdrawing him from his poetical ſtudies. It ſeemed to be forgotten that a ploughman thus exalted into a man of letters was unfitted for his former toils, without being regularly qualified to enter the career of any new profeſſion; and that it became incumbent upon thoſe patrons who had called him from the plough, not merely to make him their companion in the hour of riot, not ſimply to fill his purſe with gold for a few tranſient expences, but to ſecure him as far as was poſſible from being ever overwhelmed in diſtreſs in conſequence of the favour which they had ſhown him, and of the habits of life into which they had ſeduced him. Perhaps indeed the ſame deluſion of fancy betrayed both Burns and his patrons into the miſtaken idea, that, after all which had paſſed, it was ſtill poſſible for him to return in cheerful content to the homely joys and ſimple toils of undiſſipated rural life.

In this temper of Burns's mind, in this ſtate of his fortune, a farm and the exciſe were the objects upon which his choice ultimately fixed for future employment and ſupport. By the ſurgeon who attended him during his illneſs, he was recommended with effect to the commiſſioners of exciſe; and Patrick Millar, Eſq. of Dalſwinton, deceived, like Burns himſelf and Burns's other friends, into an idea that the poet and exciſeman might yet be reſpectable and happy as a farmer, generouſly propoſed to eſtabliſh him in a farm, upon conditions of leaſe which prudence and induſtry might eaſily render exceedingly advantageous. Burns eagerly accepted the offers of this benevolent patron. Two of the poet's friends from Airſhire were invited to ſurvey that farm in Dumfriesſhire which Mr Millar offered. A leaſe was granted to the poetical farmer at that annual rent which his own friends declared that the due cultivation of his farm might eaſily enable him to pay. What yet remained of the profits of his publication was laid out in the purchaſe of farm-ſtock; and Mr Millar might, for ſome ſhort time, pleaſe himſelf with the perſuaſion that he had approved himſelf the liberal patron of genius; had acquired a good tenant upon his eſtate; and had placed a deſerving man in the very ſituation in which alone he himſelf deſired to be placed, in order to be happy to his wiſhes.

Burns, with his Jane, whom he now married, took up their reſidence upon his farm. The neighbouring farmers and gentlemen, pleaſed to obtain for an inmate among them the poet by whoſe works they had been delighted, kindly ſought his company, and invited him to their houſes. He found an inexpreſſible charm in ſitting down beſide his wife, at his own fireſide; in wandering over his own grounds; in once more putting his hand to the ſpade and the plough; in forming his encloſures, and managing his cattle. For ſome months he felt almoſt all that felicity which fancy had taught him to expect in his new ſituation. He had been for a time idle; but his muſcles were not yet unbraced for rural toil. He now ſeemed to find a joy in being the huſband of the miſtreſs of his affections, in ſeeing himſelf the father of her children, ſuch as might promiſe to attach him for ever to that modeſt, humble, and domeſtic life, in which alone he could hope to be permanently happy. Even his engagements in the ſervice of the exciſe did not, at the very firſt, threaten neceſſarily to debaſe him by aſſociation with the mean, the groſs, and the profligate, to contaminate the poet, or to ruin the farmer.

But it could not be: it was not poſſible for Burns now to aſſume that ſoberneſs of fancy and paſſions, that ſedateneſs of feeling, thoſe habits of earneſt attention to groſs and vulgar cares, without which ſucceſs in his new ſituation was not to be expected. A thouſand difficulties were to be encountered and overcome, much money was to be expended, much weary toil was to be exerciſed, before his farm could be brought into a ſtate of cultivation in which its produce might enrich the occupier. This was not a proſpect encouraging to a man who had never loved labour, and who was at this time certainly not at all diſpoſed to enter into agriculture with the enthuſiaſm of a projector. The buſineſs of the exciſe too, as he began to be more and more employed in it, diſtracted his mind from the care of his farm, led him into groſs and vulgar ſociety, and expoſed him to many unavoidable temptations to drunken exceſs, ſuch as he had no longer ſufficient fortitude to reſiſt. Amidſt the anxieties, diſtractions, and ſeducements which thus aroſe to him, home became inſenſibly leſs and leſs plea-

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ſing; even the endearments of his Jane's affection began to loſe their hold on his heart; he became every day leſs and leſs unwilling to forget in riot thoſe gathering ſorrows which he knew not to ſubdue.

Mr Millar and ſome others of his friends would gladly have exerted an influence over his mind which might have preſerved him in this ſituation of his affairs, equally from deſpondency and from diſſipation; but Burns's temper ſpurned all controul from his ſuperiors in fortune. He reſented, as an arrogant encroachment upon his independence, that tenor of conduct by which Mr Millar wiſhed to turn him from diſſolute conviviality, to that ſteady attention to the buſineſs of his farm, without which it was impoſſible to thrive in it. His croſſes and diſappointments drove him every day more and more into diſſipation; and this diſſipation tended to enhance whatever was diſagreeable and perplexing in the ſtate of his affairs. He ſunk, by degrees, into the boon companion of mere exciſemen; and almoſt every drunken fellow, who was willing to ſpend his money laviſhly in the alehouſe, could eaſily command the company of Burns. The care of his farm was thus neglected; waſte and loſſes wholly conſumed his little capital; he reſigned his leaſe into the hands of his landlord; and retired, with his family, to the town of Dumfries, determining to depend entirely for the means of future ſupport upon his income as an exciſe-officer.

Yet during this unfortunate period of his life, which paſſed between his departure from Edinburgh to ſettle in Dumfriesſhire, and his leaving the country, in order to take up his reſidence in the town of Dumfries, the energy and activity of his intellectual powers appeared to have been not at all impaired. In a collection of Scottiſh ſongs, which were publiſhed (the words with the muſic) by Mr Johnſon, engraver in Edinburgh, in 4 vols 8vo, Burns, in many inſtances, accommodated new verſes to the old tunes with admirable felicity and ſkill. He aſſiſted in the temporary inſtitution of a ſmall ſubſcription library, for the uſe of a number of the well-diſpoſed peaſants in his neighbourhood. He readily aided, and by his knowledge of genuine Scottiſh phraſeology and manners greatly enlightened, the antiquarian reſearches of the late ingenious Captain Groſe. He ſtill carried on an epiſtolary correſpondence, ſometimes gay, ſportive, humorous, but always enlivened by bright flaſhes of genius, with a number of his old friends, and on a very wide diverſity of topics. At times, as it ſhould ſeem from his writings of this period, he reflected, with inexpreſſible heart-bitterneſs, on the high hopes from which he had fallen; on the errors of moral conduct into which he had been hurried by the ardour of his ſoul, and in ſome meaſure by the very generoſity of his nature; on the diſgrace and wretchedneſs into which he ſaw himſelf rapidly ſinking; on the ſorrow with which his miſconduct oppreſſed the heart of his Jane; on the want and deſtitute miſery in which it ſeemed probable that he muſt leave her and their infants; nor amidſt theſe agonizing reflections did he fail to look, with an indignation half invidious, half contemptuous, on thoſe who, with moral habits not more excellent than his, with powers of intellect far inferior, yet baſked in the ſun-ſhine of fortune, and were loaded with the wealth and honours of the world, while his follies could not obtain pardon, nor his wants an honourable ſupply. His wit became from this time more gloomily ſarcaſtic; and his converſation and writings began to aſſume ſomething of a tone of miſanthropical malignity, by which they had not been before, in any eminent degree, diſtinguiſhed. But with all theſe failings, he was ſtill that exalted mind which had raiſed itſelf above the depreſſion of its original condition: with all the energy of the lion, pawing to ſet free his hinder limbs from the yet encumbering earth, he ſtill appeared *not leſs than archangel ruined!*

His morals were not mended by his removal from the country. In Dumfries his diſſipation became ſtill more deeply habitual; he was here more expoſed than in the country to be ſolicited to ſhare the riot of the diſſolute and the idle: fooliſh young men flocked eagerly about him, and from time to time preſſed him to drink with them, that they might enjoy his wicked wit. The Caledonian Club, too, and the Dumfriesſhire and Galloway Hunt, had occaſional meetings in Dumfries after Burns went to reſide there, and the poet was of courſe invited to ſhare their conviviality, and heſitated not to accept the invitation.

In the intervals between his different fits of intemperance, he ſuffered ſtill the keeneſt anguiſh of remorſe, and horribly afflictive foreſight. His Jane ſtill behaved with a degree of maternal and conjugal tenderneſs and prudence, which made him feel more bitterly the evil of his miſconduct, although they could not reclaim him. At laſt crippled, emaciated, having the very power of animation waſted by diſeaſe, quite broken-hearted by the ſenſe of his errors, and of the hopeleſs miſeries in which he ſaw himſelf and his family depreſſed; with his ſoul ſtill tremblingly alive to the ſenſe of ſhame, and to the love of virtue; yet even in the laſt feebleneſs, and amid the laſt agonies of expiring life, yielding readily to any temptation that offered the ſemblance of intemperate enjoyment, he died at Dumfries, in the ſummer of 1796, while he was yet three or four years under the age of forty, furniſhing a melancholy proof of the danger of *ſuddenly* elevating even the greateſt mind above its original level.

After his death, it quickly appeared that his failings had not effaced from the minds of his more reſpectable acquaintance either the regard which had once been won by his ſocial qualities, or the reverence due to his intellectual talents. The circumſtances of want in which he left his family were noticed by the gentlemen of Dumfries with earneſt commiſeration. His funeral was celebrated by the care of his friends with a decent ſolemnity, and with a numerous attendance of mourners, ſufficiently honourable to his memory. Several copies of verſes were inſerted in different newſpapers upon the occaſion of his death. A contribution, by ſubſcription, was propoſed, for the purpoſe of raiſing a ſmall fund, for the decent ſupport of his widow, and the education of his infant children.

From the preceding detail of the particulars of this poet's life, the reader will naturally and juſtly infer him to have been an honeſt, proud, warm-hearted man; of high paſſions and ſound underſtanding, and a vigorous and excurſive imagination. He was never known to deſcend to any act of deliberate meanneſs. In Dumfries he retained many reſpectable friends even to the laſt; and it may be doubted whether any poet of the preſent age has exerciſed a greater power over the minds of his readers. Burns has not failed to command one remarkable ſort of homage, ſuch as is never paid but to great original genius; a crowd of poetaſters ſtarted up to imitate him, by writing verſes as he had done in the Scottiſh dialect; but, *O imitatores! ſervum pecus!* To write rugged rhimes, in antiquated phraſe, is not to imitate the poetry of Burns.

BURRAMPOOTER. See SANDPU, *Encycl.*

BUTTER is a ſubſtance ſo well known, that it is needleſs to give here any definition of it; but as it is, in this country at leaſt, ſo general an article of food, that the proper methods of making and curing it have engaged the attention of ſome of our ableſt writers on agriculture, in addition to what has been ſaid on theſe ſubjects under the titles BUTTER and DAIRY (*Encycl.*) our readers will probably be pleaſed with the following method of curing it, which is practiſed by ſome farmers in the pariſh of Udney, in the county of Aberdeen, and gives to their butter a great ſuperiority above that of their neighbours.

Take two parts of the beſt common ſalt, one part of ſugar, and one part of ſaltpetre; beat them up together, and blend the whole completely. Take one ounce of this compoſition for every 16 ounces of butter, work it well into the maſs, and cloſe it up for uſe.

Dr James Anderſon, from whoſe View of the Agriculture of the County of Aberdeen this receipt is taken, ſays, that he knows of no ſimple improvement in economies greater than this is, when compared with the uſual mode of curing butter by means of common ſalt alone. "I have ſeen (continues he) the experiment fairly made, of one part of the butter made at one time being thus cured, and the other part cured with ſalt alone: the difference was inconceivable. I ſhould ſuppoſe that, in any open market, the one would ſell for 30 *per cent.* more than the other. The butter cured with the mixture appears of a rich marrowy conſiſtence and fine colour, and never acquires a brittle hardneſs nor taſtes ſalt; the other is comparatively hard and brittle, approaching more nearly to the appearance of tallow, and is much ſalter to the taſte. I have ate butter cured with the above compoſition that had been kept three years, and it was as ſweet as at firſt; but it muſt be noted, that butter thus cured requires to ſtand three weeks or a month before it is begun to be uſed. If it be ſooner opened, the ſalts are not ſufficiently blended with it; and ſometimes the coolneſs of the nitre will then be perceived, which totally diſappears afterwards."

The following obſervations reſpecting the proper method of keeping both milk and butter are by the ſame author, and we truſt may prove uſeful. Speaking ſtill of the county of Aberdeen, he ſays, "The pernicious practice of keeping milk in leaden veſſels, and ſalting butter in ſtone jars, begins to gain ground among ſome of the fine ladies in this county, as well as elſewhere, from an idea of cleanlineſs. The fact is, it is juſt the reverſe of cleanlineſs; for in the hands of a careful perſon nothing can be more cleanly than wooden diſhes, but under the management of a ſlattern they diſcover the ſecret which ſtone diſhes indeed do not.

"In return, theſe latter communicate to the butter and the milk, which has been kept in them, a poiſonous quality, which inevitably proves deſtructive to the human conſtitution. To the prevalence of this practice I have no doubt we muſt attribute the frequency of palſies, which begin to prevail ſo much in this kingdom; for the well known effect of the poiſon of lead is bodily debility, palſy—death!"

BYSAK, the firſt month of the Bengal year, beginning in April.

C.

CAFFRES, the inhabitants of Caffraria, are generally confounded with the Hottentots; but, according to M. Vaillant, there is a conſiderable difference between the manners, cuſtoms, and even appearance of theſe two nations.

The Caffres, ſays he, are generally taller than the Hottentots, more robuſt, more fierce, and much bolder. Their figure is likewiſe more agreeable, and their countenances have not that narrowneſs at the bottom, nor their cheeks thoſe prominences, which are ſo diſagreeable among the Hottentots. A round figure, a noſe not too flat, a broad forehead, and large eyes, give them an open and lively air; and if prejudice can overlook the colour of the ſkin, there are ſome Caffre women who, even in Europe, would be accounted pretty. Theſe people do not make their faces ridiculous, by pulling out their eye-brows like the Hottentots; they tattoo themſelves much, and particularly their bodies; their hair, which is frizzled very much, is never greaſed, but their bodies are liberally anointed, merely with a view to preſerve their vigour and agility.

The men generally beſtow more attention on their dreſs than the women, and are remarkably fond of beads and copper rings. The women wear hardly any of the ornaments in which the other ſavages in Africa take ſuch delight. They do not even wear copper bracelets; but their ſmall aprons, which are ſtill ſhorter than thoſe of the Hottentots, are bordered with a few rows of glaſs beads; and in this all their luxury conſiſts. It would appear that the Caffres are not ſo chaſte as the Hottentots, becauſe the men do not uſe a jackal to vail what nature teaches other men, even ſavages, to conceal. A ſmall cowl, which covers only the glans, inſtead of diſplaying modeſty, ſeems to announce the greateſt indecency. This ſmall covering adheres to a thong, which is faſtened round their girdles, merely that

that it may not be loſt; for a Caffre, if he be not afraid of being hurt or ſtung by inſects, cares very little whether his cowl be in its place or not. Our author ſaw one Caffre who, inſtead of a cowl, wore a caſe made of wood, and ornamented with ſculpture. This was a new and ridiculous faſhion, which he had borrowed from a nation of black people who lived at a great diſtance from Caffraria.

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

The Caffre huts are more ſpacious and higher than thoſe of the Hottentots, and have alſo a more regular form. The frames of them are conſtructed of wooden work, well put together, and very ſolid, being intended to laſt for a long time: for the Caffres, applying to agriculture, which the free Hottentots do not, remain fixed to one ſpot, unleſs ſomething unexpected interrupt their repoſe.

A more perceptible induſtry, an acquaintance with ſome of the moſt neceſſary arts of life, a little knowledge of agriculture, and a few religious dogmas, ſeem to announce that the Caffres approach much nearer to civilization than the Hottentots. They entertain a tolerably exalted idea of the Supreme Being and his power; they believe that the good will be rewarded, and the wicked puniſhed, in a future ſtate; but they have no notion of creation, which indeed was not admitted by the ſages of Greece and Rome. They practiſe circumciſion, but can give no account of its origin among them, or of the purpoſe for which the practice is continued.

Polygamy is uſed among the Caffres; and on the death of a father the male children and their mothers ſhare the ſucceſſion among them. The girls remain with their mothers without property of any kind until they can procure huſbands. One very ſingular cuſtom of the Caffres is, that they do not, in general, inter their dead, but tranſport them from the kraal to an open ditch, which is common to the whole horde. At this ditch ſavage animals feed at their leiſure on the multitude of carcaſes which are heaped together. Funeral honours are due only to kings and the chiefs of each horde, whoſe bodies are covered with a heap of ſtones collected into the form of a dome.

This nation is governed by a general, chief, or king, whoſe power is very limited. He appoints, however, the ſubordinate chiefs over the different hordes, and through them communicates his directions or orders. The arms of the Caffre are a *club*, two feet and a half in length, and where thickeſt three inches in diameter, and a plain lance or *aſſagey*. He deſpiſes poiſoned arrows, which are ſo much uſed by ſome of the neighbouring nations; and with his two ſimple weapons ſeeks always to meet his enemy face to face in the field. The Hottentot, on the contrary, concealed under a rock or behind a buſh, deals out deſtruction, without being expoſed to danger. The one is a perfidious tyger, which ruſhes treacherouſly on his prey; the other is a generous lion, which, having given warning of his approach, makes his attack boldly, and periſhes if he prevail not againſt his antagoniſt.

CALCULUS, in mathematics, denotes a certain way of performing inveſtigations and reſolutions, which occur on many occaſions, particularly in mechanical philoſophy. Thus we ſay, the *antecedental* calculus, the *algebraical* calculus, the *arithmetical* calculus, the *differential* calculus, the *exponential* calculus, the *fluxional* calculus, and the *integral* calculus. Of by much the greater part of theſe calculi ſome account has been given in the Encyclopædia Britannica; but there is one of them, of which no notice has been taken in that work. It is,

The Antecedental CALCULUS, a geometrical method of reaſoning, without any conſideration of motion or velocity, applicable to every purpoſe to which the much celebrated doctrine of fluxions of the illuſtrious Newton has been, or can be, applied. This method was invented by James Glenie, Eſq; "in which (he ſays) every expreſſion is truly and ſtrictly geometrical, is founded on principles frequently made uſe of by the ancient geometers, principles admitted into the very firſt elements of geometry, and repeatedly uſed by EUCLID himſelf. As it is a branch of general geometrical proportion, or univerſal compariſon, and is derived from an examination of the antecedents of ratios, having given conſequents and a given ſtandard of compariſon in the various degrees of augmentation and diminution they undergo by compoſition and decompoſition, I have called it the antecedental calculus. As it is purely geometrical, and perfectly ſcientific, I have, ſince it firſt occurred to me in 1779, always made uſe of it inſtead of the fluxionary and differential calculi, which are merely arithmetical. Its principles are totally unconnected with the ideas of motion and time, which, ſtrictly ſpeaking, are foreign to pure geometry and abſtract ſcience, though, in mixed mathematics and natural philoſophy, they are equally applicable to every inveſtigation, involving the conſideration of either with the two numerical methods juſt mentioned. And as many ſuch inveſtigations require compoſitions and decompoſitions of ratios, extending greatly beyond the triplicate and ſubtriplicate, this calculus in all of them furniſhes every expreſſion in a ſtrictly geometrical form. The ſtandards of compariſon in it may be any magnitudes whatever, and are of courſe indefinite and innumerable; and the conſequents of the ratios, compounded or decompounded, may be either equal or unequal, homogeneous or heterogeneous. In the fluxionary and differential methods, on the other hand, 1, or unit, is not only the ſtandard of compariſon, but alſo the conſequent of every ratio compounded or decompounded."

This method is deduced immediately from Mr Glenie's Treatiſe on the Doctrine of Univerſal Compariſon or General Proportion: And as the limits of the preſent work will not allow us to enter upon this ſubject, we therefore refer our readers to the two above mentioned treatiſes, and to the fourth volume of the Tranſactions of the Royal Society of Edinburgh.

We confeſs, however, that we do not expect ſuch great advantage from the employment of this calculus as the very acute and ingenious author ſeems to promiſe from it. The mathematical world is truly indebted to him for the clear and diſcriminating view that he has taken of the doctrine of univerſal compariſon, and we believe it to be perfectly accurate, and in ſome reſpects new. Notwithſtanding the continual occupation of mathematicians with ratios and analogies, their particular objects commonly reſtricted their manner of conceiving ratio to ſome preſent modification of it. Hence it ſeems to have happened that their conceptions of it as a magnitude have not been uniform. But Mr Glenie, by avoiding every peculiarity, has at once attributed to it all the meaſurable affections of magnitude, addition or ſubtraction, multiplication or diviſion, and ratio or proportion. He is perhaps the firſt who has roundly conſidered ratio or proportion as an affection of ratio; and it is chiefly by the employment of this undoubted affection of ratio that he has rendered the geometrical analyſis ſo comprehenſive.

But when we view this antecedental calculus, not as a method of expreſſing mathematical ſcience, but as an art, as a calculus in ſhort, and conſider the means which it muſt employ, and the notation which muſt be uſed, we become leſs ſanguine in our hopes of advantage from it. The notation cannot (we think) be more ſimple than that of the fluxionary method, juſtly called *arithmetical;* and if we inſiſt on carrying clear conceptions along with us, we imagine that the arithmetical expoſition of our ſymbols will generally be the ſimpler of the two. The *ſcience* of the antecedental calculus ſeems to conſiſt in the attainable perception of all the ſimple ratios, whether of *magnitudes* or *ratios*, or both, which concur to the formation of a compound and complicated ratio. Now this is equally, and more eaſily attainable in the fluxionary or other arithmetical method, when the conſequent is a ſimple magnitude. When it is not, the ſame proceſs is farther neceſſary in both methods, for getting rid of its complication.

We apprehend that it is a miſtake that the geometrical method is more abſtracted than the fluxionary, becauſe the latter ſuperadds to the notion of extenſion the notions of time and motion. Theſe notions were introduced by the illuſtrious inventor *for the demonſtration*, but never occupy the thoughts *in the uſe* of his propoſitions. Theſe are *geometrical* truths, no matter how demonſtrated; and when duly conſidered, involve nothing that is omitted in the antecedental calculus. We even preſume to ſay, that the complication of thought, in the contemplation of the ratios of ratios, is greater than what will generally ariſe from the additional elements, time and motion.

We do not find that any of our moſt active mathematicians have availed themſelves of the advantages of this calculus, nor do we know any ſpecimen that has been exhibited of its eminent advantages in mathematical diſcuſſions. Should it prove more fertile in geometrical expreſſions of highly compounded or complicated quantities or relations, we ſhould think it a mighty acquiſition; being fully convinced that theſe afford to the memory or imagination an object (we may call it a ſenſible picture) which it can contemplate and remember with incomparably greater clearneſs and ſteadineſs than any algebraical formula. We need only appeal to the geometrical expreſſions of many fluents, which are to be ſeen in Newton's lunar theory, in the phyſical tracts of Dr Matthew Stewart, and others who have ſhewn a partiality for this method.

It would be very preſumptuous, however, for us to ſay, that the accurate geometer and metaphyſician may not derive great advantages from proſecuting the very ingenious and recondite ſpeculations of Mr Glenie, in his doctrine of univerſal compariſon.

CALENDAR, in chronology. See *(Encycl.)* KALENDAR; and REVOLUTION, n° 184.

CALIPPIC PERIOD, in chronology, a period of 76 years, continually recurring; at every repetition of which, it was ſuppoſed by its inventor Calippus, an Athenian aſtronomer, that the mean and new full moons would always return to the ſame day and hour.

About a century before, the golden number, or cycle of 19 years, had been invented by Meton; which Calippus finding to contain 19 of Nabonaſſar's year, 4 days, and $\frac{3}{4}\frac{3}{5}\frac{1}{9}$, to avoid fractions he quadrupled it, and ſo produced his period of 76 years, or 4 times 19; after which he ſuppoſed all the lunations, &c. would regularly return to the ſame hour. But neither is this exact, as it brings them too late by a whole day in 225 years.

CALLAO, as it is called by its inhabitants, but more generally known to Europeans under the name of CAMPELLO, is a ſmall iſland, which was viſited by ſome of Lord Macartney's ſuite on their voyage to China. In conſequence of that viſit, we have the following deſcription of it in Sir George Staunton's Account of the Embaſſy.

"It lies oppoſite to, and about eight miles to the eaſtward of, the mouth of a conſiderable river on the coaſt of Cochin-china, on the banks of which is ſituated the town of Fai-foo, a place of ſome note, not far from the harbour of Turon. The bearing of the higheſt peak of Callao from this harbour is about ſouth-eaſt, diſtance thirty miles. The extreme points of the iſland lie in latitude 15° 53′, and 15° 57′ north; the greateſt length is from north-weſt to ſouth-eaſt, and is ſomewhat about five miles, and the mean breadth two miles. The only inhabited part is on the ſouth-weſt coaſt, on a ſlip of ground riſing gently to the eaſt, and contained between the bottom of a ſemilunar bay and the mountains on each ſide of it. Thoſe mountains, at a diſtance, appear as if they formed two diſtinct iſlands. The ſouthern mountain is the higheſt, and is about 1500 feet. The lower grounds contain about 200 acres. This ſmall but enchanting ſpot is beautifully diverſified with neat houſes, temples, clumps of trees, ſmall hillocks ſwelling from the plain, and richly decorated with ſhrubbery and trees of various kinds; among which the elegant areca, riſing like a Corinthian column, is eminently conſpicuous. A rill of clear water, oozing from the mountains, is contrived to be carried along the upper ridges of the vale, from whence it is occaſionally conveyed through ſluices, for the purpoſe of watering the rice grounds, and appeared, though then in the dry ſeaſon, fully ſufficient for every purpoſe for which it could be wanted.

"The houſes, in general, were clean and decent; a few were built with ſtone, and covered with tiles. One, probably the manſion of the chief perſon of the iſland, was encloſed by a ſtone wall, and the appoach to it was through a gateway between two ſtone pillars. The houſe was divided into a number of apartments, of which the arrangement did not ſeem to want either taſte or convenience. This building ſtood at the head of the principal village, which conſiſted of about thirty habitations

habitations built of wood, chiefly the bamboo. Behind the village, and on the ſide of the hill, was a cave, acceſſible only by one way, through an irregular range of rocks. Within the cave, but near its mouth, was a ſmall temple, commanding a view of the whole vale. Several other temples were diſperſed over the plain, all of which were open in front, with a colonnade before them of round wooden pillars, painted red and varniſhed. The number of houſes on the iſland ſcarcely exceeded ſixty. Behind every houſe, not immediately in the principal village, were encloſures of ſugar-canes, tobacco, and other vegetables, growing in great luxuriance. The mountains were covered with verdure, and ſeemed well calculated for rearing goats, of which the iſland produced a few.

“ Beſide the principal bay, there were ſeveral ſandy inlets, with ſmall patches of level ground behind them. Boats might eaſily land in any of theſe inlets ; but a communication between them by land appeared to be exceedingly difficult, if not entirely prevented, by the ſteep and rugged ridges which ſeparated them from each other. On this account very ſlight works, and an eſtabliſhment of a few men only, would be requiſite for the defence of the iſland, a great part of its coaſt being impregnably fortified by nature. The depth of water in the bay and road was ſufficient for ſhips of any burden, and there was perfect ſhelter from every wind except the ſouth-weſt, to which quarter it was directly open. The ſhort diſtance, however, from the continent in that direction would always prevent the ſea from riſing high, though it might not be ſufficiently near to break the force of the wind.”

The inhabitants of this iſland are ſo exceedingly ſhy and afraid of ſtrangers, that upon the approach of the Engliſh veſſel, they all, except a very few, retired on board their galleys. When the Britiſh landed, therefore, they found the doors of all the houſes open, with ſeveral domeſtic animals feeding before them, but neither man, woman, nor child within. After ſome time, however, a perſon was perceived lurking among the neighbouring trees, who, finding he was obſerved, came forward with reluctance and evident marks of fear. While he was yet at ſome diſtance, he fell upon his knees, and touched the ground with his forehead ſeveral times. On approaching to him, it was noticed that the firſt joint of every one of his fingers and toes was wanting, and as if twiſted off by violence : it was poſſible that he might have thus been treated by way of puniſhment for ſome crime, and that he was conſidered as the fitteſt perſon to be expoſed to the ſuppoſed danger of watching the movements of the ſtrangers coming aſhore. In a little time ſome others, hidden in the thickets, finding that no miſchief was ſuffered by the firſt, ventured out. None of them could underſtand the Chineſe interpreter ; and not being able to read or write, there was no converſing with them by the medium of the Chineſe characters. Recourſe was had to hieroglyphics, and rude figures were drawn of the articles which were propoſed to be purchaſed ; and this method ſucceeded tolerably well ; poultry and fruits were brought for ſale, for which high prices were given, purpoſely to conciliate the good will of thoſe iſlanders. The few that were found grew ſoon familiar ; and one old man preſſingly invited the ſtrangers to his houſe, ſituated upon an eminence, at a little diſtance. On arriving there, he introduced them to his wife, an old woman, who, after recovering from her aſtoniſhment at the ſight of figures ſo different from thoſe ſhe had ever been accuſtomed to behold, laid, in a neat manner, before them ſome fruits, ſugar, cakes, and water. On departing from the houſe, this decent and hoſpitable couple made ſigns to teſtify their deſire of ſeeing them again.”

The poſſeſſion of this iſland would be of ſuch importance to any European nation who wiſhed to trade ſecurely with Tung-quin and Cochin-china, that it is ſaid the French had formerly ſome thoughts of purchaſing it. Sir George Staunton, however, is of opinion, that the want of ſhelter in the ſouth-weſt monſoon would render it of little value, without a further ſettlement near it upon the main land of Cochin-china : and he thinks, that if a ſolid eſtabliſhment there could be productive of advantage to any European nation, it would neceſſarily be ſo to Great Britain ; becauſe, beſide the opening which it would make for the ſale of Britiſh manufactures among the people of the country, the Britiſh poſſeſſions in Hindoſtan would be ſure of a very conſiderable demand for their productions.

CAMEL, in navigation, is a machine which has been deſcribed with ſufficient accuracy in the Encyclopædia ; but the following account of its invention, given by Profeſſor Beckmann, is perhaps not unworthy of a place in this Supplement.

“ In the Zuyder-Zee, oppoſite to the mouth of the river Y, about ſix miles from the city of Amſterdam, there are two ſand banks, between which is a paſſage called the *Pampus*, which is ſufficiently deep for ſmall ſhips, but not for ſuch as are large or heavy laden. In 1672 the Dutch contrived, however, to carry their numerous fleet through this paſſage, by means of large empty cheſts faſtened to the bottom of each ſhip ; and this contrivance gave riſe to the invention of the *camel*.” In the Encyclopædia Britannica its invention is given to the famous De Wit ; in the German Cyclopædia to Meyer a Dutch engineer of very conſiderable eminence ; but the Dutch writers, almoſt unanimouſly, aſcribe the invention of the camel to a citizen of Amſterdam, who calls himſelf Meeuves Meindertſoon Bakker. “ Some make the year of the invention to have been 1688, and others 1690. Much has been ſaid of the utility of this invention ; but however beneficial it may be, we have reaſon to ſuppoſe that ſuch heavy veſſels as ſhips of war cannot be raiſed up, in ſo violent a manner, without ſuſtaining injury. A ſure proof of this is the well known circumſtance mentioned by Muſchenbroek *(Introductio ad Philoſoph. Natur.)*, that the ports of a ſhip which had been raiſed by the camel could not afterwards be ſhut cloſely.”

CAMELEON, one of the conſtellations of the ſouthern hemiſphere, near the ſouth pole, and inviſible in our latitude. There are 10 ſtars marked in this conſtellation in Sharp's catalogue.

CAMELOPARDALUS, a new conſtellation of the northern hemiſphere, formed by Hevelius, conſiſting of 32 ſtars, firſt obſerved by him. It is ſituated between Cepheus, Caſſiopeia, Perſeus, the Two Bears, and Draco ; and it contains 58 ſtars in the Britiſh catalogue.

CAMELLIA, in botany (ſee *Encycl.*), is a plant which the Chineſe call *Cha-wha*, or flower of tea, on account of the reſemblance of the one to the other, and becauſe

becauſe its petals are ſometimes mixed among the teas to increaſe their fragrance. Sir George Staunton, who calls it *Camellia Seſanqua*, ſaw it flouriſhing on the ſides and very high tops of mountains, where the ſoil conſiſted of little more than fragments of ſtone, crumbled into a ſort of coarſe earth by the joint action of the ſun and rain. It yields, he ſays, a nut, from which is expreſſed an eſculent oil, equal to the beſt which comes from Florence. On this account, it is cultivated in vaſt abundance; and is particularly valuable from the facility of its culture in ſituations fit for little elſe.

CAMPBELL (George, D. D.), ſo juſtly admired for his metaphyſical acuteneſs and various erudition, was, in 1719, born at Aberdeen, where his father, the reverend Colin Campbell, was one of the miniſters of the eſtabliſhed church. He was educated in his native city; and, after paſſing through the uſual courſe of academical learning, he ſtudied divinity under the Rev. J. Chalmers, profeſſor of divinity in Mariſchal College.—He was, in 1749, an unſucceſsful candidate for the church of Fordown, though his competitor Mr Forbes was a man of very ſlender abilities, and ſuppoſed to be attached to the conſtitution and liturgy of the church of England. It might indeed be that attachment which contributed principally to procure him the living in preference to Mr Campbell.

The living of Fordown is in the gift of the crown; and it has generally been a rule with his majeſty's miniſters, to give ſuch livings, when they become vacant, to thoſe candidates who are favoured by the majority of land-owners in the pariſh. At the era of 1749, the land-owners in ſome of the northern and middle counties of Scotland were more generally attached to the conſtitution of the church of England than to that of their own eſtabliſhment; and ſuch was certainly the caſe in the pariſh of Fordown.

But whatever was the cauſe of Mr Campbell's failure, he failed by a very ſmall number, and was not long without an eſtabliſhment. In 1750, he was preſented, by Sir Thomas Burnet of Leys, to the living of Banchary Ternan, on the Dee, about twenty miles weſt from Aberdeen. From this he was tranſlated, or, as the Scotch eccleſiaſtical phraſe is, *tranſported* to Aberdeen in 1756, and nominated one of the city miniſters, in the room of Mr John Biſſet deceaſed, a puritan of the old ſchool, whoſe ſtrictneſs and peculiarities are yet remembered by many in that place.

In 1759, on the deceaſe of principal Pollock, he was choſen principal of the Mariſchal college, and ſucceeded to the divinity chair in 1771, on Dr Alexander Gerard being tranſlated to the profeſſorſhip of divinity in King's college. Before his ſettling in Aberdeen, he married Miſs Grace Farquharſon, daughter of Mr Farquharſon of Whitehouſe, by whom he had no iſſue. This amiable woman died about a year before him. They were an eminent pattern of conjugal affection.

From this time he enjoyed a remarkable ſhare of good health and ſpirits. He had, all his life, a rooted averſion to medicine. He got the better of every ailment by a total and rigorous abſtinence from all kind of ſuſtenance whatever; and it was not till he was attacked by an alarming illneſs, about two years before his death, that he was perſuaded by his friends to call in medical aid. What nature could do, ſhe had all along performed well; but her day was over, and ſomething of art became neceſſary. Then, for the firſt time, he owned the utility of medical men, and declared his recantation of the very mean opinion he had formerly entertained of them and their art. A few months before his death, he reſigned his offices of principal, profeſſor of divinity, and one of the city miniſters, and was in all ſucceeded by Dr W. L. Brown, late of Utrecht, a man of diſtinguiſhed abilities. Dr Campbell retained all his faculties entire to the laſt, and died on the 6th of April 1796, in the 77th year of his age. His character has been ſo juſtly drawn by his ſucceſſor, that we ſhall give it to our readers in his words, adding only a circumſtance or two, which we have reaſon to think will contribute to endear his memory to every liberal and enlightened mind.

“Dr Campbell, as a public teacher, was long admired for the clearneſs and copiouſneſs with which he illuſtrated the great doctrines and precepts of religion, and the ſtrength and energy with which he enforced them. Intimately perſuaded of the truth and infinite conſequence of what relevation teaches, he was ſtrongly deſirous of carrying the ſame conviction to the minds of his hearers, and delivered his diſcourſes with that zeal which flows from ſtrong impreſſions, and that power of perſuaſion which is the reſult of ſincerity of heart, combined with clearneſs of underſtanding. He was ſatisfied, that the more the pure dictates of the goſpel were ſtudied, the more they would approve themſelves to the mind, and bring forth, in the affections and conduct, all the peaceable fruits of righteouſneſs. The unadulterated dictates of Chriſtianity, he was, therefore, only ſtudious to recommend and inculcate, and knew perfectly to diſcriminate them from the inventions and traditions of men. His chief ſtudy ever was, to direct belief to the great objects of practice; and, without theſe, he viewed the moſt orthodox profeſſion as “a ſounding braſs, and a tinkling cymbal.” But, beſides the character of a preacher of righteouſneſs, he had alſo that of a teacher of the ſcience of divinity to ſuſtain. How admirably he diſcharged this duty, and with what effect he conveyed the ſoundeſt and moſt profitable inſtruction to the minds of his ſcholars, let thoſe declare who are now in various congregations of this country, communicating to their fellow Chriſtians the fruits of their ſtudies under ſo able and judicious a teacher. Diſcarding all attachment to human ſyſtems, merely conſidered as ſuch, he tied his faith to the Word of God alone, poſſeſſed the happieſt talent in inveſtigating its meaning, and communicated to his hearers the reſult of his own inquiries, with a preciſion and perſpicuity which brought light out of obſcurity, and rendered clear and ſimple what appeared intricate and perplexed. He expoſed, without reſerve, the corruptions which ignorance, craft, and hypocriſy, had introduced into religion, and applied his talent for ridicule to the beſt of all purpoſes, to hold up to contempt the abſurdities with which the pureſt and ſublimeſt truths had been loaded.

“Placed at the head of a public ſeminary of learning, he felt all the importance of ſuch a ſituation, and uniformly directed his influence to public utility. His enlarged and enlightened mind juſtly appreciated the extenſive conſequence of the education of youth. He anticipated all the effects reſulting to the great community of mankind, from numbers of young men iſſuing, in regular ſucceſſion, from the univerſity over which he preſided, and occupying the different departments of ſocial life.

“ His benevolent heart delighted to repreſent to itſelf the ſtudents under his direction uſefully and honourably diſcharging the reſpective duties of their different profeſſions; and ſome of them, perhaps, filling the moſt diſtinguiſhed ſtations of civil ſociety. With theſe proſpects before him, he conſtantly directed his public conduct to their attainment. He never ſuffered his judgment to be warped by prejudice or partiality, or his heart to be ſeduced by paſſion or private intereſt. Thoſe mean and ignoble motives by which many are actuated in the diſcharge of important truſts, approached not his mind. A certain honourable pride, if pride it may be called, diffuſed an uniform dignity over the whole of his behaviour. He felt the man degraded by the perverſion of public character. His underſtanding alſo clearly ſhewed him even perſonal advantage attached to ſuch principles and practice, as he adopted from a ſenſe of obligation, and thoſe elevated conceptions of real worth which were ſo congenial to his ſoul. He ſaw, he experienced, eſteem, reſpect, and influence, following in the train of integrity and beneficence; but contempt, diſgrace, averſion, and complete inſignificance, cloſely linked to corruption and ſelfiſhneſs. Little minds are ſeduced and overpowered by ſelfiſh-conſiderations, becauſe they have not the capacity to look beyond the preſent advantage, and to extend to the miſery that ſtands on the other ſide of it. The ſame circumſtance that betrays the perverſity of their hearts, alſo evinces the weakneſs of their judgments.

“ His reputation as a writer is as extenſive as the preſent intercourſe of letters; not confined to his own country, but ſpread through every civilized nation. In his literary purſuits, he aimed not, as is very often the caſe, with men of diſtinguiſhed literary abilities, merely at eſtabliſhing his own celebrity, or increaſing his fortune; but had chiefly at heart the defence of the great cauſe of Religion, or the elucidation of her dictates.

“ At an early period he entered the liſts as a champion for Chriſtianity againſt one of its acuteſt opponents. He not only triumphantly refuted his arguments, but even conciliated his reſpect by the handſome and dexterous manner in which his defence was conducted. While he refuted the infidel, he ſpared the man, and exhibited the uncommon ſpectacle of a polemical writer poſſeſſing all the moderation of a Chriſtian. But while he defended Chriſtianity againſt its enemies, he was deſirous of contributing his endeavours to increaſe, among its profeſſors, the knowledge of the ſacred writings. Accordingly, in the latter part of his life, he favoured the world with a work, the fruit of copious erudition, of unwearied application, for almoſt thirty years, and of a clear and comprehenſive judgment. We have only to regret, that the other writings of the New Teſtament have not been elucidated by the ſame pen that tranſlated the Goſpels. Nor were his literary merits confined to theology, and the ſtudies more immediately connected with it. Philoſophy, and the fine arts, are alſo indebted to his genius and labours; and in him the polite ſcholar was eminently joined to the deep and liberal divine.

“ Political principles will always be much affected by general character. This was alſo the caſe with Dr Campbell. In politics, he maintained that moderation which is the ſureſt criterion of truth and rectitude, and was equally diſtant from thoſe extremes into which men are ſo apt to run on great political queſtions. He cheriſhed that patriotiſm which conſiſts in wiſhing, and endeavouring to promote the greateſt happineſs of his country, and is always ſubordinate to univerſal benevolence. Firmly attached to the Britiſh conſtitution, he was animated with that genuine love of liberty which it inſpires and invigorates. He was equally averſe to deſpotiſm and to popular anarchy; the two evils into which political parties are ſo frequently hurried, to the deſtruction of all that is valuable in government. Party-ſpirit, of whatever deſcription, he conſidered as having an unhappy tendency to pervert, to the moſt pernicious purpoſes, the beſt principles of the human mind, and to clothe the moſt iniquitous actions with the moſt ſpecious appearances. Although tenacious of thoſe ſentiments, whether in religion or politics, which he was convinced to be rational and juſt, he never ſuffered mere difference of opinion to impair his good-will, to obſtruct his good offices, or to cloud the cheerfulneſs of converſation. His own converſation was enlivened by a vein of the moſt agreable pleaſantry.”

So far was he from being influenced by jealouſy, or any portion of that corporation-ſpirit which ſometimes incites men of undoubted abilities to detract from the merit of every writer who fills not a ſtation as conſpicuous as their own, that he was loud in his praiſes of thoſe, whom men of meaner minds would have looked upon with diſguſt, as upon preſumptuous rivals. This generoſity was fully experienced by the writer of the article MIRACLE, in the Encyclopædia Britannica, who, though he had preſumed to treat the ſubject differently from Dr Campbell, received from him ſuch a teſtimony of approbation of what he had done, as he will hardly look for from any other man in ſimilar circumſtances.

Among his other qualities, which ſo much endeared him to all who had the honour of his acquaintance, Dr Campbell poſſeſſed an uncommon facility of paſſing from the graveſt to the moſt airy ſubjects, and from the livelieſt to the graveſt, without degrading the one or diminiſhing the pleaſure of the other. The infirmities of age abated not the cheerfulneſs of his temper, nor did even the perſuaſion of approaching diſſolution impair his ſerenity.

We cannot conclude this ſhort ſketch better than with a liſt of his works, in the order in which they were publiſhed. In 1752, he publiſhed a Sermon, preached before the Synod of Aberdeen.

1761. A Diſſertation on Miracles, againſt Mr Hume. This treatiſe is well known to the learned world. He obtained, and deſervedly obtained, a very high reputation, not only from the able manner in which he handled the ſubject, but from the liberal ſtyle in which he addreſſed his antagoniſt. It was ſpeedily tranſlated into French, German, and Dutch.

1771. A Sermon before the Society for Propagating Chriſtian Knowledge, Edinburgh.

——— ——— before the Synod of Aberdeen.

1776. The Philoſophy of Rhetoric, 2 vols 8vo. A work which diſcovers a clearneſs of diſcernment, and accuracy of obſervation, which juſtly entitled him to be ranked among the moſt judicious critics. He entered on this inquiry as early as 1750, when a part of the work was compoſed. The laws of elegant compoſition and criticiſm are laid down with great perſpicuity: but the moſt valuable part of the work is undoubtedly the *theory of evidence*, to which we know nothing ſuperior, perhaps nothing equal, on the ſubject, in our own or any other language. His philoſophy, in general, is the philoſophy of Dr Reid; and where he differs from that acute reaſoner reſpecting *abſtraction*, and ſome other objects of metaphyſical diſquiſition, we think it impoſſible to refuſe him the pre-eminence in every thing but ſtyle.

1777. A Sermon on the King's Faſt-day, on Allegiance, firſt printed in 4to, and afterwards, at the expence of government, ſix thouſand copies were printed in 12mo, enlarged with notes, and ſent to America, when the unhappy ſtruggle had, however, put on appearances which prevented the effect hoped for from this ſermon.

1780. An Addreſs to the People of Scotland on the Alarms which have been raiſed by what is called the Popiſh Bill. This is a powerful diſſuaſive from bigotry, and every ſpecies of religious perſecution.

1793. His *Magnum Opus*. The tranſlation of the Goſpels, with Preliminary Diſſertations, 2 vols 4to.

1800. Lectures on Eccleſiaſtical Hiſtory, a poſthumous work, in 2 vols 8vo; which, in the opinion of moſt people, ſhould have been ſuppreſſed.

CAMPHOR, or CAMPHIRE, (ſee *Encycl.*), is, in China, obtained by boiling the branches, twigs, and leaves, of the *Laurus-Camphora* in water, upon the ſurface of which it is found ſwimming in the form of an oil, or adhering, in a glutinous form, to a wooden rod, with which the boiling matter is conſtantly ſtirred. The glutinous maſs is then mixed with clay and lime, and put into an earthen veſſel, with another of the ſame ſize properly luted over it; the lower veſſel being placed over a ſlow fire, the camphor gradually ſublimes through the clay and lime, and adheres to the ſides of the upper veſſel, forming a cake of a ſhape correſponding to the cavity which received it. It is, however, leſs pure and much weaker than what is diſcovered in a ſolid ſtate among the fibres of the trunk, as turpentine is found in different ſorts of pines. In the great, but ill-peopled, iſland of Borneo, and alſo in Japan, the camphor tree is felled for the ſole purpoſe of finding this coſtly drug in ſubſtance among the ſplinters of the trunk, in the ſame manner as other trees are felled in Louiſiana merely for collecting the fruit they bear upon their ſummits. The Borneo, or Japan camphor, is pure, and ſo very ſtrong, as readily to communicate much of its odour and its virtues to other inſpiſſated oils, which thus paſs for real camphor; and this adulterated drug is ſold by Chineſe artiſts at a vaſtly lower price than they gave themſelves for the genuine ſubſtance from Borneo or Japan.

Sir George Staunton, from whom we have this account, does not inform us whether the camphor-tree of China, if felled and torn into ſplinters, would not produce as large quantities of the drug, and equally pure, as the trees of Borneo and Japan; but he aſſures us, that in China it is never ſo torn, being there a large and valuable timber-tree. "It is uſed (ſays he) in the beſt buildings of every kind, as well as for maſts of veſſels, and bears too high a price to allow of any part, except the branches, being cut up for the ſake of the drug."

CANALS OF COMMUNICATION may be of ſuch advantage in a commercial or agricultural country, that every attempt to render them more convenient, and leſs expenſive in the conſtruction, is intitled to public notice. In the Encyclopædia, an account, ſufficiently perſpicuous, is given of the common canals with locks; but in many caſes it is very difficult to provide a ſufficient quantity of water for the conſumption of a canal where many boats are to paſs. Different attempts have therefore been made, by ingenious men, to ſave water in the paſſing of boats or lighters from one lock of a canal to another; and, among theſe, perhaps none is more deſerving of public favour than the following, by the late Mr James Playfair of Ruſſel-ſtreet, architect. We ſhall ſtate his invention in his own words.

"The nature and principle of this manner of ſaving water conſiſt in letting the water which has ſerved to raiſe or fall a boat or barge from the lock, paſs into reſervoirs or ciſterns, whoſe apertures of communication with the lock are upon different levels, and which may be placed or conſtructed at the ſide or ſides of the lock with which they communicate, or in any other contiguous ſituation that circumſtances may render eligible; which apertures may be opened or ſhut at pleaſure, ſo that the water may paſs from the lock to each reſervoir of the canal, or from each reſervoir to the lock, in the following manner: The water which fills the lock, when a boat is to aſcend or deſcend, inſtead of being paſſed immediately into the lower part of the canal, is let paſs into theſe ciſterns or reſervoirs, upon different levels; then, their communications with the lock being ſhut, they remain full until another veſſel is wanted to paſs; then, again, the ciſterns are emptied into the lock, which is thereby nearly filled, ſo that only the remainder which is not filled is ſupplied from the higher part of the canal. Each of theſe ciſterns muſt have a ſurface not leſs than that of the lock, and muſt contain half as much water as is meant to be expended for the paſſing of each veſſel. The ciſtern the moſt elevated is placed twice its own depth (meaſuring by the aperture, or communicating opening of the ciſterns) under the level of the water in the higher part of the canal. The ſecond ciſtern is placed once its own depth under the firſt, and ſo on are the others to the loweſt; which laſt is placed once its own depth above the level of the water in the lower part of the canal. The apertures of the intermediate ciſterns, whatever their number may be, muſt all be equally divided into different levels; the ſurface of the water in the one being always on the level of the bottom of the aperture of the ciſtern which is immediately above. As an example of the manner and rule for conſtructing theſe ciſterns, ſuppoſe that a lock is to be conſtructed twelve feet deep, that is, that the veſſel may aſcend or deſcend twelve feet in paſſing. Suppoſe the lock ſixty feet long and ſix feet wide, the quantity of water required to fill the lock, and to paſs a boat, is 4320 cubic feet; and ſuppoſe that, in calculating the quantity of water that can be procured for ſupplying the canal, after allowing for waſte, it is found (according to the number of boats that may be expected to paſs) that there will not be above 800 cubic feet for each; then it will be neceſſary to ſave five-ſixths of the whole quantity that in the common caſe would be neceſſary: to do which ten ciſterns muſt be made (the mode of placing which is expreſſed

preſſed in the drawing, fig. 1. Plate VII.), each of which muſt be one foot deep, or deeper at pleaſure, and each muſt have a ſurface of 360 feet ſquare, equal to the ſurface of the lock. The bottom of the aperture of the loweſt ciſtern muſt be placed one foot above the level of the water in the lower part of the canal, or eleven feet under the level of the high water; the ſecond ciſtern muſt be two feet above the level of the low water; the third three feet, and ſo on of the others; the bottom of the tenth, or uppermoſt ciſtern, being ten feet above the low water, and two feet lower than the high water; and, as each ciſtern muſt be twelve inches in depth, the ſurface of the water in the higher ciſtern will be one foot under the level of the water in the upper part of the canal. The ciſterns being thus conſtructed, when the lock is full, and the boat to be let down, the communications between the lock and the ciſterns, which until then have all been ſhut, are to be opened in the following manner: firſt, the communication with the higher ciſtern is opened, which, being at bottom two feet under the level of the water in the lock, is filled to the depth of one foot, the water in the lock deſcending one foot alſo at the ſame time; that communication is then ſhut, and the communication between the lock and the ſecond ciſtern is opened; one foot more of the water then paſſes into that ciſtern from the lock, and fills it; the opening is then ſhut: the ſame is done with the third, fourth, fifth, ſixth, ſeventh, eighth, ninth, and tenth, ciſterns, one by one, until they are all filled; and when the tenth, or lowermoſt ciſtern, is filled, there remains but two feet depth of water in the lock. The communication between the lock and the lower part of the canal is then opened, and the laſt two feet depth of water is emptied into the lower part of the canal. By this means, it is evident that, inſtead of twelve feet depth of water being let deſcend into the lower part of the canal, there is only two feet depth that deſcends, or one-ſixth of the whole; therefore, inſtead of 4320 cubic feet being uſed, there are only 720 cubic feet uſed: the remainder of the water in the ciſterns being uſed as follows: When another boat is to mount, the ſluices being then ſhut, and the boat in the lock, the tenth or lowermoſt ciſtern is emptied into the lock, which it fills one foot; the communication being then ſhut, the next loweſt ciſtern, or the ninth, is emptied into the lock, which is thereby filled another foot; and ſo, in like manner, all the other ciſterns are emptied one after another, until the higher ciſtern being emptied, which fills the tenth foot of water in the lock, there remains but two feet of water to fill, which is done from the upper part of the canal by opening the higher ſluice to paſs the boat; by that means, the ſame quantity of water deſcends from the upper part of the canal into the lock, that in the other caſe deſcended from the lock into the lower part of the canal; ſo that, in both caſes, the ſame quantity of water is ſaved, that is, five-ſixths of what would be neceſſary were there no ciſterns. Suppoſe again that, upon the ſame canal, and immediately after the twelve feet lock, it would be advantageous to conſtruct one of eighteen feet; then, in order not to uſe any greater quantity of water, it will be neceſſary to have ſixteen ciſterns, upon different levels, communicating with the lock in the ſame manner. Should, again, a lock of only ſix feet be wanted, after that of eighteen, then it will only be neceſſary to have four ciſterns on different levels, and ſo of any other height of lock. The rule is this: For finding the number and ſize of the ciſterns, each ciſtern being the ſame in ſuperficies with the lock, its depth muſt be ſuch as to contain one half the quantity of water meant to be uſed in the paſſing of one boat. The depth of the lock, divided by the depth neceſſary for ſuch a ciſtern, will give, in all caſes, the whole number of ciſterns, and two more: deduct the number two, therefore, from the number which you find by dividing the depth of the lock by the depth of one ciſtern, and you have always the number of ciſterns required; which are to be placed upon different levels, according to the rule already given. The above is the principle and manner of uſing the lock, for ſaving water in canals, and for enabling engineers to conſtruct locks of different depths upon the ſame canal, without uſing more water for the deep locks than for the ſhallow ones. With regard to the manner of diſpoſing the ciſterns, the circumſtances of the ground, the declivity, &c. will be the beſt guide for the engineer."

But ſuppoſing a ſufficiency of water, or admitting that this method of Mr Playfair's of ſaving it, where defective, is adequate to his fondeſt expectations, ſtill, in paſſing numerous locks, where the riſe is conſiderable, the interruption is ſo great, that it has often been wiſhed that an eligible method of lowering and elevating boats could be deviſed, without the aſſiſtance of water-locks. Though this is evidently at firſt view practicable, and ſeveral different modes of doing it have been ſuggeſted, ſome of which have actually been carried into effect, yet all of them have been found to be attended with ſuch inconvenience as to render an improvement in this reſpect ſtill neceſſary.

In China, where water-carriage is more generally practiſed than in any kingdom of Europe, boats are raiſed and lowered from one canal into another, by ſliding them along an inclined plane: but the contrivances for effecting that purpoſe are ſo awkward, and ſuch a number of hands are required, that it has in general been deemed inexpedient to reſort to that mode of practice in Europe. Several devices, that diſcover conſiderable ingenuity, however, have been publiſhed, with a view to facilitate this operation; either by rendering the motion up the inclined plane more equable, or producing a power ſufficient to move theſe great weights. But none of them have yet been ſo ſimple in their conſtruction as could be wiſhed, nor have they afforded ſatisfaction in practice. For the greater part of them, likewiſe, patents have been granted; ſo that whatever be their value, no engineer could avail himſelf of them without previouſly purchaſing a licence from the patentee.

The following contrivance for this purpoſe is the invention of James Anderſon, LL. D. whoſe knowledge of economics is well known, and of whoſe public ſpirit there cannot be a doubt. Inſtead of applying for a patent, to ſecure to himſelf the fruits of his ingenuity, he publiſhed, for the good of his countrymen in general, his device, in the View of the Agriculture of the County of Aberdeen, which he drew up for the conſideration of the board of agriculture. He introduces it to public notice with juſtly obſerving, that it poſſeſſes at leaſt the merit of ſimplicity, in as high a degree, perhaps, as could be wiſhed ; and, " in the opinion (ſays he) of very good judges of matters of this ſort, to whom the plan has been ſhewn, it has been deemed fully adequate to the purpoſe of raiſing and lowering boats of a moderate ſize, that is, of 20 tons, or downwards ; and it is the opinion of moſt men with whom I have converſed, who are beſt acquainted with the inland navigations, that a boat of from 10 to 15 tons is better than thoſe of a larger ſize. When ſeveral are wanted to be ſent at once, they may be affixed to one another, as many as the towing-horſe can conveniently draw. Were boats of this ſize adopted, and were all the boats on one canal to be of the ſame dimenſions, it would prove a great convenience to a country in a ſtate of beginning improvements; becauſe the expence of ſuch a boat would be ſo trifling, that every farmer could have one for himſelf, and might of courſe make uſe of it when he pleaſed by the aid of his own horſe, without being obliged to have any dependence on the time that might ſuit the convenience of his neighbour ; and if two or more boats were going from the ſame neighbourhood, one horſe could ſerve the whole.

" You are to ſuppoſe that fig. 2. (Plate VII.) repreſents a bird's-eye view of this ſimple apparatus, as ſeen from above. A is ſuppoſed to be the upper reach of the canal, and B the lower reach, with the apparatus between the two. This conſiſts of three diviſions ; the middle one, extending from C to D, is a ſolid piece of maſonry, raiſed from a firm foundation below the level of the bottom of the ſecond reach : this is again divided into five parts, viz. *ddd*, where the wall riſes only to the height of the water in the upper reach, and *ee*, two pillars, raiſed high enough to ſupport the pivots of a wheel or pulley *g*, placed in the poſition there marked.

" The ſecond diviſion *h* conſiſts of a wooden coffer, of the ſame depth nearly as the water in the upper reach, and of a ſize exactly fitted to contain one of the boats. This communicates directly with the upper reach, and being upon the ſame plane with it, and ſo connected with it as to be water-tight, it is evident, from inſpection, that nothing can be more eaſy than to float a boat into this coffer from the upper reach ; the part of the wheel that projects over it being at a ſufficient height above it, ſo as to occaſion no ſort of interruption.

" Third diviſion. At *i* is repreſented another coffer, preciſely of the ſame dimenſions with the firſt. But here two ſluices, which were open in the former, and only repreſented by dotted lines, are ſuppoſed to be ſhut, ſo as to cut off all communication between the water in the canal and that in the coffer. As it was impoſſible to repreſent this part of the apparatus on ſo ſmall a ſcale, for the ſake of illuſtration it is repreſented more at large in fig. 5. where A, as before, repreſents the upper reach of the canal, and *h* one of the coffers. The ſluice *k* goes into two cheeks of wood, joined to the maſonry of the dam of the canal, ſo as to fit perfectly cloſe ; and the ſluice *f* fits equally cloſe into cheeks made in the ſide of the coffer for that purpoſe ; between theſe two ſluices is a ſmall ſpace *o*. The coffer, and this diviſion *o*, are to be ſuppoſed full of water, and it will be eaſy to ſee that theſe ſluices may be let down or drawn up at pleaſure with much facility.

" Fig. 6. repreſents a perpendicular ſection of theſe parts in the ſame direction as in fig. 5. and in which the ſame letters repreſent the ſame parts.

" Things being thus arranged, you are to ſuppoſe the coffer *h* to be ſuſpended, by means of a chain paſſed over the pulley, and balanced by a weight that is ſufficient to counterpoiſe it, ſuſpended at the oppoſite end of the chain. Suppoſe, then, that the counterpoiſe be made ſomewhat lighter than the coffer with its contents, and that the line *mn* (fig. 6.) repreſents a diviſion between the ſolid ſides of the dam of ſeparation, which terminates the upper reach and the wooden coffer, which had been cloſed only by the preſſure of its own weight (being puſhed a very little from A towards B, beyond its preciſe perpendicular ſwing), and that the joining all round is covered with liſts of cloth put upon it for that purpoſe ; it is evident that, ſo long as the coffer is ſuſpended to this height, the joining muſt be water-tight ; but no ſooner is it lowered down a little than this joining opens, the water in the ſmall diviſion *o* is allowed to run out, and an entire ſeparation is made between the fixed dam and this moveable coffer, which may be lowered down at pleaſure without loſing any part of the water it contained.

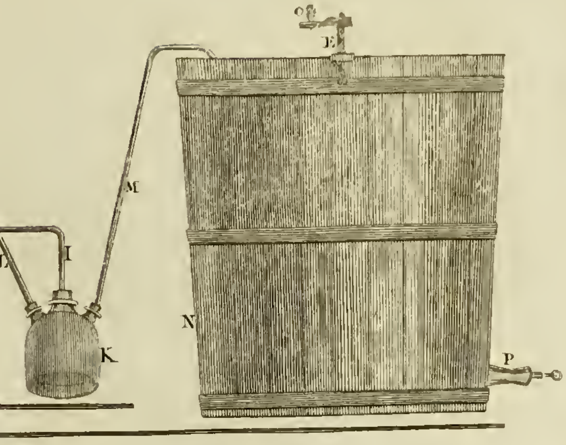
" Suppoſe the coffer now perfectly detached, turn to fig. 3. which repreſents a perpendicular ſection of this apparatus, in the direction of the dotted line *pp* (fig. 2.) In fig. 3. *h* repreſents an end view of the coffer, indicated by the ſame letter as in fig. 2. ſuſpended by its chain, and now perfectly detached from all other objects, and balanced by a counterpoiſe *i*, which is another coffer exactly of the ſame ſize, as low down as the level of the lower reach. From inſpection only, it is evident, that in proportion as the one of theſe weights riſes, the other muſt deſcend. For the preſent, then, ſuppoſe that the coffer *h* is by ſome means rendered more weighty than *i*, it is plain it will deſcend while the other riſes ; and they will thus continue till *h* comes down to the level of the lower reach, and *i* riſes to the level of the higher one.

" Fig. 4. repreſents a ſection in the direction AB (fig. 2.), in which the coffer *i* (ſeen in both ſituations) is ſuppoſed to have been gradually raiſed from the level of the lower reach B, to that of the higher A, where it now remains ſtationary ; while the coffer *h* (which is concealed behind the maſonry) has deſcended in the mean time to the level of the lower reach, where it cloſes by means of the juncture *rs*, fig. 6. (which juncture is covered with liſts of cloth, as before explained at *mn*, and is of courſe become water-tight), when, by lifting the ſluice *t*, and the correſponding ſluice at the end of the canal, a perfect communication by water is eſtabliſhed between them. If, then, inſtead of water only, this coffer had contained a boat, floated into it from the upper reach, and then lowered down, it is very plain that when theſe ſluices were removed, after it had reached the level of the lower reach, that boat might have been floated out of the coffer with as much facility as it was let into it above. Here then we have a boat taken from the higher into the lower canal ; and, by reverſing this movement, it is very obvious that it might be, with equal eaſe, raiſed from the lower into the higher one. It now only remains that I ſhould explain by what means the equilibrium between

PLATE VII.

LARGE SNOUTED BOAR

BLEACHING



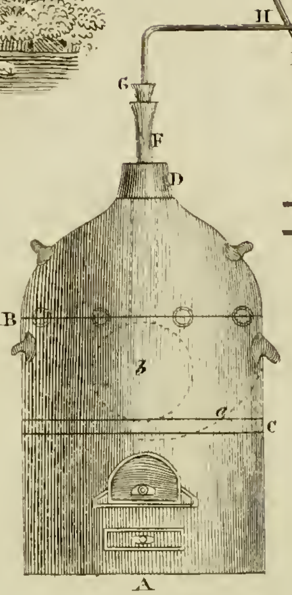
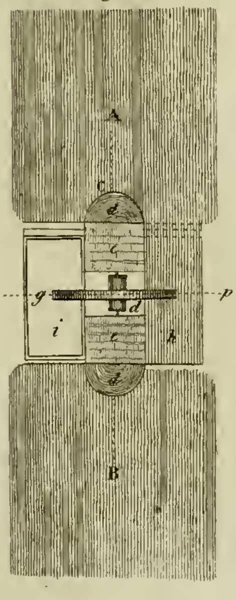


Fig. 2.



CANALS

Fig. 1.

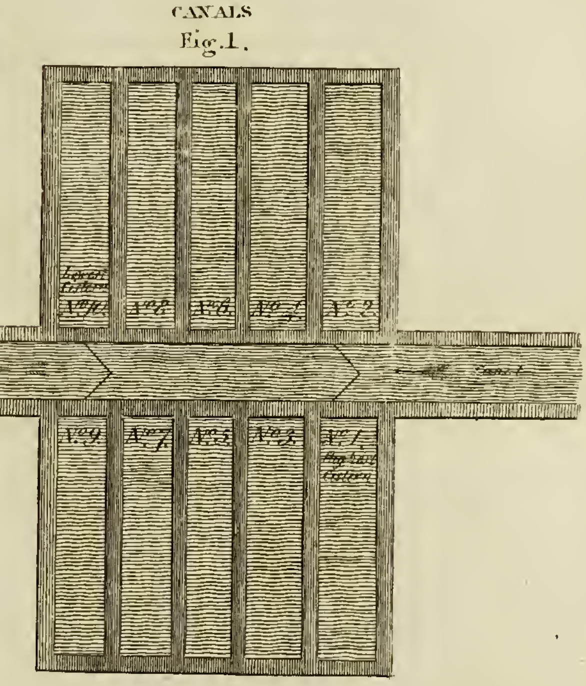


Fig. 3.

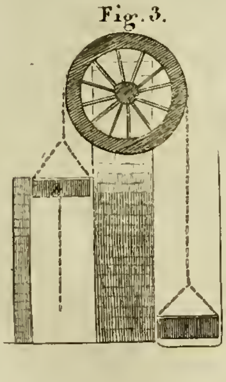


Fig. 4.

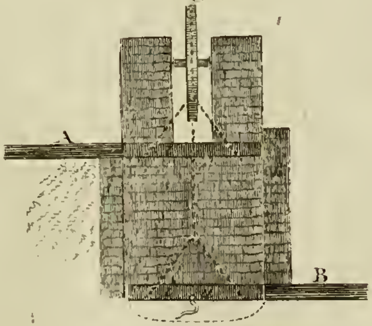


Fig. 5.

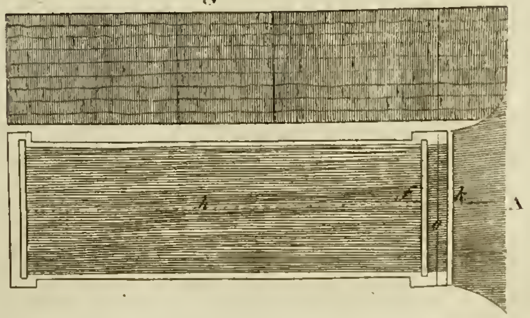
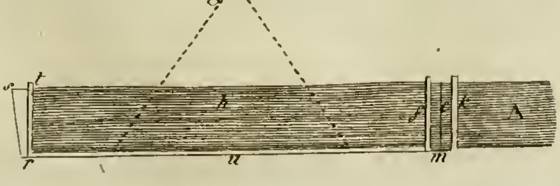


Fig. 6.



theſe counterbalancing weights can be deſtroyed at pleaſure, and the motion of courſe produced.

“ It is very evident, that if the two correſponding coffers be preciſely of the ſame dimenſions, their weight will be exactly the ſame when they are both filled to the ſame depth of water. It is equally plain, that ſhould a boat be floated into either or both of them, whatever its dimenſions or weight may be, ſo that it can be contained afloat in the coffer, the weight of the coffer and its contents will continue preciſely the ſame as when it was filled with water only : hence, then, ſuppoſing one boat is to be lowered, or one to be raiſed at a time, or ſuppoſing one to be raiſed and another lowered at the ſame time—they remain perfectly in equilibrium in either place, till it is your pleaſure to deſtroy that equilibrium. Suppoſe, then, for the preſent, that both coffers are loaded with a boat in each, the double ſluices both above and below cloſed ; and ſuppoſe alſo that a ſtop-cock *u*, in the under edge of the ſide of the lower coffer (fig. 4. and 6.), is opened, ſome of the water which ſerved to float the boat in the coffer will flow out of it, and conſequently that coffer will become lighter than the higher one ; the upper coffer will of courſe deſcend, while the other mounts upwards. When a gentle motion has been thus communicated, it may be prevented from accelerating, merely by turning the ſtop-cock ſo as to prevent the loſs of more water, and thus one coffer will continue to aſcend, and the other to deſcend, till they have aſſumed their ſtations reſpectively ; when, in conſequence of a ſtop below, and another above, they are rendered ſtationary at the level of the reſpective canals (A).

“ Preciſely the ſame effect will be produced when the coffers are filled entirely with water.

“ It is unneceſſary to add more to this explanation, except to obſerve that the ſpace for the coffer to deſcend into muſt be deeper than the bottom of the lower canal, in order to allow a free deſcent for the coffer to the requiſite depth ; and of courſe it will be neceſſary to have a ſmall conduit to allow the water to get out of it. Two or three inches free, below the bottom of the canal, is all that would be neceſſary.

“ Where the height is inconſiderable, there will be no occaſion for providing any counterpoiſe for the chain, as that will give only a ſmall addition to the weight of the undermoſt coffer, ſo as to make it preponderate, in circumſtances where the two coffers would otherwiſe be in perfect equilibrium : but, where the height is conſiderable, there will be a neceſſity for providing ſuch a counterpoiſe ; as, without it, the chain, by becoming more weighty every foot it deſcended, would tend to deſtroy the equilibrium too much, and accelerate the motion to an inconvenient degree. To guard againſt this inconvenience, let a chain of the ſame weight, per foot, be appended at the bottom of each coffer, of ſuch a length as to reach within a few yards of the ground where the coffer is at its greateſt height (ſee fig. 3.) ; it will act with its whole weight upon the higheſt coffer while in this poſition ; but, as that gradually deſcended, the chain would reach the ground, and, being there ſupported, its weight would be diminiſhed in proportion to its deſcent ; while the weight of the chain on the oppoſite ſide would be augmented in the ſame proportion, ſo as to counterpoiſe each other exactly, in every ſituation, until the uppermoſt chain was raiſed from the ground. After which it would increaſe its weight no more; and, of courſe, would then give the under coffer that preponderance which is neceſſary for preſerving the machine ſteady. The under coffer, when it reached its loweſt poſition, would touch the bottom on its edges, which would then ſupport it, and keep every thing in the ſame poſition, till it was made lighter for the purpoſe of aſcending.

“ What conſtitutes one particular excellence of the apparatus here propoſed is, that it is not only unlimited as to the extent of the riſe or depreſſion of which it is ſuſceptible (for it would not require the expenditure of one drop more water to lower it one hundred feet than one foot) ; but it would alſo be eaſy ſo to augment the number of pulleys at any one place as to admit of two, three, four, or any greater number of boats being lowered or elevated at the ſame time ; ſo that let the ſucceſſion of boats on ſuch a canal be nearly as rapid as that of carriages upon a highway, none of them need be delayed one moment to wait an opportunity of paſſing : a thing that is totally impracticable where water-locks are employed ; for the intercourſe, on every canal conſtructed with water-locks, is neceſſarily limited to a certain degree, beyond which it is impoſſible to force it.

“ For example : ſuppoſe a hundred boats are following each other, in ſuch a rapid ſucceſſion as to be only half a minute behind each other : By the apparatus here propoſed, they would all be elevated preciſely as they came ; in the other, let it be ſuppoſed that the lock is ſo well conſtructed as that it takes no more than five minutes to cloſe and open it ; that is, ten minutes in the whole to each boat (for the lock, being once filled, muſt be again emptied before it can receive another in the ſame direction) : at this rate, ſix boats only could be paſſed in an hour, and of courſe it would take ſixteen hours and forty minutes to paſs the whole hundred ; and as the laſt boat would reach the lock in the ſpace of fifty minutes after the firſt, it would be detained fifteen hours and fifty minutes before its turn would come to be raiſed. This is an immenſe detention ; but if a ſucceſſion of boats, at the ſame rate, were to follow continually, they never could paſs at all. In ſhort, in a canal conſtructed with water-locks, not more than ſix boats, on an average, can be paſſed in an hour, ſo that beyond that extent all commerce muſt be ſtopped; but, of the plan here propoſed, ſixty, or ſix hundred, might be paſſed in an hour if neceſſary, ſo as to occaſion no ſort of interruption whatever. Theſe are advantages of a very important nature, and ought not to be overlooked in a commercial country.

“ This apparatus might be employed for innumerable other uſes as a moving power, which it would be foreign to our preſent purpoſe here to ſpecify. Nor does its power admit of any limitation, but that of the ſtrength of the chain, and of the coffers which are to ſupport the weights. All the other parts admit of

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(A) “ It does not ſeem neceſſary to adopt any other contrivance than the above for regulating the motions ; but if it ſhould be found neceſſary, it would be eaſy to put a ratch-wheel on the ſame axle.”

being made ſo immoveably firm as to be capable of ſupporting almoſt any aſſignable weight.

" I will not enlarge on the benefits that may be derived from this very ſimple apparatus: its cheapneſs, when compared with any other mode of raiſing and lowering veſſels that has ever yet been practiſed, is very obvious; the waſte of water it would occaſion is next to nothing; and when it is conſidered that a boat might be raiſed or lowered fifty feet nearly with the ſame eaſe as five, it is evident that the interruptions which ariſe from frequent locks would be avoided, and an immenſe ſaving be made in the original expence of the canal, and in the annual repairs.

" It is alſo evident that an apparatus, on the ſame principle, might be eaſily applied for raiſing coals or metals from a great depth in mines, wherever a very ſmall ſtream of water could be commanded, and where the mine was level-free."

CANARY-BIRD, of which a deſcription is given in the Encyclopædia, was not known in Europe till towards the end of the 15th century. Even in 1555, Bellon, who about that time deſcribed all the birds then known, does not ſo much as mention it. When it was firſt brought from the Canary Iſlands, it was ſo dear that it could be purchaſed only by people of fortune, who were often impoſed upon. It was called the *ſugar-bird*, becauſe it was ſaid to be fond of the ſugar-cane, and could eat ſugar in great abundance. This is rather a ſingular circumſtance, ſugar being to many fowls a poiſon. Experiments have ſhewn that a pigeon, to which four drams of ſugar was given, died in four hours; and that a duck, which had ſwallowed five drams, did not live ſeven hours.

In the middle of the laſt century canary-birds began to be bred in Europe; and to this the following circumſtance, related by Olina, ſeems to have given occaſion: " A veſſel which, among other commodities, was carrying a number of canary birds to Leghorn, was wrecked on the coaſt of Italy; and theſe birds being thus ſet at liberty, flew to the neareſt land, which was the iſland of Elba, where they found the climate ſo favourable, that they multiplied, and perhaps would have become domeſticated, had they not been caught in ſnares; for it appears that the breed of them there has been long deſtroyed. Olina ſays that the breed ſoon degenerated; but it is probable that by much the greater part of theſe canary-birds were males, which coupling with birds of the iſland, produced mules, ſuch as are deſcribed by Geſner and other naturaliſts."

" Various treatiſes have been publiſhed in different languages, on the manner of breeding theſe birds, and many people have made it a trade, by which they have acquired conſiderable gain. It does no diſcredit to the induſtry of the Tyrolians, that they have carried it to the greateſt extent. At Ymſt there is a company, who, after the breeding ſeaſon is over, ſend out perſons to different parts of Germany and Switzerland to purchaſe birds from thoſe who breed them. Each perſon brings with him commonly from three to four hundred, which are afterwards carried for ſale, not only through every part of Germany, but alſo to England, Ruſſia, and even Conſtantinople. About ſixteen hundred are brought every year to England; where the dealers in them, notwithſtanding the conſiderable expence they are at, and after carrying them about on their backs, perhaps a hundred miles, ſell them for five ſhillings a piece. This trade, hitherto neglected, is now carried on in Schwartzwalde; and at preſent there is a citizen at Gottingen who takes with him every year to England ſeveral canary-birds and bulfinches *(loxia pyrrhula)*, with the produce of which he purchaſes ſuch ſmall wares as he has occaſion for."—*Profeſſor Beckmann's Hiſtory of Inventions and Diſcoveries.*

Canary-Seed. See PHALARIS, *Encycl.*—Profeſſor Beckmann doubts whether the plant which bears the canary-ſeed be the *phalaris* of the ancients, becauſe that name ſeems to have been given by Pliny to more than one ſpecies of graſs. He thinks it very probable, however, that the plant, which the modern botaniſts call *phalaris*, was firſt brought from the Canary Iſlands to Spain, where it began to be cultivated, as well as in the ſouth of France, as ſoon as canary-birds came into general eſteem. At preſent it is cultivated in various places, and forms no inconſiderable branch of trade, particularly in the iſland of Sicily, where it is called *Scagliuola* or *Scaghiola*. Were it not that the grains are not eaſily freed from the huſks, this plant might be cultivated for the food of man, for its ſeeds yield a good kind of meal. The phalaris has by ſeveral writers been confounded with *argol* or the *lichen rocolla* of Linnæus; but they are very different plants. See *LICHEN Rocolla* in this Supplement.

CANDLE, a thing ſo univerſally known as to need no particular deſcription. Its uſe, however, is ſo great, that every information tending to its improvement muſt, we ſhould think, be acceptable to our readers. Of the common method of making candles, whether of wax or of tallow, a ſufficient account has been given in the Encyclopædia; but candles of every kind are far from being yet brought to that degree of perfection of which they ſeem ſuſceptible. Thus, for example, the light of a candle, which is ſo exceedingly brilliant when firſt ſnuffed, is very ſpeedily diminiſhed to one half, and is uſually not more than one-fifth or one-ſixth, before the uneaſineſs of the eye induces us to ſnuff it. Hence it follows, that if candles could be made ſo as not to require ſnuffing, the average quantity of light afforded by the ſame quantity of combuſtible matter would be more than doubled. It may likewiſe be worthy of inquiry, ſince the coſt and duration of candles are eaſily aſcertainable, whether more or leſs light is obtained at the ſame expence during a given time, by burning a number of ſmall candles inſtead of one of greater thickneſs.

To determine this laſt point, a method muſt be found of meaſuring the comparative intenſities of light, for which ſee PHOTOMETER in this Supplement. With reſpect to the deſideratum firſt mentioned, we have ſome very ingenious obſervations and well-contrived experiments by Mr Nicholſon, in the ſecond number of his valuable Journal, which we ſhall here inſert nearly in the words of their author.

In every proceſs of combuſtion the free acceſs of air is of the utmoſt conſequence. When a candle has a very ſlender wick, the flame is ſmall and of a brilliant white colour; if the wick be large, the combuſtion is leſs perfect, and the flame brown; and a wick ſtill larger, not only exhibits a brown flame, but the lower internal part appears dark, and is occupied by a portion of volatilized matter, which does not become ignited till it has aſcended towards the point. When the wick is

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either very large or very long, part of this matter eſcapes combuſtion, and ſhews itſelf in the form of coal or ſmoke. The ſame things take place in the burning of a lamp; but when the wick of a lamp is once adjuſted as to its length, the flame continues nearly in the ſame ſtate for a much longer time than the flame of a candle.

"Upon comparing a candle with a lamp (ſays Mr Nicholſon), two very remarkable particulars are immediately ſeen. In the firſt place, the tallow itſelf, which remains in the unfuſed ſtate, affords a cup or cavity to hold that portion of melted tallow which is ready to flow into the lighted part of the wick. In the ſecond place, the combuſtion, inſtead of being confined, as in the lamp, to a certain determinate portion of the fibrous matter, is carried, by a ſlow ſucceſſion, through the whole length. Hence ariſes the greater neceſſity for frequent ſnuffing the candle; and hence alſo the ſtation of the freezing point of the fat oil becomes of great conſequence. For it has been ſhewn, that the brilliancy of the flame depends very much on the diameter of the wick being as ſmall as poſſible; and this requiſite will be moſt attainable in candles formed of a material that requires a higher degree of heat to fuſe it. The wick of a tallow candle muſt be made thicker in proportion to the greater fuſibility of the material, which would otherwiſe melt the ſides of the cup, and run over in ſtreams. The flame will therefore be yellow, ſmoky, and obſcure, excepting for a ſhort time immediately after ſnuffing. Tallow melts at the 92d degree of Fahrenheit's thermometer; ſpermaceti at the 133d degree; the fatty matter formed of fleſh, after long immerſion in water, melts at 127 degrees; the *pela* of the Chineſe at 145 degrees; bees-wax at 142 degrees; and bleached wax at 155 degrees. Two of theſe materials are well known in the fabrication of candles. Wax in particular does not afford ſo brilliant a flame as tallow; but, on account of its leſs fuſibility, the wick can be made ſmaller, which not only affords the advantage of a clear perfect flame, but from its flexibility it is diſpoſed to turn on one ſide, and come in contact with the external air, which completely burns the extremity of the wick to white aſhes, and thus performs the office of ſnuffing. We ſee therefore that the important object to ſociety of rendering tallow candles equal to thoſe of wax, does not at all depend on the combuſtibility of the reſpective materials, but upon a mechanical advantage in the cup, which is afforded by the inferior degree of fuſibility in the wax; and that, to obtain this valuable object, one of the following effects muſt be produced: Either the tallow muſt be burned in a lamp, to avoid the gradual progreſſion of the flame along the wick; or ſome means muſt be deviſed to enable the candle to ſnuff itſelf, as the wax candle does; or, laſtly, the tallow itſelf muſt be rendered leſs fuſible by ſome chemical proceſs. I have no great reaſon to boaſt of ſucceſs in the endeavour to effect theſe; but my hope is, that the facts and obſervations here preſented may conſiderably abridge the labour of others in the ſame purſuit.

"The makers of thermometers and other ſmall articles with the blow-pipe and lamp, give the preference to tallow inſtead of oil, becauſe its combuſtion is more complete, and does not blacken the glaſs. In this operation the heat of the lamp melts the tallow which is occaſionally brought into its vicinity by the workman. But for the uſual purpoſes of illumination, it cannot be ſuppoſed that a perſon can attend to ſupply the combuſtible matter. Conſiderable difficulties ariſe in the project for affording this gradual ſupply as it may be wanted. A cylindrical piece of tallow was inſerted into a metallic tube, the upper aperture of which was partly cloſed by a ring, and the central part occupied by a metallic piece nearly reſembling that part of the common lamp which carries the wick. In this apparatus the piece laſt deſcribed was intended to anſwer the ſame purpoſe, and was provided with a ſhort wick. The cylinder of tallow was ſupported beneath in ſuch a manner that the metallic tube and other part of this lamp were left to reſt with their whole weight upon the tallow at the ring or contraction of the upper aperture. In this ſituation the lamp was lighted. It burned for ſome time with a very bright clear flame, which, when compared with that of a candle, poſſeſſed the advantage of uniform intenſity, and was much ſuperior to the ordinary flame of a lamp in its colour, and the perfect abſence of ſmell. After ſome minutes it began to decay, and very ſoon afterwards went out. Upon examination, it was found that the metallic piece which carried the wick had fuſed a ſufficient quantity of tallow for the ſupply during the combuſtion; that part of this tallow had flowed beneath the ring, and to other remote parts of the apparatus, beyond the influence of the flame; in conſequence of which, the tube and the cylinder of tallow were faſtened together, and the expected progreſſion of ſupply prevented. It ſeems probable that, in every lamp for burning conſiſtent oils, the material ought to be ſo diſpoſed that it may deſcend to the flame upon the principle of the fountain reſervoir. I ſhall not here ſtate the obſtacles which preſent themſelves in the proſpect of this conſtruction, but ſhall diſmiſs the ſubject by remarking, that a contrivance of this nature would be of the greateſt public utility.

"The wick of a candle being ſurrounded by the flame, is nearly in the ſituation of a body expoſed to deſtructive diſtillation in a cloſe veſſel. After loſing its volatile products, the carbonaceous reſidue retains its figure, until, by the deſcent of the flame, the external air can have acceſs to its upper extremity. But, in this caſe, the requiſite combuſtion, which might ſnuff it, is not effected: for the portion of oil emitted by the long wick is not only too large to be perfectly burned, but alſo carries off much of the heat of the flame while it aſſumes the elaſtic ſtate. By this diminiſhed combuſtion and increaſed efflux of half-decompoſed oil, a portion of coal or ſoot is depoſited on the upper part of the wick, which gradually accumulates, and at length aſſumes the appearance of a fungus. The candle does not then give more than one-tenth of the light emitted in its beſt ſtate. Hence it is that a candle of tallow cannot ſpontaneouſly ſnuff itſelf. It was not probable that the addition of a ſubſtance containing vital air or oxygen would ſupply that principle at the preciſe period of time required; but as experiment is the teſt of every probability of this nature, I ſoaked a wick of cotton in a ſolution of nitre, then dried it, and made a candle. When this came to be lighted, nothing remarkable happened for a ſhort time; at the expiration of which a decrepitation followed at the lower extremity of the flame, which completely divided the wick

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where the blackened part commences. The whole of the matter in combuſtion therefore fell off, and the candle was of courſe inſtantly extinguiſhed. Whether this would have happened in all proportions of the ſalt or conſtructions of the candle, I did not try, becauſe the ſmell of azot was ſufficiently ſtrong and unpleaſant to forbid the uſe of nitre in the purſuit. From various conſiderations, I am diſpoſed to think that the ſpontaneous ſnuffing of candles made of tallow, or other fuſible materials, will ſcarcely be effected but by the diſcovery of ſome material for the wick which ſhall be voluminous enough to abſorb the tallow, and at the ſame time ſufficiently flexible to bend on one ſide.

“ The moſt promiſing ſpeculation reſpecting this moſt uſeful article, ſeems to direct itſelf to the cup which contains the melted tallow. The imperfection of this part has already been noticed, namely, that it breaks down by fuſion, and ſuffers its fluid contents to eſcape. The Chineſe have a kind of candle about half an inch in diameter, which, in the harbour of Canton, is called a *lobchock;* but whether the name be Chineſe, or the corruption of ſome European word, I am ignorant. The wick is of cotton, wrapped round a ſmall ſtick or match of the bamboo cane. The body of the candle is white tallow; but the external part, to the thickneſs of perhaps one thirtieth of an inch, conſiſts of a waxy matter coloured red. This covering gives a conſiderable degree of ſolidity to the candle, and prevents its guttering, becauſe leſs fuſible than the tallow itſelf. I did not obſerve that the ſtick in the middle was either advantageous or the contrary; and as I now write from the recollection of this object at ſo remote a period as 25 years ago, I can only conjecture that it might be of advantage in throwing up a leſs quantity of oil into the flame than would have been conveyed by a wick of cotton ſufficiently ſtout to have occupied its place unſupported in the axis of the candle.

“ Many years ago I made a candle in imitation of the lobchock. The expedient to which I had recourſe conſiſted in adapting the wick in the uſual pewter mould: wax was then poured in, and immediately afterwards poured out: the film of wax which adhered to the inner ſurface of the mould ſoon became cool, and the candle was completed by filling the mould with tallow. When it was drawn out, it was found to be cracked longitudinally on its ſurface, which I attributed to the contraction of the wax, by cooling, being greater than that of the tallow. At preſent I think it equally probable that the cracking might have been occaſioned by too ſudden cooling of the wax before the tallow was poured in; but other avocations prevented the experiments from being varied and repeated. It is probable that the Chineſe external coating may not be formed of pure hard bleached wax.

“ But the moſt deciſive remedy for the imperfection of this cheapeſt, and in other reſpects beſt, material for candles, would undoubtedly be to diminiſh its fuſibility. Various ſubſtances may be combined with tallow, either in the direct or indirect method. In the latter way, by the decompoſition of ſoap, a number of experiments were made by Berthollet, of which an account is inſerted in the memoirs of the Academy at Paris for the year 1780, and copied into the 26th volume of the *Journal de Phyſique.* None of theſe point directly to the preſent object; beſides which, it is probable that the ſoap made uſe of by that eminent chemiſt was formed not of tallow, but oil. I am not aware of any regular ſeries of experiments concerning the mutual action of fat oils and other chemical agents, more eſpecially ſuch as may be directed to this important object of diminiſhing its ſolubility; for which reaſon I ſhall mention a few experiments made with this view.

“ 1. Tallow was melted in a ſmall ſilver veſſel. Solid tallow ſinks in the fluid, and diſſolves without any remarkable appearance. 2. Gum ſandarach in tears was not diſſolved, but emitted bubbles, ſwelled up, became brown, emitted fumes, and became criſp or friable. No ſolution nor improvement of the tallow. 3. Shell-lac ſwelled up with bubbles, and was more perfectly fuſed than the gum ſandarach in the former experiment. When the tallow was poured off, it was thought to congeal rather more ſpeedily. The lac did not appear to be altered. 4. Benzoin bubbled without much ſwelling, was fuſed, and emitted fumes of an agreeable ſmell, though not reſembling the flowers of benzoin. A ſlight or partial ſolution ſeemed to take place. The benzoin was ſofter and of a darker colour than before, and the tallow leſs conſiſtent. 5. Common reſin unites very readily with melted tallow, and forms a more fuſible compound than the tallow itſelf. 6. Camphor melts eaſily in tallow, without altering its appearance. When the tallow is near boiling, camphoric fumes fly off. The compound appeared more fuſible than tallow. 7. The acid or flowers of benzoin diſſolves in great quantities without any ebullition or commotion. Much ſmoke ariſes from the compound, which does not ſmell like the acid of benzoin. Tallow alone does not fume at a low heat, though it emits a ſmell ſomething like that of oil olive. When the proportion of the acid was conſiderable, ſmall needled cryſtals appeared as the temperature diminiſhed. The appearances of ſeparation are different according to the quantity of acid. The compound has the hardneſs and conſiſtence of firm ſoap, and is partially tranſparent. 8. Vitriolated tartar, nitre, white ſugar, cream of tartar, cryſtallized borax, and the ſalt ſold in the markets under the name of ſalt of lemons, but which is ſuppoſed to be the eſſential ſalt of ſorrel, or vegetable alkali ſuperſaturated with acid of ſugar, were reſpectively tried without any obvious mutual action or change of properties in the tallow. 9. Calcined magneſia rendered tallow opaque and turbid, but did not ſeem to diſſolve. Its effect reſembled that of lime.

“ It is propoſed to try the oxygenated acetous acid, or radical vinegar; the acid of ants, of ſugar, of borax, of galls, the tanning principle, the ſerous and gelatinous animal matter, the fecula of vegetables, vegetable gluten, bird-lime, and other principles, either by direct or indirect application. The object, in a commercial point of view, is intitled to an extenſive and aſſiduous inveſtigation. Chemiſts in general ſuppoſe the hardneſs or leſs fuſibility of wax to ariſe from oxygen; and to this object it may perhaps be advantageous to direct a certain portion of the inquiry. The metallic ſalts and calces are the combinations from which this principle is moſt commonly obtained; but the combinations of theſe with fat oils have hitherto afforded little promiſe of the improvement here ſought. The ſubject is, however, ſo little known, that experiments of the looſeſt and moſt conjectural kind are by no means to be deſpiſed.”

Thus far Mr Nicholſon : but it is probable that many of the advantages which he propoſes by theſe mixtures might be obtained merely by purifying the tallow, and keeping it in that ſtate for a long time expoſed to the air before it be formed into candles. It is certain that tallow is rendered more difficult of fuſion by age ; and this is the ſole reaſon that old candles are leſs apt to run, and therefore more valuable than ſuch as have been lately made.

CANONGOES, in Bengal, are the regiſters of land and hereditary expounders of the uſages of the country. They have their officers and deputies everywhere ; they are not liable to removal ; and all papers atteſted by them are received as authentic and deciſive in all diſputes relative to lands and their boundaries. See *Sir Charles Rouſe Boughton's Diſſertation on the Landed Property of Bengal.*

CAOUTCHOUC, ELASTIC GUM, or *Indian Rubber*, is a ſubſtance of which a pretty full account has been given in the Encyclopædia. It has there been likewiſe obſerved how uſeful it might be, if we could form it into catheters and other flexible inſtruments, by diſſolving it in a menſtruum leſs expenſive, or at leaſt more eaſily attained, than ether. Since that article was publiſhed, we have ſeen an account of ſuch a menſtruum in the *Annales de Chimie*, by M. Groſſart (Chirly) ; and of the expence of that menſtruum, or the difficulty of procuring it, no complaint will be made, when it is known to be nothing more than very hot water.

The author was led to this diſcovery by ſome experiments made with ether on caoutchouc ; of which he gives the following account :

" It appeared, even in my firſt experiments, that I was attempting too much, and giving myſelf uſeleſs trouble, in ſearching for a manner of completely diſſolving the elaſtic gum, ſo that it might be again made up in new forms. I then thought that it would be eaſier to find out a method, as it were, of ſoldering it, and of not acting upon it more than might be neceſſary to cauſe its ſoftened parts to reunite. Experience has ſhewn me, that a ſtrong preſſure made upon two pieces of caoutchouc (when brought to that ſtate of ſoftneſs) and continued until they are entirely dry, cauſed them to contract ſo ſtrong an adheſion, that the piece, being pulled out till it broke, often broke, not at the united part, but by the ſide of it.

" By means of ether I immediately ſucceeded in making theſe tubes. The method which appears to me to ſucceed the beſt is, to cut a bottle circularly in a ſpiral ſlip of a few lines in breadth. It is very eaſy to cut a bottle in ſuch a manner as to form a ſingle long ſlip, and thus unneceſſary joinings are avoided.

" The whole ſlip is to be plunged into ether until it is ſufficiently ſoftened, which comes to paſs ſooner or later according to the quality of the vitriolic ether that is employed. Half an hour frequently ſuffices ; but I have already obſerved, that there is a great diverſity in the manner in which different ſorts of vitriolic ether act, and of which the cauſe is not yet, ſo far as I know, determined.

" The ſlip being taken out, one of the extremities is to be taken hold of and rolled, firſt upon itſelf at the bottom of the tube, preſſing it ; then the rolling is to be continued, mounting ſpirally along the mould, and taking care to lay over and compreſs with the hand every edge, one againſt the other, ſo that there may not be any vacant ſpace, and that all the edges may join exactly. The whole then is to be bound hard with a tape of an inch in width, taking care to turn it the ſame way with the ſlip of elaſtic gum. The tape is to be tied up with packthread, ſo that, by every turn of the packthread joining another, an equal preſſure is given to every part : it is then left to dry, and the tube is made.

" The bandage is to be taken off with great care, that none of the outward ſurfaces, which may have been lodged within the hollows of the tape (of which the caoutchouc takes the exact impreſſion), may be pulled away. I adviſe the application of a tape before packthread, becauſe, eſpecially in the thinner tubes, we ſhould run the riſk of cutting the caoutchouc if the packthread were applied immediately upon it.

" It is eaſy to take off the tube of elaſtic gum which has been formed upon a ſolid mould of one piece : if the mould be made rather conic, it may be made to ſlide off by the ſmaller end ; at the worſt, it is eaſily accompliſhed by plunging it into hot water ; for it is ſoftened by the heat, and is diſtended : without this precaution it would be ſometimes difficult to draw it off when dry, becauſe, having been applied upon the mould whilſt it had its volume augmented by the interpoſition of the ether, the parts of the caoutchouc are drawn nearer each other by the evaporation of the interpoſed bodies.

" The great affinity between theſe two bodies is ſeen by the length of time that the odour of the ether remains, notwithſtanding the great volatility of the latter, and that the apparent dryneſs of the tube ſeems to ſhew that there is none remaining ; nevertheleſs, after a certain time, the odour diſappears entirely. One of thoſe tubes, which was made with ether after the method here deſcribed, does not retain the leaſt trace of the ſolvent. It is needleſs to ſay that it is eaſy to make tubes as thin or as thick as may be judged proper.

" Although the proceſs that I am now deſcribing is but very little expenſive, yet I have tried to employ other ſolvents in lieu of ether, becauſe it is not to be had in every place, and requires particular care in its preſervation. I have employed, with ſome ſucceſs, the eſſential oils of lavender and of turpentine: both of them ſpeedily dilate the caoutchouc, and are of no great price. The diſagreeable ſmell of the oil of turpentine becomes, perhaps, in proceſs of time, leſs diſagreeable than that of lavender. This laſt is dearer : but the difference is not ſo great as it appears at firſt; for we may make ſome advantage of the oil of lavender that is employed by the following operation : Upon plunging into alcohol the elaſtic tube prepared with the oil of lavender, the alcohol charges itſelf with the oil, and forms a very good lavender water; the ſame as would be made by an immediate mixture of oil of lavender with ſpirit of wine. Immerſion in this liquor alſo ſerves to haſten the drying of the caoutchouc inſtruments thus made by means of eſſential oils. I have made tubes with the oils of turpentine and of lavender; both are much ſlower in evaporating than ether. The oil of turpentine particularly appeared to me always to have a kind of ſtickineſs, and I know not as yet that we have any means whereby to get ſpeedily rid of its ſmell.

" Nevertheleſs there is a ſolvent which has not that inconvenience; it is cheaper, and may eaſily be procured by every one: this ſolvent is *water*. I conceive it will appear ſtrange to mention water as a ſolvent of elaſtic gum, that liquid having been always ſuppoſed to have no action upon it. I myſelf reſiſted the idea; but reflecting that ether, by being ſaturated with water, is the better enabled to act on caoutchouc, and that this gum when plunged into boiling water becomes more tranſparent at the edges, I preſumed that this effect was not due ſimply to the dilatation of its volume by the heat. I thought that, at that temperature, ſome action might take place, and that a long-continued ebullition might produce more ſenſible effects. I was not diſappointed in my expectations, and one of thoſe tubes was prepared without any other ſolvent than water and heat. I proceeded in the ſame manner as with ether: the elaſtic gum dilates but very little in boiling water; it becomes whitiſh, but recovers its colour again by drying it in the air and light. It is ſufficiently prepared for uſe when it has been a quarter of an hour in boiling water: by this time its edges are ſometimes tranſparent. It is to be turned ſpirally round the mould, in the manner we deſcribed before, and replunged frequently into the boiling water during the time that is employed in forming the tube, to the end that the edges may be diſpoſed to unite together. When the whole is bound with packthread, it is to be kept ſome hours in boiling water; after which it is to be dried, ſtill keeping on the binding.

" If we wiſh to be more certain that the connection is perfect, the ſpiral may be doubled; but we muſt always avoid placing the exterior ſurfaces of the ſlips one upon the other, as thoſe ſurfaces are the parts which moſt reſiſt the action of ſolvents. This precaution is leſs neceſſary when ether is employed, on account of its great action upon the caoutchouc.

" It might be feared that the action of water upon caoutchouc would deprive us of the advantages which might otherwiſe be expected; but theſe fears will be removed, if we conſider that the affinities differ according to the temperatures; that it is only at a very high temperature that water exerciſes any ſenſible action upon caoutchouc. I can affirm, that at 120° of Reaumur's thermometer (302° of Fahrenheit) this affinity is not ſuch as that the water can give a liquid form to caoutchouc; and it does not appear that we have any thing to fear in practice from a combination between theſe two bodies, which, though it really is a true ſolution, does not take place in any ſenſible degree but at a high temperature. It is therefore at preſent eaſy to make of caoutchouc whatever inſtruments it may be advantageous to have of a flexible, ſupple, and elaſtic ſubſtance, which is impermeable to water at the temperature of our atmoſphere, and reſiſts the action of acids as well as that of moſt other ſolvents. As to the durability of theſe inſtruments, few ſubſtances promiſe more than this, becauſe it may be ſoldered afreſh in a damaged part. Any woven ſubſtance may be covered with it; it is only required that the ſubſtance ſhould be of a nature not to be acted upon during the preparation, either by ether or by boiling water; for theſe two agents are thoſe which appear to me to merit the preference. Artiſts will frequently find an advantage in employing ether, as it requires leſs time; ſo that a perſon may make, in a ſingle day, any tube he may have occaſion for. The expence of ether is very little, ſince it is needful only to diſpoſe the caoutchouc to adhere; and being brought into that ſtate, the caoutchouc may be kept in a veſſel perfectly well cloſed. It would alſo diminiſh the expence of the ether if, inſtead of waſhing it with a large quantity of water, there ſhould be added to it only as much water as it can take up."

CAP and BUTTON, are two ſmall iſlands, or rather rocks, lying in longitude 105° 48′ 30″ eaſt; and in latitude, the former 5° 58′ 30″, the latter 5° 49′ ſouth. They were viſited by ſome of the perſons attending Lord Macartney on his embaſſy to China; and are thus deſcribed by Sir George Staunton.

" At a little diſtance they might be miſtaken for the remains of old caſtles, mouldering into heaps of ruins, with tall trees already growing upon the tops; but at a nearer view, they betrayed evident marks of a volcanic origin. Exploſions from ſubterraneous fires, produce, for the moſt part, hills of a regular ſhape, and terminating in truncated cones; but when from a ſubaqueous volcano eruptions are thrown up above the ſurface of the ſea, the materials, falling back into the water, are more irregularly diſperſed, and generally leave the ſides of the new creation naked and miſhapen, as in the inſtance of AMSTERDAM, and of thoſe ſmaller ſpots called, from ſome reſemblance in ſhape, the Cap and Button.

" In the Cap were found two caverns, running horizontally into the ſide of the rock; and in theſe were a number of thoſe birds neſts ſo much prized by the Chineſe epicures. They ſeemed to be compoſed of fine filaments cemented together by a tranſparent viſcous matter, not unlike what is left by the foam of the ſea upon ſtones alternately covered by the tide, or thoſe gelatinous animal ſubſtances found floating on every coaſt. The neſts adhere to each other, and to the ſides of the cavern, moſtly in rows, without any break or interruption. The birds that build theſe neſts are ſmall grey ſwallows, with bellies of a dirty white. They were flying about in conſiderable numbers; but they were ſo ſmall, and their flight ſo quick, that they eſcaped the ſhot fired at them. The ſame neſts are ſaid alſo to be found in deep caverns, at the foot of the higheſt mountains in the middle of Java, and at a diſtance from the ſea, from which the birds, it is thought, derive no materials, either for their food or the conſtruction of their neſts; as it does not appear probable they ſhould fly, in ſearch of either, over the intermediate mountains, which are very high, or againſt the boiſterous winds prevailing thereabouts. They feed on inſects, which they find hovering over ſtagnated pools between the mountains, and for catching which their wide opening beaks are particularly adapted. They prepare their neſts from the beſt remnants of their food. Their greateſt enemy is the kite, who often intercepts them in their paſſage to and from the caverns, which are generally ſurrounded with rocks of grey limeſtone or white marble. The neſts are placed in horizontal rows at different depths, from 50 to 500 feet. The colour and value of the neſts depend on the quantity and quality of the inſects caught, and perhaps alſo on the ſituation where they are built. Their value is chiefly determined by the uniform fineneſs and delicacy of their texture; thoſe that are white and tranſparent being moſt eſteemed, and fetching often in China their weight in ſilver.

Theſe neſts are a conſiderable object of traffic among the Javaneſe, and many are employed in it from their infancy. The birds having ſpent near two months in preparing their neſts, lay each two eggs, which are hatched in about fifteen days. When the young birds become fledged, it is thought time to ſeize upon their neſts, which is done regularly thrice a-year, and is effected by means of ladders of bamboo and reeds, by which the people deſcend into the cavern; but when it is very deep, rope ladders are preferred. This operation is attended with much danger; and ſeveral break their necks in the attempt. The inhabitants of the mountains generally employed in it begin always by ſacrificing a buffalo; which cuſtom is conſtantly obſerved by the Javaneſe on the eve of every extraordinary enterpriſe. They alſo pronounce ſome prayers, anoint themſelves with ſweet-ſcented oil, and ſmoke the entrance of the cavern with gum-benjamin. Near ſome of thoſe caverns a tutelar goddeſs is worſhipped, whoſe prieſt burns incenſe, and lays his protecting hands on every perſon preparing to deſcend into the cavern. A flambeau is carefully prepared at the ſame time, with a gum which exudes from a tree growing in the vicinity, and is not eaſily extinguiſhed by fixed air or ſubterraneous vapours. The ſwallow which builds thoſe neſts is deſcribed as not having its tail feathers marked with white ſpots, which is a character attributed to it by Linnæus; and it is poſſible that there are two ſpecies or varieties of the ſwallow, whoſe neſts are alike valuable." See *Birds-Neſts*, Encycl.

CAPE of Good Hope. See *Good Hope*, both in *Encycl.* and this *Supplement*.

CAPITAL of a Bastion, is an imaginary line dividing any work into two equal and ſimilar parts; or a line drawn from the angle of the polygon to the point of the baſtion, or from the point of the baſtion to the middle of the gorge.

CAPRA, or the She-goat, a name given to the ſtar Capella, on the left ſhoulder of Auriga, and ſometimes to the conſtellation Capricorn. Some again repreſent Capra as a conſtellation in the northern hemiſphere, conſiſting of three ſtars, compriſed between the 45th and 55th degree of latitude.—The poets fable her to be Amalthea's goat, which ſuckled Jupiter in his infancy.

CAPUT Draconis, or *Dragon's Head*, a name given by ſome to a fixed ſtar of the firſt magnitude, in the head of the conſtellation Draco.

CARBON. See Chemistry in this *Supplement*, Part I. Chap. II. Sect. iii.

CARP. See Cyprinus, both in the *Encycl.* and in this *Supplement*.

CARPENTRY,

1 efinition. THE art of framing timber for the purpoſes of architecture, machinery, and, in general, for all conſiderable ſtructures.

It is not intended in this article to give a full account of carpentry as a *mechanical* art, or to deſcribe the various ways of executing its different works, ſuited to the variety of materials employed, the proceſſes which muſt be followed for faſhioning and framing them for our purpoſes, and the tools which muſt be uſed, and the manner in which they muſt be handled: This would be an occupation for volumes; and though of great importance, muſt be entirely omitted here. Our only aim at preſent will be to deduce, from the principles and laws of mechanics, and the knowledge which experience and judicious inferences from it have given us concerning the ſtrength of timber, in relation to the ſtrain laid on it, ſuch maxims of conſtruction as will unite economy with ſtrength and efficacy.

This object is to be attained by a knowledge, 1ſt, of the ſtrength of our materials, and of the abſolute ſtrain that is to be laid on them; 2dly, of the modifications of this ſtrain, by the place and direction in which it is exerted, and the changes that can be made by a proper diſpoſition of the parts of our ſtructure; and, 3dly, having diſpoſed every piece in ſuch a manner as to derive the utmoſt advantage from its relative ſtrength, we muſt know how to form the joints and other connections in ſuch a manner as to ſecure the advantages derived from this diſpoſition.

2
n impor-
nt branch
mechani-
l ſcience

This is, evidently, a branch of mechanical ſcience, which makes carpentry a *liberal* art, conſtitutes part of the learning of the Engineer, and diſtinguiſhes him from the workman. Its importance in all times and ſtates of civil ſociety is manifeſt and great. In the preſent condition of theſe kingdoms, raiſed, by the active ingenuity and energy of our countrymen, to a pitch of proſperity and influence unequalled in the hiſtory of the world, a condition which conſiſts chiefly in the ſuperiority of our manufactures, attained by prodigious multiplication of engines of every deſcription, and for every ſpecies of labour, the Science (ſo to term it) of carpentry is of immenſe conſequence. We regret therefore exceedingly, that none of our celebrated artiſts have done honour to themſelves and their country, by digeſting into a body of conſecutive doctrines the reſults of their great experience, ſo as to form a ſyſtem from which their pupils might derive the firſt principles of their education. The many volumes called Complete Instructors, Manuals, Jewels, &c. take a much humbler flight, and content themſelves with inſtructing the mere workman, or ſometimes give the maſter-builder a few approved forms of roofs and other framings, with the rules for drawing them on paper; and from thence forming the working draughts which muſt guide the ſaw and the chiſſel of the workman. Hardly any of them offer any thing that can be called a principle, applicable to many particular caſes, with the rules for this adaptation. We are indebted for the greateſt part of our knowledge of this ſubject to the labours of literary men, chiefly foreigners, who have publiſhed in the memoirs of the learned academies diſſertations on different parts of what may be termed the *ſcience of carpentry*. It is ſingular that the members of the Royal Society of London, and even of that eſtabliſhed and ſupported by the patriotiſm of theſe days for the encouragement of the arts, have contributed ſo little to the public inſtruction in this reſpect. We obſerve of late ſome beginnings of this kind, ſuch as the laſt part of Nicholſon's

3
Principally indebted to foreigners for a knowledge of this ſubject.

Nicholſon's Carpenters and Joiners Assistant, publiſhed by J. Taylor, Holborn, 1797. And it is with pleaſure that we can ſay, that we were told by the editor, that this work was prompted in a great meaſure by what has been delivered in the *Encyclopædia Britannica* in the articles Roof and *Strength of Materials*. It abounds more in important and new obſervations than any book of the kind that we are acquainted with. We again call on ſuch as have given a ſcientific attention to this ſubject, and pray that they would render a meritorious ſervice to their country by imparting the reſult of their reſearches. The very limited nature of this work does not allow us to treat the ſubject in detail; and we muſt confine our obſervations to the fundamental and leading propoſitions.

4
Theory, founded on what.

The theory (ſo to term it) of carpentry is founded on two diſtinct portions of mechanical ſcience, namely, a knowledge of the ſtrains to which framings of timber are expoſed, and a knowledge of their *relative* ſtrength.

We ſhall therefore attempt to bring into one point of view the propoſitions of mechanical ſcience that are more immediately applicable to the art of carpentry, and are to be found in various articles of our work, particularly Roof and *Strength of Materials*. From theſe propoſitions we hope to deduce ſuch principles as ſhall enable an attentive reader to comprehend diſtinctly what is to be aimed at in framing timber, and how to attain this object with certainty: and we ſhall illuſtrate and confirm our principles by examples of pieces of carpentry which are acknowledged to be excellent in their kind.

5
Compoſition and reſolution of forces

The moſt important propoſition of general mechanics to the carpenter is that which exhibits the compoſition and reſolution of forces; and we beg our practical readers to endeavour to form very diſtinct conceptions of it, and to make it very familiar to their mind. When accommodated to their chief purpoſes, it may be thus expreſſed:

Plate VIII.

1. If a body, or any part of a body, be at once preſſed in the two directions AB, AC (fig. 1), and if the intenſity or force of thoſe preſſures be in the proportion of theſe two lines, the body is affected in the ſame manner as if it were preſſed by a ſingle force acting in the direction AD, which is the diagonal of the parallelogram ABDC formed by the two lines, and whoſe intenſity has the ſame proportion to the intenſity of each of the other two that AD has to AB or AC.

Such of our readers as have *ſtudied* the laws of motion, know that this is fully demonſtrated. We refer them to the article Mechanics, n° 5, &c. where it is treated at ſome length. Such as wiſh for a very accurate view of this propoſition, will do well to read the demonſtration given by D. Bernoulli, in the firſt volume of the *Comment. Petropol.* and the improvement of this demonſtration by D'Alembert in his *Opuſcles*, and in the *Comment. Taurinenſ.* The practitioner in carpentry will get more uſeful confidence in the doctrine, if he will ſhut his book, and verify the theoretical demonſtrations by actual experiments. They are remarkably eaſy and convincing. Therefore it is our requeſt that the artiſt, who is not ſo habitually acquainted with the ſubject, do not proceed further till he has made it quite familiar to his thoughts. Nothing is ſo conducive to this as the actual experiment; and ſince this only requires the trifling expence of two ſmall pulleys and a few yards of whipcord, we hope that none of our practical readers will omit it: They will thank us for this injunction.

6
Illuſtrated by experiment.

2. Let the threads A *d*, AF *b*, and AE *c* (fig. 2.), have the weights *d*, *b*, and *c*, appended to them, and let two of the threads be laid over the pulleys F and E. By this apparatus the knot A will be drawn in the directions AB, AC, and AK. If the ſum of the weights *b* and *c* be greater than the ſingle weight *d*, the aſſemblage will of itſelf ſettle in a certain determined form; if you pull the knot A out of its place, it will always return to it again, and will reſt in no other poſition. For example, if the three weights are equal, the threads will always make equal angles, of 120 degrees each, round the knot. If one of the weights be three pounds, another four, and the third five, the angle oppoſite to the thread ſtretched by five pounds will always be ſquare, &c. When the knot A is thus in equilibrio, we muſt infer, that the action of the weight *d*, in the direction A *d*, is in direct oppoſition to the combined action of *b*, in the direction AB, and of *c*, in the direction AC. Therefore, if we produce *d* A to any point D, and take AD to repreſent the magnitude of the force, or preſſure exerted by the weight *d*, the preſſures exerted on A by the weights *b* and *c*, in the directions AB, AC, are in fact equivalent to a preſſure acting in the direction AD, whoſe intenſity we have repreſented by AD. If we now meaſure off by a ſcale on AF and AE the lines AB and AC, having the ſame proportions to AD that the weights *b* and *c* have to the weight *d*, and if we draw DB and DC, we ſhall find DC to be equal and parallel to AB, and DB equal and parallel to AC; ſo that AD is the diagonal of a parallelogram ABDC. We ſhall find this always to be the caſe, whatever are the weights made uſe of; only we muſt take care that the weight which we cauſe to act without the intervention of a pulley be leſs than the ſum of the other two: if any one of the weights exceeds the ſum of the other two, it will prevail, and drag them along with it.

Now, ſince we know that the weight *d* would juſt balance an equal weight *g*, pulling directly upwards by the intervention of the pulley G; and ſince we ſee that it juſt balances the weights *b* and *c*, acting in the directions AB, AC, we muſt infer, that the knot A is affected in the ſame manner by thoſe two weights, or by the ſingle weight *g*; and therefore that *two preſſures, acting in the directions, and with the intenſities,* AB, AC, *are equivalent to a ſingle preſſure having the direction and proportion of* AD. In like manner, the preſſures AB, AK, are equivalent to AH, which is equal and oppoſite to AC. Alſo AK and AC are equivalent to AI, which is equal and oppoſite to AB.

7
Conſidered more particularly.

We ſhall conſider this combination of preſſures a little more particularly.

Suppoſe an upright beam BA (fig. 3.) puſhed in the direction of its length by a load B, and abutting on the ends of two beams AC, AD, which are firmly reſiſted at their extreme points C and D, which reſt on two blocks, but are nowiſe joined to them: theſe two beams can reſiſt no way but in the directions CA, DA; and therefore the preſſures which they ſuſtain from the beam BA are in the directions AC, AD. We wiſh to know how much each ſuſtains? Produce BA to E, taking

taking AE from a ſcale of equal parts, to repreſent the number of tons or pounds by which BA is preſſed. Draw EF and EG parallel to AD and AC; then AF, meaſured on the ſame ſcale, will give us the number of pounds by which AC is ſtrained or cruſhed, and AG will give the ſtrain on AD.

It deſerves particular remark here, that the length of AC or AD has no influence on the ſtrain, ariſing from the thruſt of BA, while the directions remain the ſame. The effects, however, of this ſtrain are modified by the length of the piece on which it is exerted. This ſtrain compreſſes the beam, and will therefore compreſs a beam of double length twice as much. This may change the form of the aſſemblage. If AC, for example, be very much ſhorter than AD, it will be much leſs compreſſed: The line CA will turn about the centre C, while DA will hardly change its poſition; and the angle CAD will grow more open, the point A ſinking down. The artiſt will find it of great conſequence to pay a very minute attention to this circumſtance, and to be able to ſee clearly the change of ſhape which neceſſarily reſults from theſe mutual ſtrains. He will ſee in this the cauſe of failure in many very great works.—By thus changing ſhape, ſtrains are often produced in places where there were none before, and frequently of the very worſt kind, tending to break the beams acroſs.

The dotted lines of this figure ſhew another poſition of the beam AD′. This makes a prodigious change, not only in the ſtrain on AD′, but alſo in that on AC. Both of them are much increaſed; AG is almoſt doubled, and AF is four times greater than before. This addition was made to the figure, to ſhew what enormous ſtrains may be produced by a very moderate force AE, when it is exerted on a very obtuſe angle.

The 4th and 5th figures will aſſiſt the moſt uninſtructed reader in conceiving how the very ſame ſtrains AF, AG, are laid on theſe beams, by a weight ſimply hanging from a billet reſting on A, preſſing hard on AD, and alſo leaning a little on AC; or by an upright piece AE, joggled on the two beams AC, AD, and performing the office of an ordinary king-poſt. The reader will thus learn to call off his attention from the means by which the ſtrains are produced, and learn to conſider them abſtractedly, merely as ſtrains, in whatever ſituation he finds them, and from whatever cauſe they ariſe.

We preſume that every reader will perceive, that the proportions of theſe ſtrains will be preciſely the ſame if every thing be inverted, and each beam be drawn or pulled in the oppoſite direction. In the ſame way that we have ſubſtituted a rope and weight in fig. 4. or a king-poſt in fig. 5. for the loaded beam BA of fig. 3. we might have ſubſtituted the framing of fig. 6. which is a very uſual practice. In this framing, the batten DA is ſtretched by a force AG, and the piece AC is compreſſed by a force AF. It is evident that we may employ a rope, or an iron rod hooked on at D, in place of the batten DA, and the ſtrains will be the ſame as before.

This ſeemingly ſimple matter is ſtill full of inſtruction; and we hope that the well-informed reader will pardon us, though we dwell a little longer on it for the ſake of the young artiſt.

By changing the form of this framing, as in fig. 7. we produce the ſame ſtrains as in the diſpoſition repreſented by the dotted lines in fig. 3. The ſtrains on both the battens AD, AC, are now greatly increaſed.

The ſame conſequences reſult from an improper change of the poſition of AC. If it is placed as in fig. 8. the ſtrains on both are vaſtly increaſed. In ſhort, the rule is general; that the more open we make the angle againſt which the puſh is exerted, the greater are the ſtrains which are brought on the ſtruts or ties which form the ſides of the angle.

The reader may not readily conceive the piece AC of fig. 8. as ſuſtaining a compreſſion; for the weight B appears to hang from AC as much as from AD. But his doubts will be removed by conſidering whether he could employ a rope in place of AC. He cannot: But AD may be exchanged for a rope. AC is therefore a ſtrut and not a tie.

In fig. 9. AD is again a ſtrut, butting on the block D, and AC is a tie: and the batten AC may be replaced by a rope. While AD is compreſſed by the force AG, AC is ſtretched by the force AF.

If we give AC the poſition repreſented by the dotted lines, the compreſſion of AD is now AG′, and the force ſtretching AC′ is now AF′; both much greater than they were before. This diſpoſition is analogous to fig. 8. and to the dotted lines in fig. 3. Nor will the young artiſt have any doubts of AC′ being on the ſtretch, if he conſider whether AD can be replaced by a rope. It cannot, but AC′ may; and it is therefore not compreſſed, but ſtretched.

In fig. 10. all the three pieces, AC, AD, and AB, are ties on the ſtretch. This is the complete inverſion of fig. 3.; and the dotted poſition of AC induces the ſame changes in the forces AF′, AG′, as in fig. 3.

Thus have we gone over all the varieties which can happen in the bearings of three pieces on one point. All calculations about the ſtrength of carpentry are reduced to this caſe: for when more ties or braces meet in a point (a thing that rarely happens), we reduce them to three, by ſubſtituting for any two the force which reſults from their combination, and then combining this with another; and ſo on.

The young artiſt muſt be particularly careful not to miſtake the kind of ſtrain that is exerted on any piece of the framing, and ſuppoſe a piece to be a brace which is really a tie. It is very eaſy to avoid all miſtakes in this matter by the following rule, which has no exception.

8
Rule for diſtinguiſhing the caſes of compreſſion and extenſion.

Take notice of the direction in which the piece acts from which the ſtrain proceeds. Draw a line in that direction *from* the point on which the ſtrain is exerted; and let its length (meaſured on ſome ſcale of equal parts) expreſs the magnitude of this action in pounds, hundreds, or tons. From its *remote* extremity draw lines parallel to the pieces on which the ſtrain is exerted. The line parallel to one piece will neceſſarily cut the other, or its direction produced: If it cut the piece itſelf, that piece is compreſſed by the ſtrain, and it is performing the office of a ſtrut or brace: if it cut its direction produced, the piece is ſtretched, and it is a tie. In ſhort, the ſtrains on the pieces AC, AD, are to be eſtimated in the direction of the points F and G *from* the ſtrained point A. Thus, in fig. 3. the upright piece BA, loaded with the weight B, preſſes the point A in the direction AE: ſo does the rope AB in the other figures, or the batten AB in fig. 5.

In general, if the ſtraining piece is within the angle formed by the pieces which are ſtrained, the ſtrains which they ſuſtain are of the oppoſite kind to that which it exerts. If it be puſhing, they are drawing; but if it be within the angle formed by their directions produced, the ſtrains which they ſuſtain are of the ſame kind. All the three are either drawing or preſſing. If the ſtraining piece lie within the angle formed by one piece and the produced direction of the other, its own ſtrain, whether compreſſion or extenſion, is of the ſame kind with that of the moſt remote of the other two, and oppoſite to that of the neareſt. Thus, in fig. 9. where AB is drawing, the remote piece AC is alſo drawing, while AD is puſhing or reſiſting compreſſion.

In all that has been ſaid on this ſubject, we have not ſpoken of any joints. In the calculations with which we are occupied at preſent, the reſiſtance of joints has no ſhare; and we muſt not ſuppoſe that they exert any force which tends to prevent the angles from changing. The joints are ſuppoſed perfectly flexible, or to be like compaſs joints; the pin of which only keeps the pieces together when one or more of the pieces draws or pulls. The carpenter muſt always ſuppoſe them all compaſs joints when he calculates the thruſts and draughts of the different pieces of his frames. The ſtrains on joints, and their power to produce or balance them, are of a different kind, and require a very different examination.

9
General expreſſion of the magnitude of the ſtrain.

Seeing that the angles which the pieces make with each other are of ſuch importance to the magnitude and the proportion of the excited ſtrains, it is proper to find out ſome way of readily and compendiouſly conceiving and expreſſing this analogy.

In general, the ſtrain on any piece is proportional to the ſtraining force. This is evident.

Secondly, the ſtrain on any piece AC is proportional to the ſine of the angle, which the ſtraining force makes with the other piece directly, and to the ſine of the angle which the pieces make with each other inverſely.

For it is plain, that the three preſſures AE, AF, and AG, which are exerted at the point A, are in the proportion of the lines AE, AF, and FE (becauſe FE is equal to AG). But becauſe the ſides of a triangle are proportional to the ſines of the oppoſite angles, the ſtrains are proportional to the ſines of the angles AFE, AEF, and FAE. But the ſine of AFE is the ſame with the ſine of the angle CAD, which the two pieces AC and AD make with each other; and the ſine of AEF is the ſame with the ſine of EAD, which the ſtraining piece BA makes with the piece AC. Therefore we have this analogy, Sin. CAD : Sin. EAD = AE : AF, and $AF = AE \times \frac{\text{Sin. EAD}}{\text{Sin. CAD}}$.—Now the ſines of angles are moſt conveniently conceived as decimal fractions of the radius, which is conſidered as unity. Thus, *Sin.* 30° is the ſame thing with 0,5, or $\frac{1}{2}$; and ſo of others. Therefore, to have the ſtrain on AC, ariſing from any load AE acting in the direction AE, multiply AE by the ſine of EAD, and divide the product by the ſine of CAD.

This rule ſhews how great the ſtrains muſt be when the angle CAD becomes very open, approaching to 180 degrees. But when the angle CAD becomes very ſmall, its ſine (which is our diviſor) is alſo very ſmall; and we ſhould expect a very great quotient in this caſe alſo. But we muſt obſerve, that in this caſe the ſine of EAD is alſo very ſmall; and this is our multiplier. In ſuch a caſe, the quotient cannot exceed unity.

But it is unneceſſary to conſider the calculation by the tables of ſines more particularly. The angles are ſeldom known any otherwiſe but by drawing the figure of the frame of carpentry. In this caſe, we can always obtain the meaſures of the ſtrains from the ſame ſcale, with equal accuracy, by drawing the parallelogram AFCG.

10
Strains propagated to the points of ſupport.

Hitherto we have conſidered the ſtrains excited at A only as they affect the pieces on which they are exerted. But the pieces, in order to ſuſtain, or be ſubject to, any ſtrain, muſt be ſupported at their ends C and D; and we may conſider them as mere intermediums, by which theſe ſtrains are made to act on thoſe points of ſupport: Therefore AF and AG are alſo meaſures of the forces which preſs or pull at C and D. Thus we learn the ſupports which muſt be found for theſe points. Theſe may be infinitely various. We ſhall attend only to ſuch as ſomehow depend on the framing itſelf.

11
Action of a ſtraining beam.

Such a ſtructure as fig. 11. very frequently occurs, where a beam BA is ſtrongly preſſed to the end of another beam AD, which is prevented from yielding, both becauſe it lies on another beam HD, and becauſe its end D is hindered from ſliding backwards. It is indifferent from what this preſſure ariſes: we have repreſented it as owing to a weight hung on at B, while B is withheld from yielding by a rod or rope hooked to the wall. The beam AD may be ſuppoſed at full liberty to exert all its preſſure on D, as if it were ſupported on rollers lodged in the beam HD; but the loaded beam BA preſſes both on the beam AD and on HD. We wiſh only to know what ſtrain is borne by AD?

All bodies act on each other in the direction perpendicular to their touching ſurfaces; therefore the ſupport given by HD is in a direction perpendicular to it. We may therefore ſupply its place at A by a beam AC, perpendicular to HD, and firmly ſupported at C. In this caſe, therefore, we may take AE, as before, to repreſent the preſſure exerted by the loaded beam, and draw EG perpendicular to AD, and EF parallel to it, meeting the perpendicular AC in F. Then AG is the ſtrain compreſſing AD, and AF is the preſſure on the beam HD.

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

It may be thought, that ſince we aſſume as a principle that the mutual preſſures of ſolid bodies are exerted perpendicular to their touching ſurfaces, this balance of preſſures, in framings of timbers, depends on the directions of their butting joints: but it does not, as will readily appear by conſidering the preſent caſe. Let the joint or abutment of the two pieces BA, AD be mitred, in the uſual manner, in the direction *f* A *f'*. Therefore, if A *e* be drawn perdendicular to A *f*, it will be the direction of the actual preſſure exerted by the loaded beam BA on the beam AD. But the reaction of AD, in the oppoſite direction A *t*, will not balance the preſſure of BA; becauſe it is not in the direction preciſely oppoſite. BA will therefore ſlide along the joint, and preſs on the beam HD. AE repreſents the load on the mitre joint A. Draw E *e* perpendicular to A*e*, and E *f* parallel to it. The preſſure AE will be balanced by the reactions *e* A and *f* A: or, the preſſure AE produces the preſſures A *e* and A *f*; of of which Af muſt be reſiſted by the beam HD, and Ae by the beam AD. The preſſure Af not being perpendicular to HD, cannot be fully reſiſted by it; becauſe (by our aſſumed principle) it reacts only in a direction perpendicular to its ſurface. Therefore draw fp, fi parallel to HD, and perpendicular to it. The preſſure Af will be reſiſted by HD with the force pA; but there is required another force iA, to prevent the beam BA from ſlipping outwards. This muſt be furniſhed by the reaction of the beam DA.—In like manner, the other force Ae cannot be fully reſiſted by the beam AD, or rather by the prop D, acting by the intervention of the beam; for the action of that prop is exerted through the beam in the direction DA. The beam AD, therefore, is preſſed to the beam HD by the force Ae, as well as by Af. To find what this preſſure on HD is, draw eg perpendicular to HD, and eo parallel to it, cutting EG in r. The forces gA and oA will reſiſt, and balance Ae.

Thus we ſee, that the two forces Ae and Af, which are equivalent to AE, are equivalent alſo to Ap, Ai, Ao, and Ag. But becauſe Af and eE are equal and parallel, and Er and fi are alſo parallel, as alſo er and fp, it is evident, that if is equal to rE, or to oF, and iA is equal to re, or to Gg. Therefore the four forces Ag, Ao, Ap, Ai, are equal to AG and AF. Therefore AG is the compreſſion of the beam AD, or the force preſſing it on D, and AF is the force preſſing it on the beam HD. The proportion of theſe preſſures, therefore, is not affected by the form of the joint.

This remark is important; for many carpenters think the form and direction of the butting joint of great importance; and even the theoriſt, by not proſecuting the general principle through *all* its conſequences, may be led into an error. The form of the joint is of no importance, in as far as it affects the ſtrains in the direction of the beams; but it is often of great conſequence, in reſpect to its own firmneſs, and the effect it may have in bruiſing the piece on which it acts, or being crippled by it.

13 rigin cf ne ſtrain n a tie- eam.

The ſame compreſſion of AB, and the ſame thruſt on the point D by the intervention of AD, will obtain, in whatever way the original preſſure on the end A is produced. Thus ſuppoſing that a cord is made faſt at A, and pulled in the direction AE, and with the ſame force, the beam AD will be equally compreſſed, and the prop D muſt react with the ſame force.

But it often happens that the obliquity of the preſſure on AD, inſtead of compreſſing it, ſtretches it; and we deſire to know what tenſion it ſuſtains? Of this we have a familiar example in a common roof. Let the two rafters AC, AD (fig. 12.), preſs on the tie-beam DC. We may ſuppoſe the whole weight to preſs vertically on the ridge A, as if a weight B were hung out there. We may repreſent this weight by the portion Ab of the vertical or plumb line, intercepted between the ridge and the beam. Then drawing bf and bg parallel to AD and AC, Ag and Af will repreſent the preſſures on AC and AD. Produce AC till CH be equal to Af. The point C is forced out in this direction, and with a force repreſented by this line. As this force is not perpendicularly acroſs the beam, it evidently ſtretches it; and this extending force muſt be withſtood by an equal force pulling it in the oppoſite direction. This muſt ariſe from a ſimilar oblique thruſt of the oppoſite rafter on the other end D. We concern ourſelves only with this extenſion at preſent; but we ſee that the coheſion of the beam does nothing but ſupply the balance to the extending forces. It muſt ſtill be ſupported externally, that it *may reſiſt*, and, by reſiſting obliquely, be ſtretched. The points C and D are ſupported on the walls, which they preſs in the directions CK and DO, parallel to Ab. If we draw HK parallel to DC, and HI parallel to CK (that is, to Ab), meeting DC produced in I, it follows from the compoſition of forces, that the point C would be ſupported by the two forces KC and IC. In like manner, making DN = Ag, and completing the parallelogram DMNO, the point D would be ſupported by the forces OD and MD. If we draw go and fk parallel to DC, it is plain that they are equal to NO and CK, while Ao and Ak are equal to DO and CK, and Ab is equal to the ſum of DO and CK (becauſe it is equal to $Ao + Ak$). The weight of the roof is equal to its vertical preſſure on the walls.

Thus we ſee, that while a preſſure on A, in the direction Ab, produces the ſtrains Af and Ag, on the pieces AC and AD, it alſo excites a ſtrain CI or DM in the piece DC. And this completes the mechaniſm of a frame; for all derive their efficacy from the triangles of which they are compoſed, as will appear more clearly as we proceed.

14 External action of a frame.

But there is more to be learned from this. The conſideration of the ſtrains on the two pieces AD and AC, by the action of a force at A, only ſhewed them as the means of propagating the ſame ſtrains in their own direction to the points of ſupport. But, by adding the ſtrains exerted in DC, we ſee that the frame becomes an intermedium, by which exertions may be made on other bodies, in certain directions and proportions; ſo that this frame may become part of a more complicated one, and, as it were, an element of its conſtitution. It is worth while to aſcertain the proportion of the preſſures CK and DO, which are thus exerted on the walls. The ſimilarity of triangles gives the following analogies:

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

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

Alſo, ſince Ab is = DO + CK, we have

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

In general, any two of the three parallel forces Ab, DO, CK, are to each other in the reciprocal proportion of the parts of CD, intercepted between their directions and the direction of the third.

And this explains a ſtill more important office of the frame ADC. If one of the points, ſuch as D, be ſupported, an external power acting at A, in the direction Ab, and with an intenſity which may be meaſured by Ab, may be ſet in equilibrio, with another acting at C, in the direction CL, oppoſite to CK or Ab, and with an intenſity repreſented by CK: for ſince the preſſure CH is partly withſtood by the force IC, or the firmneſs of the beam DC ſupported at D, the force KC will complete the balance. When we do not attend to the ſupport at D, we conceive the force Ab to be balanced by by KC, or KC to be balanced by A *b*. And, in like manner, we may neglect the ſupport or force acting at A, and conſider the force DO as balanced by CK.

15
It becomes a lever.

Thus our frame becomes a lever, and we are able to trace the interior mechanical procedure which gives it its efficacy: it is by the intervention of the forces of coheſion, which connect the points to which the external forces are applied with the ſupported point or fulcrum, and with each other.

Theſe ſtrains or preſſures A *b*, DO, and CK, not being in the directions of the beams, may be called *tranſverſe*. We ſee that by their means a frame of carpentry may be conſidered as a ſolid body: but the example which brought this to our view is too limited for explaining the efficacy which may be given to ſuch conſtructions. We ſhall therefore give a general propoſition, which will more diſtinctly explain the procedure of nature, and enable us to trace the ſtrains as they are propagated through all the parts of the moſt complicated framing, finally producing the exertion of its moſt diſtant points.

16
General propoſition.

We preſume that the reader is now pretty well habituated to the conception of the ſtrains as they are propagated along the lines joining the points of a frame, and we ſhall therefore employ a very ſimple figure.

Let the ſtrong lines ACBD (fig. 13.) repreſent a frame of carpentry. Suppoſe that it is pulled at the point A by a force acting in the direction AE, but that it reſts on a fixed point C, and that the other extreme point B is held back by a power which reſiſts in the direction BF: It is required to determine the proportion of the ſtrains excited in its different parts, the proportion of the external preſſures at A and B, and the preſſure which is produced on the obſtacle or fulcrum C?

It is evident that each of the external forces at A and B tend one way, or to one ſide of the frame, and that each would cauſe it to turn round C if the other did not prevent it; and that if, notwithſtanding their action, it is turned neither way, the forces in actual exertion are in equilibrio by the intervention of the frame. It is no leſs evident that theſe forces concur in preſſing the frame on the prop C. Therefore, if the piece CD were away, and if the joints C and D be perfectly flexible, the pieces CA, CB would be turned round the prop C, and the pieces AD, DB would alſo turn with them, and the whole frame change its form. This ſhews, by the way, and we deſire it to be carefully kept in mind, that the firmneſs or ſtiffneſs of framing depends entirely on the triangles bounded by beams which are contained in it. An open quadrilateral may always change its ſhape, the ſides revolving round the angles. A quadrilateral may have an infinity of forms, without any change of its ſides, by merely puſhing two oppoſite angles towards each other, or drawing them aſunder. But when the three ſides of a triangle are determined, its ſhape is alſo invariably determined; and if two angles be held faſt, the third cannot be moved. It is thus that, by inſerting the bar CD, the figure becomes unchangeable; and any attempt to change it by applying a force to an angle A, immediately excites forces of attraction or repulſion between the particles of the ſtuff which form its ſides. Thus it happens, in the preſent inſtance, that a change of ſhape is prevented by the bar CD. The power at A preſſes its end againſt the prop; and in doing this it puts the bar AD on the ſtretch, and alſo the bar DB. Their places might therefore be ſupplied by cords or metal wires. Hence it is evident that DC is compreſſed, as is alſo AC: and, for the ſame reaſon, CB is alſo in a ſtate of compreſſion; for either A or B may be conſidered as the point that is impelled or withheld. Therefore DA and DB are ſtretched, and are reſiſting with attractive forces. DC and CB are compreſſed, and are reſiſting with repulſive forces. DB is alſo acting with repulſive forces, being compreſſed in like manner: and thus the ſupport of the prop, combined with the firmneſs of DC, puts the frame ADBC into the condition of the two frames in fig. 8 and fig. 9. Therefore the external force at A is really in equilibrio with an attracting force acting in the direction AD, and a repulſive force acting in the direction AK. And ſince all the connecting forces are mutual and equal, the point D is pulled or drawn in the direction DA. The condition of the point B is ſimilar to that of A, and D is alſo drawn in the direction DB. Thus the point D, being urged by the forces in the directions DA and DB, preſſes the beam DC on the prop, and the prop reſiſts in the oppoſite direction. Therefore the line DC is the diagonal of the parallelogram, whoſe ſides have the proportion of the forces which connect D with A and B. This is the principle on which the reſt of our inveſtigation proceeds. We may take DC as the repreſentation and meaſure of their joint effect. Therefore draw CH, CG, parallel to DA, DB. Draw HL, GO, parallel to CA, CB, cutting AE, BF in L and O, and cutting DA, DB in I and M. Complete the parallelograms ILKA, MONB. Then DG and AI are the equal and oppoſite forces which connect A and D; for GD = CH, = AI. In like manner DH and BM are the forces which connect D and B.

The external force at A is in immediate equilibrio with the combined forces, connecting A with D and with C. AI is one of them: Therefore AK is the other; and AL is the compound force with which the external force at A is in immediate equilibrium. This external force is therefore equal and oppoſite to AL. In like manner, the external force at B is equal and oppoſite to BO; and AL is to BO as the external force at A to the external force at B. The prop C reſiſts with forces equal to thoſe which are propagated to it from the points D, A, and C. Therefore it reſiſts with forces CH, CG, equal and oppoſite to DG, DH; and it reſiſts the compreſſions KA, NB, with equal and oppoſite forces C *k*, C *n*. Draw *k l*, *n o* parallel to AD, BD, and draw C *l* Q, C *o* P: It is plain that *k* CH *l* is a parallelogram equal to KAIL, and that C *l* is equal to AL. In like manner C *o* is equal to BO. Now the forces C *k*, CH, exerted by the prop, compoſe the force C *l*; and C *n*, CG compoſe the force C *o*. Theſe two forces C *l*, C *o* are equal and parallel to AL and BO; and therefore they are equal and oppoſite to the external forces acting at A and B. But they are (primitively) equal and oppoſite to the preſſures (or at leaſt the compounds of the preſſures) exerted on the prop, by the forces propagated to C from A, D, and B. Therefore the preſſures exerted on the prop are the ſame as if the external forces were applied there in the ſame directions as they are applied to A and B. Now if we make CV, CZ equal to C *l* and C *o*,

and

and complete the parallelogram CVYZ; it is plain that the force YC is in equilibrio with *l*C and *o*C. Therefore the preſſures at A, C, and B, are ſuch as would balance if applied to one point.

Laſtly, in order to determine their proportions, draw CS and CR perpendicular to DA and DB. Alſo draw A *d*, B *f* perpendicular to CQ and CP; and draw C *g*, C *i* perpendicular to AE, BF.

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

In like manner the triangles CQS and AQ *d* are ſimilar. Alſo the triangles CHR, CGS are ſimilar, by reaſon of the equal angles at H and G, and the right angles at R and S. Hence we obtain the following analogies:

$$\begin{array}{lcl} \mathrm{C}o : \mathrm{CP} = \mathrm{O}n : \mathrm{PB}, = & & \mathrm{CG} : \mathrm{PB} \\ \mathrm{CP} : \mathrm{CR} = & & \mathrm{PB} : f\mathrm{B} \\ \mathrm{CR} : \mathrm{CS} = & & \mathrm{CH} : \mathrm{CG} \\ \mathrm{CS} : \mathrm{CQ} = & & \mathrm{A}d : \mathrm{AQ} \\ \mathrm{CQ} : \mathrm{C}l = \mathrm{AQ} : \mathrm{K}l, = & & \mathrm{AQ} : \mathrm{CH}. \end{array}$$

Therefore, by equality,

$$\begin{array}{lcl} \mathrm{C}o : \mathrm{C}l = & & \mathrm{A}d : f\mathrm{B} \\ \text{or } \mathrm{BO} : \mathrm{AL} = & & \mathrm{C}g : \mathrm{C}i. \end{array}$$

That is, the external forces are reciprocally proportional to the perpendiculars drawn from the prop on the lines of their direction (A).

17 tenſive ſequen-

This propoſition (ſufficiently general for our purpoſe) is fertile in conſequences, and furniſhes many uſeful inſtructions to the artiſt. The ſtrains LA, OB, CY, that are excited, occur, in many, we may ſay in all, framings of carpentry, whether for edifices or engines, and are the ſources of their efficacy. It is alſo evident, that the doctrine of the tranſverſe ſtrength of timber is contained in this propoſition; for every piece of timber may be conſidered as an aſſemblage of parts, connected by forces which act in the direction of the lines which join the ſtrained points on the matter which lies between thoſe points, and alſo act on the reſt of the matter, exciting thoſe lateral forces which produce the inflexibility of the whole. See *Strength of Materials*, Encycl.

Thus it appears that this propoſition contains the principles which direct the artiſt to frame the moſt powerful levers; to ſecure uprights by ſhores or braces, or by ties and ropes; to ſecure ſcaffoldings for the erection of ſpires, and many other moſt delicate problems of his art. He alſo learns, from this propoſition, how to aſcertain the ſtrains that are produced, without his intention, by pieces which he intended for other offices, and which, by their tranſverſe action, put his work in hazard. In ſhort, this propoſition is the key to the ſcience of his art.

We would now counſel the artiſt, after he has made the tracing of the ſtrains and thruſts through the various parts of a frame familiar to his mind, and even amuſed himſelf with ſome complicated fancy framings, to read over with care the articles *Strength of Materials* and Roof in the *Encyclopædia Britannica*. He will now conceive its doctrines much more clearly than when he was conſidering them as abſtract theories. The mutual action of the woody fibres will now be eaſily comprehended, and his confidence in the reſults will be greatly increaſed.

18 Deciſion of a diſputed and very important queſtion.

There is a propoſition (nº 19. in the article Roof) which has been called in queſtion by ſeveral very intelligent perſons; and they ſay that Belidor has demonſtrated, in his Science des Ingenieurs, that a beam firmly fixed at both ends is not twice as ſtrong as when ſimply lying on the props, and that its ſtrength is increaſed only in the proportion of 2 to 3; and they ſupport this determination by a liſt of experiments recited by Belidor, which agree *preciſely* with it. Belidor alſo ſays that Pitot had the ſame reſult in his experiments. Theſe are reſpectable authorities: but Belidor's reaſoning is any thing but demonſtration; and his experiments are deſcribed in ſuch an imperfect manner, that we cannot build much on them. It is not ſaid in what manner the battens were ſecured at the ends, any farther than that it was by *chevalets*. If by this word is meant a treſsle, we cannot conceive how they were employed; but we ſee it ſometimes uſed for a wedge or key. If the battens were wedged in the holes, their reſiſtance to fracture may be made what we pleaſe: they may be looſe, and therefore reſiſt little more than when ſimply laid on the props. They may be (and probably were) wedged very faſt, and bruiſed or crippled.

Our propoſition mentioned diſtinctly the ſecurity given to the ends of the beams. They were mortiſed into remote poſts. Our *preciſe* meaning was, that they were ſimply kept from riſing by theſe mortiſes, but at full liberty to bend up between E and I, and between

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(A) The learned reader will perceive, that this analogy is preciſely the ſame with that of forces which are in equilibrio by the intervention of a lever. In fact, this whole frame of carpentry is nothing elſe than a *built* or *framed lever* in equilibrio. It is acting in the ſame manner as a ſolid, which occupies the whole figure compreſſed in the frame, or as a body of any ſize and ſhape whatever that will admit the three points of application A, C, and B. It is always in equilibrio in the caſe firſt ſtated; becauſe the preſſure *produced* at B by a force applied to A is always ſuch as balances it. The reader may alſo perceive, in this propoſition, the analyſis or tracing of thoſe internal mechanical forces which are indiſpenſably requiſite for the functions of a lever. The mechanicians have been extremely puzzled to find a legitimate demonſtration of the equilibrium of a lever ever ſince the days of Archimedes. Mr Vince has the honour of firſt demonſtrating, moſt ingeniouſly, the principle aſſumed by Archimedes, but without ſufficient ground, for *his* demonſtration: but Mr Vince's demonſtration is only a putting the mind into that perplexed ſtate which makes it acknowledge the propoſition, but without a clear perception of its truth. The difficulty has proceeded from the abſtract notion of a lever, conceiving it as a mathematical line—inflexible, without reflecting how it is inflexible—for the very ſource of this indiſpenſable quality furniſhes the mechanical connection between the remote preſſures and the fulcrum; and this ſupplies the demonſtration (without the leaſt difficulty) of the deſperate caſe of a ſtraight lever urged by parallel forces. See Rotation, nº 11. *Encycl.*

G and K. Our aſſertion was not made from theory alone (although we think the reaſoning incontrovertible), but was agreeable to numerous experiments made in thoſe preciſe circumſtances. Had we mortiſed the beams firmly into two very ſtout poſts, which could not be drawn nearer to each other by bending, the beam would have borne a *much* greater weight, as we have verified by experiment. We hope that the following mode of conceiving this caſe will remove all doubts.

Let LM be a long beam (fig. 14.) divided into ſix equal parts, in the points D, B, A, C, E. Let it be firmly ſupported at L, B, C, M. Let it be cut through at A, and have compaſs-joints at B and C. Let FB, GC be two equal uprights, reſting on B and C, but without any connection. Let AH be a ſimilar and equal piece, to be occaſionally applied at the ſeam A. Now let a thread or wire AGE be extended over the piece GC, and made faſt at A, G, and E. Let the ſame thing be done on the other ſide of A. If a weight be now laid on at A, the wires AFD, AGE will be ſtrained, and may be broken. In the inſtant of fracture we may ſuppoſe their ſtrains to be repreſented by Af and Ag. Complete the parallelogram, and Aa is the magnitude of the weight. It is plain that nothing is concerned here but the coheſion of the wires; for the beam is ſawed through at A, and its parts are perfectly moveable round B and C.

Inſtead of this proceſs apply the piece AH below A, and keep it there by ſtraining the ſame wire BHC over it. Now lay on a weight. It muſt preſs down the ends of BA and CA, and cauſe the piece AH to ſtrain the wire BHC. In the inſtant of fracture of *the ſame* wire, its reſiſtance Hb and Hc muſt be equal to Af and Ag, and the weight bH which breaks them muſt be equal to Aa.

Laſtly, employ all the three pieces FB, AH, GC, with the ſame wire attached as before. There can be no doubt but that the weight which breaks all the four wires muſt be $= a\,A + b$, or twice $A\,a$.

The reader cannot but ſee that the wires perform the very ſame office with the fibres of an entire beam LM held faſt in the four holes D, B, C, and E, of ſome upright poſts.

In the experiments for verifying this, by breaking ſlender bars of fine deal, we get complete demonſtration, by meaſuring the curvatures produced in the parts of the beam thus held down, and comparing them with the curvature of a beam ſimply laid on the props B and C: and there are many curious inferences to be made from theſe obſervations, but we have not room for them in this place.

19
The beſt manner of framing purlins.

We may obſerve, by the way, that we learn from this caſe, that purlins are able to carry twice the load when notched into the rafters that they carry when mortiſed into them, which is the moſt uſual manner of framing them. So would the binding joiſts of floors; but this would double the thickneſs of the flooring. But this method ſhould be followed in every poſſible caſe, ſuch as breaſt ſummers, lintels over ſeveral pillars, &c. Theſe ſhould never be cut off and mortiſed into the ſides of every upright; numberleſs caſes will occur which ſhew the importance of the maxim.

We muſt here remark, that the proportion of the ſpaces BC and CM, or BC and LB, has a very ſenſible effect on the ſtrength of the beam BC; but we have not yet ſatisfied our minds as to the *rationale* of this effect. It is undoubtedly connected with the ſerpentine form of the curve of the beam before fracture. This ſhould be attended to in the conſtruction of the ſprings of carriages. Theſe are frequently ſupported at a middle point (and it is an excellent practice), and there is a certain proportion which will give the eaſieſt motion to the body of the carriage. We alſo think that it is connected with that deviation from the beſt theory obſervable in Buffon's experiments on various lengths of the ſame ſcantling. The force of the beams diminiſhed much more than in the inverſe proportion of their lengths.

20
Ties are in general better than ſtruts.

We have ſeen that it depends entirely on the poſition of the pieces in reſpect of their points of ultimate ſupport, and of the direction of the external force which produces the ſtrains, whether any particular piece is in a ſtate of extenſion or of compreſſion. The knowledge of this circumſtance may greatly influence us in the choice of the conſtruction. In many caſes we may ſubſtitute ſlender iron rods for maſſive beams, when the piece is to act the part of a tie. But we muſt not invert this diſpoſition; for when a piece of timber acts as a ſtrut, and is in a ſtate of compreſſion, it is next to certain that it is not equally compreſſible in its oppoſite ſides through the whole length of the piece, and that the compreſſing force on the abutting joint is not acting in the moſt equable manner all over the joint. A very trifling inequality in either of theſe circumſtances (eſpecially in the firſt) will compreſs the beam more on one ſide than on the other. This cannot be without the beam's bending, and becoming concave on that ſide on which it is moſt compreſſed. When this happens, the frame is in danger of being cruſhed, and ſoon going to ruin. It is therefore indiſpenſably neceſſary to make uſe of beams in all caſes where ſtruts are required of conſiderable length, rather than of metal rods of ſlender dimenſions, unleſs in ſituations where we can effectually prevent their bending, as in truſſing a girder internally, where a caſt iron ſtrut may be firmly caſed in it, ſo as not to bend in the ſmalleſt degree. In caſes where the preſſures are enormous, as in the very oblique ſtruts of a centre or arch frame, we muſt be particularly cautious to do nothing which can facilitate the compreſſion of either ſide. No mortiſes ſhould be cut near to one ſide; no lateral preſſure, even the ſlighteſt, ſhould be allowed to touch it. We have ſeen a pillar of fir 12 inches long and one inch in ſection, when loaded with three tons, ſnap in an inſtant when preſſed on one ſide by 16 pounds, while another bore 4½ tons without hurt, becauſe it was incloſed (looſely) in a ſtout pipe of iron.

In ſuch caſes of enormous compreſſion, it is of great importance that the compreſſing force bear equally on the whole abutting ſurfaces. The German carpenters are accuſtomed to put a plate of lead over the joint. This prevents, in ſome meaſure, the penetration of the end fibres. Mr Perronet, the celebrated French architect, formed his abutments into arches of circles, the centre of which was the remote end of the ſtrut. By this contrivance the unavoidable change of form of the triangle made no partial bearing of either angle of the abutment. This always has a tendency to ſplinter off the heel of the beam where it preſſes ſtrongeſt. It is a very judicious practice.

When circumſtances allow it, we ſhould rather employ

ploy ties than ſtruts for ſecuring a beam againſt lateral ſtrains. When an upright pillar, ſuch as a flag-ſtaff, a maſt, or the uprights of a very tall ſcaffolding, are to be ſhored up, the dependence is more certain on thoſe braces that are ſtretched by the ſtrain than on thoſe which are compreſſed. The ſcaffolding of the iron bridge near Sunderland had ſome ties very judiciouſly diſpoſed, and others with leſs judgment.

We ſhould proceed to conſider the tranſverſe ſtrains as they affect the various parts of a frame of carpentry; but we have very little to add to what has been ſaid already in the article *Strength of Materials* (Encycl.), and in the article Roof. What we ſhall add in this article will find a place in our occaſional remarks on different works. It may, however, be of uſe to recal to the reader's memory the following propoſitions.

21 General theorems concerning the relative ſtrength of beams.

1. When a beam AB (fig. 15.) is firmly fixed at the end A, and a ſtraining force acts perpendicularly to its length at any point B, the ſtrain occaſioned at any ſection C between B and A is proportional to CB, and may therefore be repreſented by the product W×CB; that is, by the product of the number of tons. pounds, &c. which meaſure the ſtraining force, and the number of feet, inches, &c. contained in CB. As the loads on a beam are eaſily conceived, we ſhall ſubſtitute this for any other ſtraining force.

2. If the ſtrain or load is uniformly diſtributed along any part of the beam lying beyond C (that is, further from A), the ſtrain at C is the ſame as if the load were all collected at the middle point of that part; for that point is the centre of gravity of the load.

3. The ſtrain on any ſection D of a beam AB (fig. 16.) reſting freely on two props A and B, is $w \times \frac{AD \times DB}{AB}$ (ſee Roof, n° 19. and *Strength of Materials*, n° 92, &c. *Encycl.*) Therefore,

4. The ſtrain on the middle point, by a force applied there, is one fourth of the ſtrain which the ſame force would produce, if applied to one end of a beam of the ſame length, having the other end fixed.

5. The ſtrain on any ſection C of a beam, reſting on two props A and B, occaſioned by a force applied perpendicularly to another point D, is proportional to the rectangle of the exterior ſegments, or is equal to $w \times \frac{AC \times DB}{AB}$. Therefore

The ſtrain at C occaſioned by the preſſure on D, is the ſame with the ſtrain at D occaſioned by the ſame preſſure on C.

6. The ſtrain on any ſection D, occaſioned by a load uniformly diffuſed over any part EF, is the ſame as if the two parts ED, DF of the load were collected at their middle points *e* and *f*. Therefore

The ſtrain on any part D, occaſioned by a load uniformly diſtributed over the whole beam, is one-half of the ſtrain that is produced when the ſame load is laid on at D; and

The ſtrain on the middle point C, occaſioned by a load uniformly diſtributed over the whole beam, is the ſame which half that load would produce if laid on at C.

7. A beam ſupported at both ends on two props B and C (fig. 14.) will carry twice as much when the ends beyond the props are kept from riſing, as it will carry when it reſts looſely on the props.

8. Laſtly, the tranſverſe ſtrain on any ſection, occaſioned by a force applied obliquely, is diminiſhed in the proportion of the ſine of the angle which the direction of the force makes with the beam. Thus, if it be inclined to it in an angle of thirty degrees, the ſtrain is one half of the ſtrain occaſioned by the ſame force acting perpendicularly.

On the other hand, the relative strength of a beam, or its power in any particular ſection to reſiſt any tranſverſe ſtrain, is proportional to the abſolute coheſion of the ſection directly, to the diſtance of its centre of effort from the axis of fracture directly, and to the diſtance from the ſtrained point inverſely.

Thus in a rectangular ſection of the beam, of which *b* is the breadth, *d* the depth (that is, the dimenſion in the direction of the ſtraining force), meaſured in inches, and *f* the number of pounds which one ſquare inch will juſt ſupport without being torn aſunder, we muſt have $f \times b \times d^2$, proportional to $w \times CB$ (fig. 15.) Or, $f \times b \times d^2$, multiplied by ſome number *m*, depending on the nature of the timber, muſt be equal to $w \times CB$. Or, in the caſe of the ſection C of fig. 16. that is ſtrained by the force *w* applied at D, we muſt have $m \times f b d^2 = w \times \frac{AC \times DB}{AB}$. Thus if the beam is of ſound oak, *m* is very nearly $= \frac{1}{9}$ (ſee *Strength of Materials*, n° 116. Encycl.) Therefore we have $\frac{f b d^2}{9} = w \times \frac{AC \times CB}{AB}$.

Hence we can tell the preciſe force *w* which any ſection C can juſt reſiſt when that force is applied in any way whatever. For the above-mentioned formula gives $w = \frac{f b d^2}{9CB}$, for the caſe repreſented by fig 15. But the caſe repreſented in fig. 16. having the ſtraining force applied at D, gives the ſtrain at C $(= w) = f \times \frac{b d^2 \times AB}{9AC \times CB}$.

Example. Let an oak beam, four inches ſquare, reſt freely on the props A and B, ſeven feet apart, or 84 inches. What weight will it juſt ſupport at its middle point C, on the ſuppoſition that a ſquare inch rod will juſt carry 16,000 pounds, pulling it aſunder?

The formula becomes $w = \frac{16000 \times 4 \times 16 \times 84.}{9 \times 42 \times 42}$ or $w = \frac{86016000}{15876}$, = 5418 pounds. This is very near what was employed in Buffon's experiment, which was 5312.

Had the ſtraining force acted on a point D, half way between C and B, the force ſufficient to break the beam at C would be $= \frac{16000 \times 4 \times 16 \times 84}{9 \times 42 \times 21} =$ 10836 lbs.

Had the beam been ſound red fir, we muſt have taken $f =$ 10,000 nearly, and *m* nearly 8; for although fir be leſs coheſive than oak in the proportion of 5 to 8 nearly, it is leſs compreſſible, and its axis of fracture is therefore nearer to the concave ſide.

22 Of joints.

Having conſidered at ſufficient length the ſtrains of different kinds which ariſe from the form of the parts of a frame of carpentry, and the direction of the external forces which act on it, whether conſidered as impelling or as ſupporting its different parts, we muſt now

now proceed to conſider the means by which this form is to be ſecured, and the connections by which thoſe ſtrains are excited and communicated.

The joinings practiſed in carpentry are almoſt infinitely various, and each has advantages which make it preferable in ſome circumſtances. Many varieties are employed merely to pleaſe the eye. We do not concern ourſelves with theſe: Nor ſhall we conſider thoſe which are only employed in connecting ſmall works, and can never appear on a great ſcale: yet even in ſome of theſe, the ſkill of the carpenter may be diſcovered by his choice; for in all caſes it is wiſe to make every, even the ſmalleſt, part of his work as ſtrong as the materials will admit. He will be particularly attentive to the changes which will neceſſarily happen by the ſhrinking of timber as it dries, and will conſider what dimenſions of his framings will be affected by this, and what will not; and will then diſpoſe the pieces which are leſs eſſential to the ſtrength of the whole, in ſuch a manner that their tendency to ſhrink ſhall be in the ſame direction with the ſhrinking of the whole framing. If he do otherwiſe, the ſeams will widen, and parts will be ſplit aſunder. He will diſpoſe his boardings in ſuch a manner as to contribute to the ſtiffneſs of the whole, avoiding at the ſame time the giving them poſitions which will produce lateral ſtrains on truſs beams which bear great preſſures; recollecting, that although a ſingle board has little force, yet many united have a great deal, and may frequently perform the office of very powerful ſtruts.

Our limits confine us to the joinings which are moſt eſſential for connecting the parts of a ſingle piece of a frame when it cannot be formed of one beam, either for want of the neceſſary thickneſs or length; and the joints for connecting the different ſides of a truſſed frame.

23 Of building up beams. Much ingenuity and contrivance has been beſtowed on the manner of building up a great beam of many thickneſſes, and many ſingular methods are practiſed as great noſtrums by different artiſts: but when we conſider the manner in which the coheſion of the fibres performs its office, we will clearly ſee that the ſimpleſt are equally effectual with the moſt refined, and that they are leſs apt to lead us into falſe notions of the ſtrength of the aſſemblage.

24 Building up a girder or lever. 25 Joggling preferable to ſcarfing. Thus, were it required to build up a beam for a great lever or a girder, ſo that it may act nearly as a beam of the ſame ſize of one log—it may either be done by plain joggling, as in fig. 17. A, or by ſcarfing, as in fig. 17. B or C. If it is to act as a lever, having the gudgeon on the lower ſide at C, we believe that moſt artiſts will prefer the form B and C; at leaſt this has been the caſe with nine-tenths of thoſe to whom we have propoſed the queſtion. The beſt informed only heſitated; but the ordinary artiſts were all confident in its ſuperiority; and we found their views of the matter very coincident. They conſider the upper piece as graſping the lower in its hooks; and ſeveral imagined that, by driving the one very tight on the other, the beam would be ſtronger than an entire log: but if we attend carefully to the internal procedure in the loaded lever, we ſhall find the upper one clearly the ſtrongeſt. If they are formed of equal logs, the upper one is thicker than the other by the depth of the joggling or ſcarfing, which we ſuppoſe to be the ſame in both; conſequently, if the coheſion of the fibres in the intervals is able to bring the uppermoſt filaments into full action, the form A is ſtronger than B, in the proportion of the greater diſtance of the upper filaments from the axis of the fracture: this may be greater than the difference of the thickneſs, if the wood is very compreſſible. If the gudgeon be in the middle, the effect, both of the joggles and the ſcarfings, is conſiderably diminiſhed; and if it is on the upper ſide, the ſcarfings act in a very different way. In this ſituation, if the loads on the arms are alſo applied to the upper ſide, the joggled beam is ſtill more ſuperior to the ſcarfed one. This will be beſt underſtood by reſolving it in imagination into a truſſed frame. But when a gudgeon is thus put on that ſide of the lever which grows convex by the ſtrain, it is uſual to connect it with the reſt by a powerful ſtrap, which embraces the beam, and cauſes the oppoſite point to become the reſiſting point. This greatly changes the internal actions of the filaments, and, in ſome meaſure, brings it into the ſame ſtate as the firſt, with the gudgeon below. Were it poſſible to have the gudgeon on the upper ſide, and to bring the whole into action without a ſtrap, it would be the ſtrongeſt of all; becauſe, in general, the reſiſtance to compreſſion is greater than to extenſion. In every ſituation the joggled beam has the advantage; and it is the eaſieſt executed.

We may frequently gain a conſiderable acceſſion of ſtrength by this building up of a beam; eſpecially if the part which is ſtretched by the ſtrain be of oak, and the other part be fir. Fir being ſo much ſuperior to oak as a pillar (if Muſſchenbroek's experiments may be confided in), and oak ſo much preferable as a tie, this conſtruction ſeems to unite both advantages. But we ſhall ſee much better methods of making powerful levers, girders, &c. by truſſing.

Obſerve that the efficacy of both methods depends entirely on the difficulty of cauſing the piece between the croſs joints to ſlide along the timber to which it adheres. Therefore, if this be moderate, it is wrong to make the notches deep; for as ſoon as they are ſo deep that their ends have a force ſufficient to puſh the ſlice along the line of junction, nothing is gained by making them deeper; and this requires a greater expenditure of timber.

Scarfings are frequently made oblique, as in fig. 18. but we imagine that this is a bad practice. It begins to yield at the point, where the wood is crippled and ſplintered off, or at leaſt bruiſed out a little: as the preſſure increaſes, this part, by ſqueezing broader, cauſes the ſolid parts riſe to a little upwards, and gives them ſome tendency, not only to puſh their antagoniſts along the baſe, but even to tear them up a little. For ſimilar reaſons, we diſapprove of the favourite practice of many artiſts, to make the angles of their ſcarfings acute, as in fig. 19. This often cauſes the two pieces to tear each other up. The abutments ſhould always be perpendicular to the directions of the preſſures. Leſt it ſhould be forgotten in its proper place, we may extend this injunction alſo to the abutments of different pieces of a frame, and recommend it to the artiſt even to attend to the ſhrinking of the timbers by drying. When two timbers abut obliquely, the joint ſhould be moſt

full

full at the obtuſe angle of the end; becauſe, by drying, that angle grows more obtuſe, and the beam would then be in danger of ſplintering off at the acute angle.

16 We muſt not wedge too hard.

It is evident that the niceſt work is indiſpenſably neceſſary in building up a beam. The parts muſt abut on each other completely, and the ſmalleſt play or void takes away the whole efficacy. It is uſual to give the butting joints a ſmall taper to one ſide of the beam, ſo that they may require moderate blows of a maul to force them in, and the joints may be perfectly cloſe when the external ſurfaces are even on each ſide of the beam. But we muſt not exceed in the leaſt degree; for a very taper wedge has great force; and if we have driven the pieces together by very heavy blows, we leave the whole in a ſtate of violent ſtrain, and the abutments are perhaps ready to ſplinter off by a ſmall addition of preſſure. This is like too ſevere a proof for artillery; which, though not ſufficient to burſt the pieces, has weakened them to ſuch a degree, that the ſtrain of ordinary ſervice is ſufficient to complete the fracture. The *workman* is tempted to exceed in this, becauſe it ſmooths off and conceals all uneven ſeams; but he muſt be watched. It is not unuſual to leave ſome abutments open enough to admit a thin wedge reaching through the beam. Nor is this a bad practice, if the wedge is of materials which is not compreſſed by the driving or the ſtrain of ſervice. Iron would be preferable for this purpoſe, and for the joggles, were it not that by its too great hardneſs it cripples the fibres of timber to ſome diſtance. In conſequence of this, it often happens that, in beams which are ſubjected to deſultory and ſudden ſtrains (as in the levers of reciprocating engines), the joggles or wedges widen the holes, and work themſelves looſe: Therefore ſkilful engineers never admit them, and indeed as few bolts as poſſible, for the ſame reaſon: but when reſiſting a ſteady or dead pull, they are not ſo improper, and are frequently uſed.

27 Building of maſts.

Beams are built up not only to increaſe their dimenſions in the direction of the ſtrain (which we have hitherto called their depth), but alſo to increaſe their breadth or the dimenſions perpendicular to the ſtrain. We ſometimes double the breadth of a girder which is thought too weak for its load, and where we muſt not increaſe the thickneſs of the flooring. The maſt of a great ſhip of war muſt be made bigger athwartſhip, as well as fore and aft. This is one of the niceſt problems of the art; and profeſſional men are by no means agreed in their opinions about it. We do not preſume to decide; and ſhall content ourſelves with exhibiting the different methods.

28 Method ed in the rench avy.

The moſt obvious and natural method is that ſhewn in fig. 20. It is plain that (independent of the connection of croſs bolts, which are uſed in them all when the beams are ſquare) the piece C cannot bend in the direction of the plane of the figure without bending the piece D along with it. This method is much uſed in the French navy; but it is undoubtedly imperfect. Hardly any two great trees are of equal quality, and ſwell and ſhrink alike. If C ſhrinks more than D, the feather of C becomes looſe in the groove wrought in D to receive it; and when the beam bends, the parts can ſlide on each other like the plates of a coach ſpring; and if the bending is in the direction *e f*, there is nothing to hinder this ſliding but the bolts, which ſoon work themſelves looſe in the bolt-holes.

29 Another method.

Fig. 21. exhibits another method. The two halves of the beam are tabled into each other in the ſame manner as in fig. 17. It is plain that this will not be affected by the unequal ſwelling or ſhrinking, becauſe this is inſenſible in the direction of the fibres; but when bent in the direction *a b*, the beam is weaker than fig. 20. bent in the direction *e f*. Each half of fig. 20. has, in every part of its length, a thickneſs greater than half the thickneſs of the beam. It is the contrary in the alternate portions of the halves of fig. 21. When one of them is bent in the direction AB, it is plain that it drags the other with it by means of the croſs butments of its tables, and there can be no longitudinal ſliding. But unleſs the work is accurately executed, and each hollow completely filled up by the table of the other piece, there will be a lateral ſlide along the croſs joints ſufficient to compenſate for the curvature; and this will hinder the one from compreſſing or ſtretching the other in conformity to this curvature.

30 Its imperfection.

The imperfection of this method is ſo obvious, that it has ſeldom been practiſed: but it has been combined with the other, as is repreſented in fig. 22. where the beams are divided along the middle, and the tables in each half are alternate, and alternate alſo with the tables of the other half. Thus 1, 3, 4, are prominent, and 5, 2, 6, are depreſſed. This conſtruction evidently puts a ſtop to both ſides, and obliges every part of both pieces to move together. *a b* and *c d* ſhow ſections of the built-up beam correſponding to AB and CD.

No more is intended in this practice by any intelligent artiſt, than the cauſing the two pieces to act together in all their parts, although the ſtrains may be unequally diſtributed on them. Thus, in a built-up girder, the binding joints are frequently mortiſed into very different parts of the two ſides. But many ſeem to aim at making the beam ſtronger than if it were of one piece; and this inconſiderate project has given riſe to many whimſical modes of tabling and ſcarfing, which we need not regard.

31 Britiſh method;

The practice in the Britiſh dock-yards is ſomewhat different from any of theſe methods. The pieces are tabled as in fig 22. but the tables are not thin parallelopipeds, but thin priſms. The two outward joints or viſible ſeams are ſtraight lines, and the table nº 1. riſes gradually to its greateſt thickneſs in the axis. In like manner, the hollow 5 for receiving the oppoſite table, ſinks gradually from the edge to its greateſt depth in the axis. Fig. 23. repreſents a ſection of a round piece of timber built up in this way, where the full line EFGH is the ſection correſponding to AB of fig. 22. and the dotted line EGFH is the ſection correſponding to CD.

This conſtruction, by making the external ſeam ſtraight, leaves no lodgment for water, and looks much fairer to the eye: but it appears to us that it does not give ſuch firm hold when the maſt is bent in the direction EH. The exterior parts are moſt ſtretched and moſt compreſſed by this bending; but there is hardly any abutment in the exterior parts of theſe tables. In the very axis, where the abutment is the firmeſt, there is little or no difference of extenſion and compreſſion.

But this conſtruction has an advantage, which we imagine much more than compenſates for theſe imperfections, ſections, at leaſt in the particular caſe of a round maſt: it will draw together by hooping incomparably better than any of the others. If the cavity be made ſomewhat too ſhallow for the prominence of the tables, and if this be done uniformly along the whole length, it will make a ſomewhat open ſeam; and this opening can be regulated with the utmoſt exactneſs from end to end by the plane. The heart of thoſe vaſt trunks is very ſenſibly ſofter than the exterior circles: Therefore, when the whole is hooped, and the hoops hard driven, and at conſiderable intervals between each ſpell —we are confident that all may be compreſſed till the ſeam diſappears; and then the whole makes one piece, *much* ſtronger than if it were an original log of that ſize; becauſe the middle has become, by compreſſion, as ſolid as the cruſt, which was naturally firmer, and reſiſted further compreſſion. We verified this beyond a doubt, by hooping a built ſtick of a timber which has this inequality of firmneſs in a remarkable degree, and it was nearly twice as ſtrong as another of the ſame ſize.

Our maſtmakers are not without their fancies and whims; and the manner in which our maſts and yards are generally built up, is not near ſo ſimple as fig. 22.: but it conſiſts of the ſame eſſential parts, acting in the very ſame manner, and derives all its efficacy from the principles which are here employed.

32 Attended with peculiar advantages.

This conſtruction is particularly ſuited to the ſituation and office of a ſhip's maſt. It has no bolts; or, at leaſt, none of any magnitude, or that make very important parts of its conſtruction. The moſt violent ſtrains perhaps that it is expoſed to, is that of twiſting, when the lower yards are cloſe braced up by the force of many men acting by a long lever. This form reſiſts a twiſt with peculiar energy: it is therefore an excellent method for building up a great ſhaft for a mill. The way in which they are uſually built up is by reducing a central log to a polygonal priſm, and then filling it up to the intended ſize by *planting* pieces of timber along its ſides, either ſpiking them down, or cocking them into it by a feather, or joggling them by ſlips of hard wood ſunk into the central log and into the ſlips. *N. B.* Joggles of elm are ſometimes uſed in the middle of the large tables of maſts; and when ſunk into the firm wood near the ſurface, they muſt contribute much to the ſtrength. But it is very neceſſary to employ wood not much harder than the pine; otherwiſe it will ſoon enlarge its bed, and become looſe; for the timber of theſe large trunks is very ſoft.

The moſt general reaſon for piecing a beam is to increaſe its length. This is frequently neceſſary, in order to procure tie-beams for very wide roofs. Two pieces muſt be ſcarfed together.—Numberleſs are the modes of doing this; and almoſt every maſter carpenter has his favourite noſtrum. Some of them are very ingenious: But here, as in other caſes, the moſt ſimple are

33 Various methods of ſcarfing.

commonly the ſtrongeſt. We do not imagine that any, the moſt ingenious, is equally ſtrong with a tie conſiſting of two pieces of the ſame ſcantling laid over each other for a certain length, and firmly bolted together. We acknowledge that this will appear an artleſs and clumſy tie-beam; but we only ſay that it will be ſtronger than any that is more artificially made up of the ſame thickneſs of timber. This, we imagine, will appear ſufficiently certain.

The ſimpleſt and moſt obvious ſcarfing (after the one now mentioned) is that repreſented in fig. 24. n° 1. and 2. If conſidered merely as two pieces of wood joined, it is plain that, as a tie, it has but half the ſtrength of an entire piece, ſuppoſing that the bolts (which are the only connections) are faſt in their holes. N° 2. requires a bolt in the middle of the ſcarf to give it that ſtrength; and, in every other part, is weaker on one ſide or the other.

But the bolts are very apt to bend by the violent ſtrain, and require to be ſtrengthened by uniting their ends by iron plates; in which caſe it is no longer a wooden tie. The form of n° 1. is better adapted to the office of a pillar than n° 2.; eſpecially if its ends be formed in the manner ſhewn in the elevation n° 3. By the ſally given to the ends, the ſcarf reſiſts an effort to bend it in that direction. Beſides, the form of n° 2. is unſuitable for a poſt; becauſe the pieces, by ſliding on each other by the preſſure, are apt to ſplinter off the tongue which confines their extremity.

Fig. 25. and 26. exhibit the moſt approved form of a ſcarf, whether for a tie or for a poſt. The key repreſented in the middle is not eſſentially neceſſary; the two pieces might ſimply meet ſquare there. This form, without a key, needs no bolts (although they ſtrengthen it greatly); but, if worked very true and cloſe, and with ſquare abutments, will hold together, and will reſiſt bending in any direction. But the key is an ingenious and a very great improvement, and will force the parts together with perfect tightneſs. The ſame precaution muſt be obſerved that we mentioned on another occaſion, not to produce a conſtant internal ſtrain on the parts by overdriving the key. The form of fig. 25. is by far the beſt; becauſe the triangle of 26. is much eaſier ſplintered off by the ſtrain, or by the key, than the ſquare wood of 25. It is far preferable for a poſt, for the reaſon given when ſpeaking of fig. 24. n° 1. and n° 2. Both may be formed with a ſally at the ends equal to the breadth of the key. In this ſhape, fig. 25. is vaſtly well ſuited for joining the parts of the long corner poſts of ſpires and other wooden towers. Fig. 25. n° 2. differs from n° 1. only by having three keys. The principle and the longitudinal ſtrength are the ſame. The long ſcarf of n° 2. tightened by the three keys, enables it to reſiſt a bending much better.

None of theſe ſcarfed tie-beams can have more than one-third of the ſtrength of an entire piece, unleſs with the aſſiſtance of iron plates; for if the key be made thinner than one-third, it has leſs than one-third of the fibres to pull by.

We are confident, therefore, that when the heads of the bolts are connected by plates, the ſimple form of fig. 24. n° 1. is ſtronger than thoſe more ingenious ſcarfings. It may be ſtrengthened againſt lateral bending by a little tongue, or by a ſally; but it cannot have both.

34 Fiſhing a beam.

The ſtrongeſt of all methods of piecing a tie-beam would be to ſet the parts end to end, and graſp them between other pieces on each ſide, as in fig. 27. This is what the ſhip-carpenter calls *fiſhing* a beam; and is a frequent practice for occaſional repairs. Mr Perronet uſed it for the tie-beams or ſtretchers, by which he connected the oppoſite feet of a centre, which was yielding to its load, and had puſhed aſide one of the piers above four inches. Six of theſe not only withſtood a ſtrain of 1800 tons, but, by wedging behind them, he brought

brought the feet of the truſs $2\frac{1}{2}$ inches nearer. The ſtretchers were 14 inches by 11 of ſound oak, and could have withſtood three times that ſtrain. Mr Perronet, fearing that the great length of the bolts employed to connect the beams of theſe ſtretchers would expoſe them to the riſk of bending, ſcarfed the two ſide pieces into the middle piece. The ſcarfing was of the triangular kind (*Trait de Jupiter*), and only an inch deep, each face being two feet long, and the bolt paſſed through cloſe to the angle.

In piecing the pump rods, and other wooden ſtretchers of great engines, no dependence is had on ſcarfing; and the engineer connects every thing by iron ſtraps. We doubt the propriety of this, at leaſt in caſes where the bulk of the wooden connection is not inconvenient. Theſe obſervations muſt ſuffice for the methods employed for connecting the parts of a beam; and we now proceed to conſider what are more uſually called the joints of a piece of carpentry.

35
quare
oints.

Where the beams ſtand ſquare with each other, and the ſtrains are alſo ſquare with the beams, and in the plane of the frame, the common mortiſe and tenon is the moſt perfect junction. A pin is generally put through both, in order to keep the pieces united, in oppoſition to any force which tends to part them. Every carpenter knows how to bore the hole for this pin, ſo that it ſhall draw the tenon tight into the mortiſe, and cauſe the ſhoulder to butt cloſe, and make neat work; and he knows the riſk of tearing out the bit of the tenon beyond the pin, if he draw it too much. We may juſt obſerve, that ſquare holes and pins are much preferable to round ones for this purpoſe, bringing more of the wood into action, with leſs tendency to ſplit it. The ſhip carpenters have an ingenious method of making long wooden bolts, which do not paſs completely through, take a very faſt hold, though not nicely fitted to their holes, which they muſt not be, leſt they ſhould be crippled in driving. They call it *foxtail wedging*. They ſtick into the point of the bolt a very thin wedge of hard wood, ſo as to project a proper diſtance; when this reaches the bottom of the hole by driving the bolt, it ſplits the end of it, and ſqueezes it hard to the ſide. This may be practiſed with advantage in carpentry. If the ends of the mortiſe are widened inwards, and a thin wedge be put into the end of the tenon, it will have the ſame effect, and make the joint equal to a dovetail. But this riſks the ſplitting the piece beyond the ſhoulder of the tenon, which would be unſightly. This may be avoided as follows: Let the tenon T, fig. 28. have two *very* thin wedges *a* and *c* ſtuck in near its angles, projecting equally; at a very ſmall diſtance within theſe, put in two ſhorter ones *b*, *d*, and more within theſe if neceſſary. In driving this tenon, the wedges *a* and *c* will take firſt, and ſplit off a thin ſlice, which will eaſily bend without breaking. The wedges *b*, *d*, will act next, and have a ſimilar effect, and the others in ſucceſſion. The thickneſs of all the wedges taken together muſt be equal to the enlargement of the mortiſe toward the bottom.

36
oxtail
edging,

When the ſtrain is tranſverſe to the plane of the two beams, the principles laid down in nº 85, 86. of the article *Strength of Materials*, will direct the artiſt in placing his mortiſe. Thus the mortiſe in a girder for receiving the tenon of a binding joiſt of a floor ſhould be as near the upper ſide as poſſible, becauſe the girder becomes concave on that ſide by the ſtrain. But as this expoſes the tenon of the binding joiſt to the riſk of being torn off, we are obliged to mortiſe farther down. The form (fig. 29.) generally given to this joint is extremely judicious. The ſloping part *a b* gives a very firm ſupport to the additional bearing *e,d*, without much weakening of the girder. This form ſhould be copied in every caſe where the ſtrain has a ſimilar direction.

37
Oblique
mortiſe and
tenon.

The joint that moſt of all demands the careful attention of the artiſt, is that which connects the ends of beams, one of which puſhes the other very obliquely, putting it into a ſtate of extenſion. The moſt familiar inſtance of this is the foot of a rafter preſſing on the tie-beam, and thereby *drawing* it away from the other wall. When the direction is very oblique (in which caſe the extending ſtrain is the greateſt), it is difficult to give the foot of the rafter ſuch a hold of the tie-beam as to bring many of its fibres into the proper action. There would be little difficulty if we could allow the end of the tie-beam to project to a ſmall diſtance beyond the foot of the rafter: but, indeed, the dimenſions which are given to tie-beams, for other reaſons, are always ſufficient to give enough of abutment when judiciouſly employed. Unfortunately this joint is much expoſed to failure by the effects of the weather. It is much expoſed, and frequently periſhes by rot, or becomes ſo ſoft and friable that a very ſmall force is ſufficient, either for pulling the filaments out of the tie-beam, or for cruſhing them together. We are therefore obliged to ſecure it with particular attention, and to avail ourſelves of every circumſtance of conſtruction.

One is naturally diſpoſed to give the rafter a deep hold by a long tenon; but it has been frequently obſerved in old roofs that ſuch tenons break off. Frequently they are obſerved to tear up the wood that is above them, and puſh their way through the end of the tie-beam. This, in all probability, ariſes from the firſt ſagging of the roof, by the compreſſion of the rafters and of the head of the king-poſt. The head of the rafter deſcends, the angle with the tie-beam is diminiſhed by the rafter revolving round its ſtep in the tie-beam. By this motion the heel or inner angle of the rafter becomes a fulcrum to a very long and powerful lever much loaded. The tenon is the other arm, very ſhort, and being ſtill freſh, it is therefore very powerful. It therefore forces up the wood that is above it, tearing it out from between the cheeks of the mortiſe, and then puſhes it along. Carpenters have therefore given up long tenons, and give to the toe of the tenon a ſhape which abuts firmly, in the direction of the thruſt, on the ſolid bottom of the mortiſe, which is well ſupported on the under ſide by the wall-plate. This form has the farther advantage of having no tendency to tear up the end of the mortiſe. This form is repreſented in fig. 30. The tenon has a ſmall portion *a b* cut perpendicular to the ſurface of the tie-beam, and the reſt *b c* is perpendicular to the rafter.

But if the tenon is not ſufficiently ſtrong (and it is not ſo ſtrong as the rafter, which is thought not to be ſtronger than is neceſſary), it will be cruſhed, and then the rafter will ſlide out along the ſurface of the beam. It is therefore neceſſary to call in the aſſiſtance of the

whole;

whole rafter. It is in this diſtribution of the ſtrain among the various abutting parts that the varieties of joints and their merits chiefly conſiſt. It would be endleſs to deſcribe every noſtrum, and we ſhall only mention a few that are moſt generally approved of.

38 Moſt approved forms.

The aim in fig. 31. is to make the abutments exactly perpendicular to the thruſts. It does this very preciſely; and the ſhare which the tenon and the ſhoulder have of the whole may be what we pleaſe, by the portion of the beam that we notch down. If the wall-plate lie duly before the heel of the rafter, there is no riſk of ſtraining the tie acroſs or breaking it, becauſe the thruſt is made direct to that point where the beam is ſupported. The action is the ſame as againſt the joggle on the head or foot of a king-poſt. We have no doubt but that this is a very effectual joint. It is not, however, much practiſed. It is ſaid that the ſloping ſeam at the ſhoulder lodges water; but the great reaſon ſeems to be a ſecret notion that it weakens the tie-beam. If we conſider the direction in which it acts as a tie, we muſt acknowledge that this form takes the beſt method for bringing the whole of it into action.

Fig. 32. exhibits a form that is more general, but certainly worſe. What part of the thruſt that is not borne by the tenon acts obliquely on the joint of the ſhoulder, and gives the whole a tendency to riſe up and ſlide outward.

The ſhoulder joint is ſometimes formed like the dotted line *a b c d e f g* of fig. 32. This is much more agreeable to the true principle, and would be a very perfect method, were it not that the intervals *b d* and *d f* are ſo ſhort that the little wooden triangles *b c d*, *d e f*, will be eaſily puſhed off their baſes *b d*, *d f*.

Fig. 33. ſeems to have the moſt general approbation. It is the joint recommended by Price (page 7.), and copied into all books of carpentry as the *true joint* for a rafter foot. The viſible ſhoulder-joint is fluſh with the upper ſurface of the tie-beam. The angle of the tenon at the tie nearly biſects the obtuſe angle formed by the rafter and the beam, and is therefore ſomewhat oblique to the thruſt. The inner ſhoulder *a c* is nearly perpendicular to *b d*. The lower angle of the tenon is cut off horizontally as at *e d*. Fig. 34. is a ſection of the beam and rafter foot, ſhewing the different ſhoulders.

We do not perceive the peculiar merit of this joint. The effect of the three oblique abutments *a b*, *a c*, *e d*, is undoubtedly to make the whole bear on the outer end of the mortiſe, and there is no other part of the tie-beam that makes immediate reſiſtance. Its only advantage over a tenon extending in the direction of the thruſt is, that it will not tear up the wood above it. Had the inner ſhoulder had the form *e c i*, having its face *i c* perpendicular, it would certainly have acted more powerfully in ſtretching many filaments of the tie-beam, and would have had much leſs tendency to force out the end of the mortiſe. The little bit *c i* would have prevented the ſliding upwards along *e c*. At any rate, the joint *a b* being fluſh with the beam, prevents any ſenſible abutment on the ſhoulder *a c*.

Fig. 33. nº 2. is a ſimpler, and in our opinion a preferable, joint. We obſerve it practiſed by the moſt eminent carpenters for all oblique thruſts; but it ſurely employs leſs of the coheſion of the tie-beam than might be uſed without weakening it, at leaſt when it is ſupported on the other ſide by the wall-plate.

Fig. 33. nº 3. is alſo much practiſed by the firſt carpenters.

Fig. 35. is propoſed by Mr Nicholſon (page 65.) as preferable to fig. 33. nº 3. becauſe the abutment of the inner part is better ſupported. This is certainly the caſe; but it ſuppoſes the whole rafter to go to the bottom of the ſocket, and the beam to be thicker than the rafter. Some may think that this will weaken the beam too much, when it is no broader than the rafter is thick; in which caſe they think that it requires a deeper ſocket than Nicholſon has given it. Perhaps the advantages of Nicholſon's conſtruction may be had by a joint like fig. 35. nº 2.

39 Circumſtances to be attended to.

Whatever is the form of theſe butting joints, great care ſhould be taken that all parts bear alike, and the artiſt will attend to the magnitude of the different ſurfaces. In the general compreſſion, the greater ſurfaces will be leſs compreſſed, and the ſmaller will therefore change moſt. When all has ſettled, every part ſhould be *equally* cloſe. Becauſe great logs are moved with difficulty, it is very troubleſome to try the joint frequently to ſee how the parts fit; therefore we muſt expect leſs accuracy in the interior parts. This ſhould make us prefer thoſe joints whoſe efficacy depends chiefly on the viſible joint.

It appears from all that we have ſaid on this ſubject, that a very ſmall part of the coheſion of the tie-beam is ſufficient for withſtanding the horizontal thruſt of a roof, even though very low pitched. If therefore no other uſe is made of the tie-beam, one much ſlenderer may be uſed, and blocks may be firmly fixed to the ends, on which the rafters might abut, as they do on the joggles on the head and foot of a king-poſt. Although a tie-beam has commonly floors or ceilings to carry, and ſometimes the workſhops and ſtore-rooms of a theatre, and therefore requires a great ſcantling, yet there frequently occur in machines and engines very oblique ſtretchers, which have no other office, and are generally made of dimenſions quite inadequate to their ſituation, often containing ten times the neceſſary quantity of timber. It is therefore of importance to aſcertain the moſt perfect manner of executing ſuch a joint. We have directed the attention to the principles that are really concerned in the effect. In all hazardous caſes, the carpenter calls in the aſſiſtance of iron ſtraps; and they are frequently neceſſary, even in roofs, notwithſtanding this ſuperabundant ſtrength of the tie-beam. But this is generally owing to bad conſtruction of the wooden joint, or to the failure of it by time. Straps will be conſidered in their place.

There needs but little to be ſaid of the joints at a joggle worked out of ſolid timber; they are not near ſo difficult as the laſt. When the ſize of a log will allow the joggle to receive the whole breadth of the abutting brace, it ought certainly to be made with a ſquare ſhoulder; or, which is ſtill better, an arch of a circle, having the other end of the brace for its centre. Indeed this in general will not ſenſibly differ from a ſtraight line perpendicular to the brace. By this circular form, the ſettling of the roof makes no change in the abutment; but when there is not ſufficient ſtuff for this, we muſt avoid bevel joints at the ſhoulders, becauſe theſe always tend to make the brace ſlide off. The brace in fig. 36. muſt not be joined as at *a*, but as at *b*, or ſome equivalent manner. Obſerve the joints at the

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

40
rting
uts.

When the very oblique action of one ſide of a frame of carpentry does not extend but compreſs the piece on which it abuts (as in fig. 11.), there is no difficulty in the joint. Indeed a joining is unneceſſary, and it is enough that the pieces abut on each other; and we have only to take care that the mutual preſſure be equally borne by all the parts, and that it do not produce lateral preſſures, which may cauſe one of the pieces to ſlide on the butting joint. A very ſlight mortiſe and tenon is ſufficient at the joggle of a king-poſt with a rafter or ſtraining beam. It is beſt, in general, to make the butting plain, biſecting the angle formed by the ſides, or elſe perpendicular to one of the pieces. In fig. 36. n° 2. where the ſtraining beam *a b* cannot ſlip away from the preſſure, the joint *a* is preferable to *b*, or indeed to any uneven joint, which never fails to produce very unequal preſſures on the different parts, by which ſome are crippled, others are ſplintered off, &c.

41
irections
r placing
on ſtraps.

When it is neceſſary to employ iron ſtraps for ſtrengthening a joint, a conſiderable attention is neceſſary, that we may place them properly. The firſt thing to be determined is the direction of the ſtrain. This is learned by the obſervations in the beginning of this article. We muſt then reſolve this ſtrain into a ſtrain parallel to each piece, and another perpendicular to it. Then the ſtrap which is to be made faſt to any of the pieces muſt be ſo fixed, that it ſhall reſiſt in the direction parallel to the piece. Frequently this cannot be done; but we muſt come as near to it as we can. In ſuch caſes we muſt ſuppoſe that the aſſemblage yields a little to the preſſures which act on it. We muſt examine what change of ſhape a ſmall yielding will produce. We muſt now ſee how this will affect the iron ſtrap which we have already ſuppoſed attached to the joint in ſome manner that we thought ſuitable. This ſettling will perhaps draw the pieces away from it, leaving it looſe and unſerviceable (this frequently happens to the plates which are put to ſecure the obtuſe angles of butting timbers, when their bolts are at ſome diſtance from the angles, eſpecially when theſe plates are laid on the inſide of the angles); or it may cauſe it to compreſs the pieces harder than before; in which caſe it is anſwering our intention. But it may be producing croſs ſtrains, which may break them; or it may be crippling them. We can hardly give any general rules; but the reader will do well to read what is written in n° 36. and 41. of the article Roof, *Encycl.* In n° 36. he will ſee the nature of the ſtrap or ſtirrup, by which the king-poſt carries the tie-beam. The ſtrap that we obſerve moſt generally ill placed is that which connects the foot of the rafter with the beam. It only binds down the rafter, but does not act againſt its horizontal thruſt. It ſhould be placed farther back on the beam, with a bolt through it, which will allow it to turn round. It ſhould embrace the rafter almoſt horizontally near the foot, and ſhould be notched ſquare with the back of the rafter. Such a conſtruction is repreſented in fig. 37. By moving round the eye-bolt, it follows the rafter, and cannot pinch and cripple it, which it always does in its ordinary form. We are of opinion that ſtraps which have eye-bolts in the very angles, and allow all motion round them, are of all the moſt perfect. A branched ſtrap, ſuch as may at once bind the king-poſt and the two braces which butt on its foot, will be more ſerviceable if it have a joint. When a roof warps, thoſe branched ſtraps frequently break the tenons, by affording a fulcrum in one of their bolts. An attentive and judicious artiſt will conſider how the beams will act on ſuch occaſions, and will avoid giving riſe to theſe great ſtrains by levers.—A ſkilful carpenter never employs many ſtraps, conſidering them as auxiliaries foreign to his art, and ſubject to imperfections in workmanſhip which he cannot diſcern nor amend. We muſt refer the reader to Nicholſon's Carpenter and Joiner's Assistant for a more particular account of the various forms of ſtirrups, ſcrewed rods, and other iron work for carrying tie-beams, &c.

As for thoſe that are neceſſary for the turning joints of great engines conſtructed of timber, they make no part of the art of carpentry.

42
Examples
of different
pieces of
carpentry.

After having attempted to give a ſyſtematic view of the principles of framing carpentry, we ſhall conclude, by giving ſome examples which will illuſtrate and confirm the foregoing principles.

43
Roof of
Greenwich
chapel.

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

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

The truſſes are 7 feet apart, and the whole is covered with lead, the boarding being ſupported by horizontal ledgers *h*, *h*, of 6 by 4 inches.

This is a beautiful roof, and contains leſs timber than moſt of its dimenſions. The parts are all diſpoſed with great judgment. Perhaps the iron rod is unneceſſary; but it adds great ſtiffneſs to the whole.

The iron ſtraps at the rafter feet would have had more effect if not ſo oblique. Thoſe at the head of the poſts are very effective.

We may obſerve, however, that the joints between the ſtraining beam and its braces are not of the beſt kind, and tend to bruiſe both the ſtraining beam and the truſs beam above it.

44
St Paul's,
Covent
Garden.

Fig. 39. the roof of St Paul's, Covent Garden, conſtructed by Mr Wapſhot in 1796.

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

This roof far excels the original one put up by Inigo Jones. One of its truſſes contains 198 feet of timber. One of the old roof had 273, but had many inactive timbers, and others ill diſpoſed. (*N. B.* The figure which we gave of it in the article Roof, copied from Price,

Price, is very erroneous). The internal truſs FCF is admirably contrived for ſupporting the exterior rafters, without any preſſure on the far projecting ends of the tie-beam. The former roof had bent them greatly, ſo as to appear ungraceful.

We think that the camber (ſix inches) of the tie-beam is rather hurtful; becauſe, by ſettling, the beam lengthens; and this muſt be accompanied by a *conſiderable* ſinking of the roof. This will appear by calculation.

45 Birmingham theatre.

Fig. 40. the roof of Birmingham theatre, conſtructed by Mr Geo. Saunders. The ſpan is 80 feet clear, and the truſſes are 10 feet apart.

A, Is an oak corbel	9×5
B, Inner plate	9×9
C, Wall plate	8×5½
D, Pole plate	7×5
E, Beam	15×15
F, Straining beam	12×9
G, Oak king-poſt (in the ſhaft)	9×9
H, Oak queen-poſt (in the ſhaft)	7×9
I, Principal rafters	9×9
K, Common ditto	4×2½
L, Principal braces	9 and 6×9
M, Common ditto	6×9
N, Purlins	7×5
Q, Straining ſill	5½×9.

This roof is a fine ſpecimen of Britiſh carpentry, and is one of the boldeſt and lighteſt roofs in Europe. The ſtraining ſill Q gives a firm abutment to the principal braces, and the ſpace between the poſts is 19½ feet wide, affording roomy workſhips for the carpenters and other workmen connected with a theatre. The contrivance for taking double hold of the wall, which is very thin, is excellent. There is alſo added a beam (marked R), bolted down to the tie-beams. The intention of this was to prevent the total failure of ſo bold a truſſing, if any of the tie-beams ſhould fail at the end by rot.

46 Drury Lane theatre.

Akin to this roof is fig. 41. the roof of Drury Lane theatre, 80 feet 3 inches in the clear, and the truſſes 15 feet apart, conſtructed by Mr Edward Grey Saunders.

A, Beams	10 by 7
B, Rafters	7×7
C, King-poſts	12×7
D, Struts	5×7
E, Purlins	9×5
G, Pole plates	5×5
I, Common rafters	5×4
K, Tie-beam to the main truſs	15×12
L, Poſts to ditto	15×12
M, Principal braces to ditto	14 and 12×12
N, Struts	8×12
P, Straining beams	12×12

The main beams are truſſed in the middle ſpace with oak truſſes 5 inches ſquare. This was neceſſary for its width of 32 feet, occupied by the carpenters, painters, &c. The great ſpace between the truſſes affords good ſtore-rooms, dreſſing-rooms, &c.

It is probable that this roof has not its equal in the world for lightneſs, ſtiffneſs, and ſtrength. The main truſs is ſo judiciouſly framed, that each of them will ſafely bear a load of near 300 tons; ſo it is not likely that they will ever be quarter loaded. The diviſion of the whole into three parts makes the exterior roofings very light. The ſtrains are admirably kept from the walls, and the walls are even firmly bound together by the roof. They alſo take off the dead weight from the main truſs one-third.

47 Remarks

The intelligent reader will perceive that all theſe roofs are on one principle, depending on a truſs of three pieces and a ſtraight tie-beam. This is indeed the great principle of a truſs, and is a ſtep beyond the roof with two rafters and a king-poſt. It admits of much greater variety of forms, and of greater extent. We may ſee that even the middle part may be carried to any ſpace, and yet be flat at top; for the truſs beam may be ſupported in the middle by an inverted king-poſt (of timber, not iron), carried by iron or wooden ties from its extremities: And the ſame ties may carry the horizontal tie-beam K; for till K be torn aſunder, or M, M, and P be crippled, nothing can fail.

The roof of St Martin's church in the Fields is conſtructed on good principles, and every piece properly diſpoſed. But although its ſpan does not exceed 40 feet from column to column, it contains more timber in a truſs than there is in one of Drury-Lane theatre. The roof of the chapel at Greenwich, that of St Paul's, Covent Garden, that of Birmingham, and that of Drury Lane theatres, form a ſeries gradually more perfect. Such ſpecimens afford excellent leſſons to the artiſts. We therefore account them a uſeful preſent to the public.

48 Project by Mr Nicho ſon.

There is a very ingenious project offered to the public by Mr Nicholſon (*Carpenter's Aſſiſtant*, p. 68.) He propoſes iron rods for king-poſts, queen-poſts, and all other ſituations where beams perform the office of ties. This is in proſecution of the notions which we publiſhed in the article Roof of the *Encycl.* (ſee nº 36, 37.) He receives the feet of the braces and ſtruts in a ſocket very well connected with the foot of his iron king-poſt; and he ſecures the feet of his queen-poſts from being puſhed inwards, by interpoſing a ſtraining ſill. He does not even mortiſe the foot of his principal rafter into the end of the tie-beam, but ſets it in a ſocket like a ſhoe, at the end of an iron bar, which is bolted into the tie-beam a good way back. All the parts are formed and diſpoſed with the preciſion of a perſon thoroughly acquainted with the ſubject; and we have not the ſmalleſt doubt of the ſucceſs of the project, and the complete ſecurity and durability of his roofs; and we expect to ſee many of them executed. We abound in iron, but we muſt ſend abroad for building timber. This is therefore a valuable project; at the ſame time, however, let us not over-rate its value. Iron is but about 12 times ſtronger than red fir, and is more than 12 times heavier; nor is it cheaper, weight for weight, or ſtrength for ſtrength.

Our illuſtrations and examples have been chiefly taken from roofs, becauſe they are the moſt familiar inſtances of the difficult problems of the art. We could have wiſhed for more room even on this ſubject. The conſtruction of dome roofs has been (we think) miſtaken, and the difficulty is much leſs than is imagined. We mean in reſpect of ſtrength; for we grant that the obliquity of the joints, and a general intricacy, increaſes the trouble of workmanſhip exceedingly. Another opportunity may perhaps occur for conſidering this ſubject.

Fig. 1.

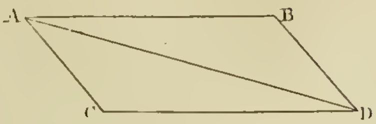


Fig. 2.

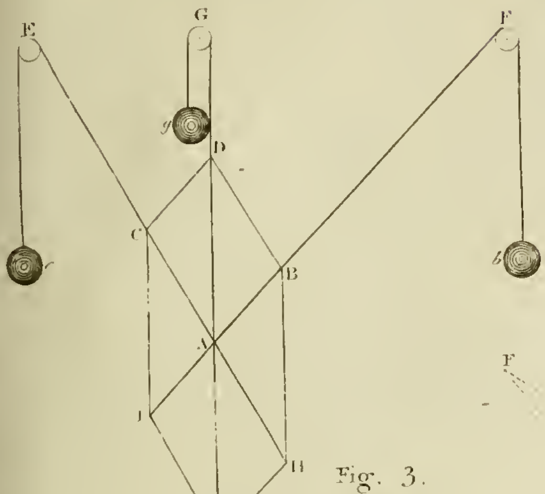


Fig. 4.

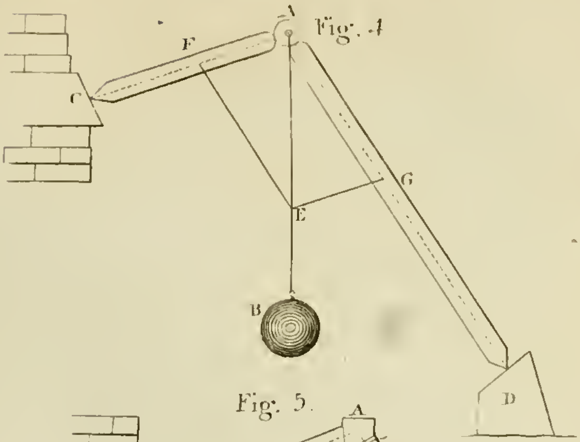


Fig. 5.

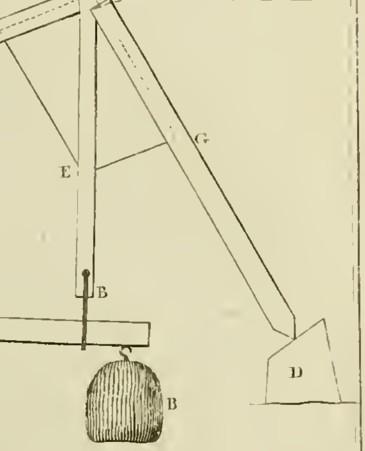


Fig. 8.

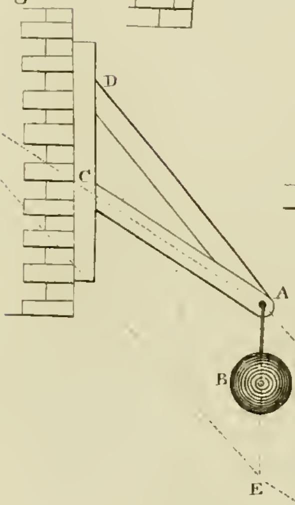


Fig. 3.

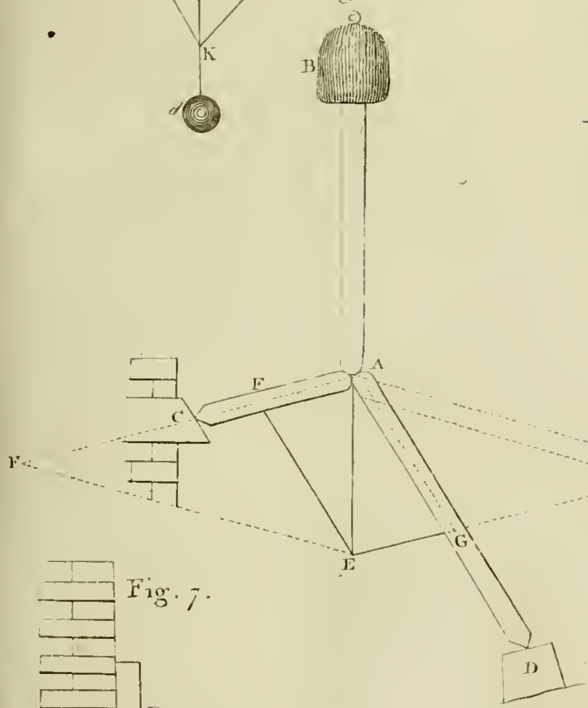


Fig. 6.

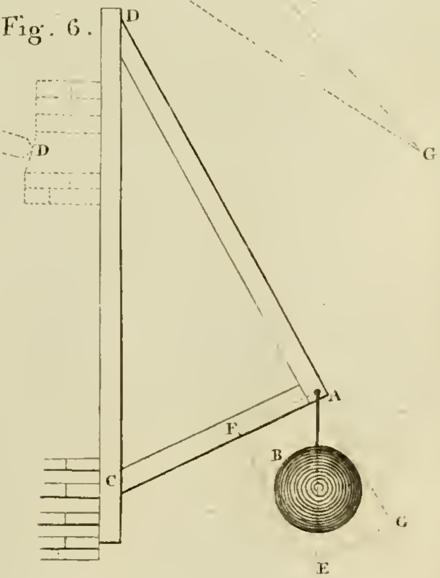


Fig. 7.

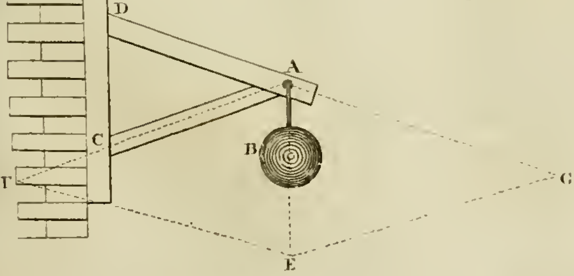
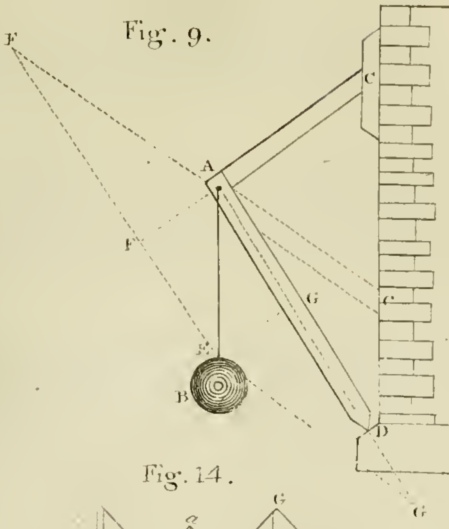


Fig. 9.



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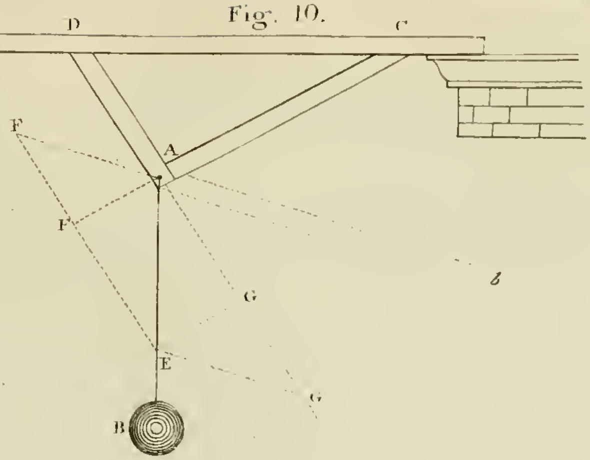

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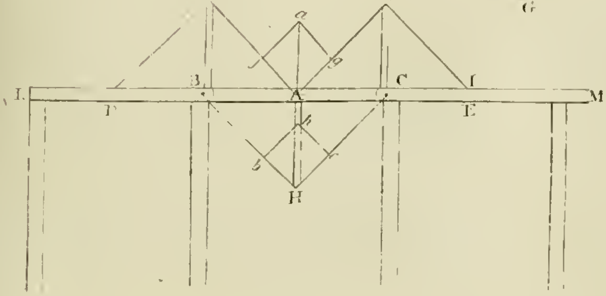

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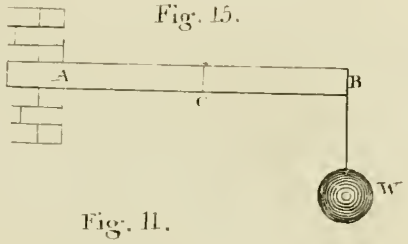

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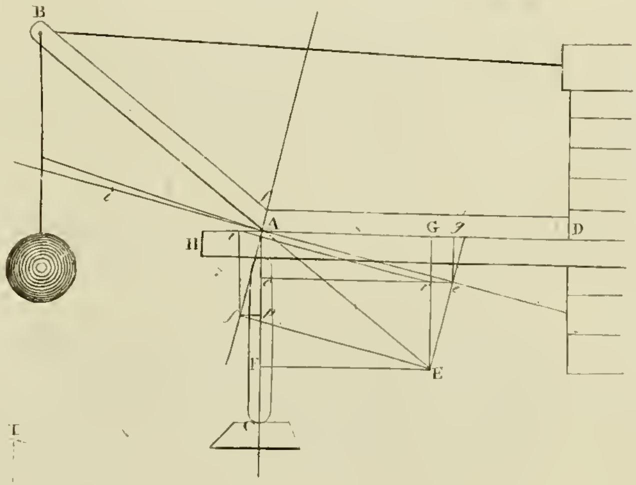

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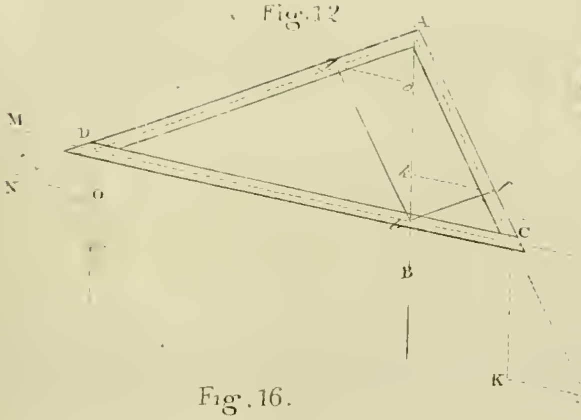

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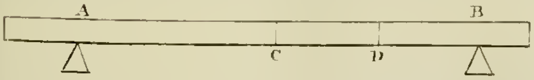

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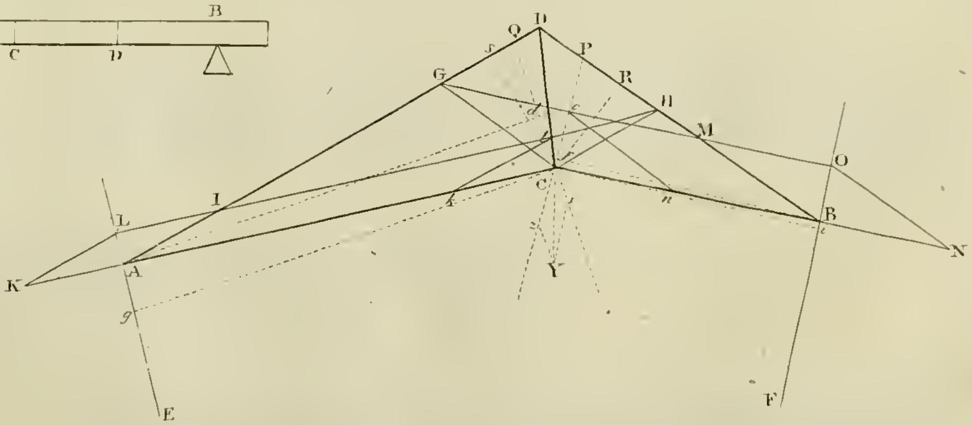

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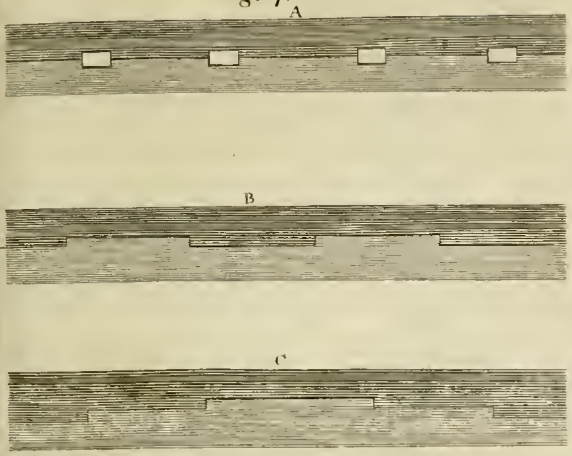

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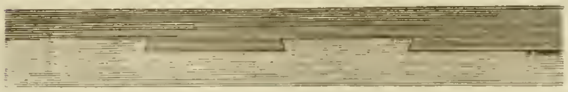

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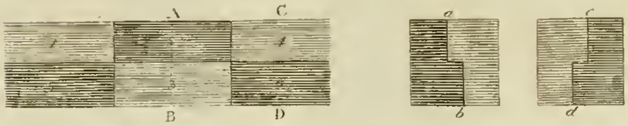

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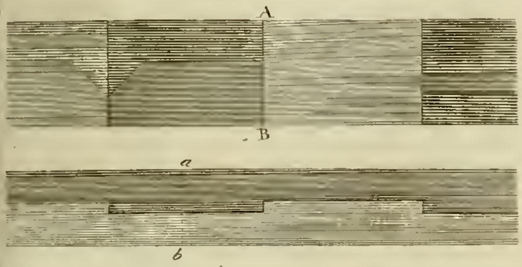

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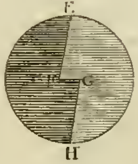

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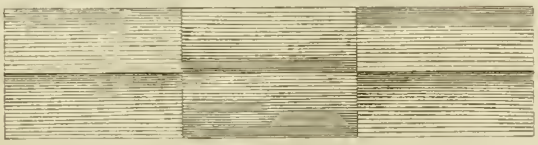

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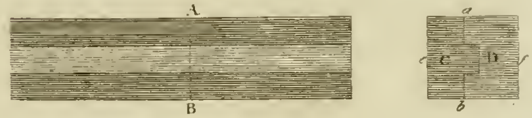

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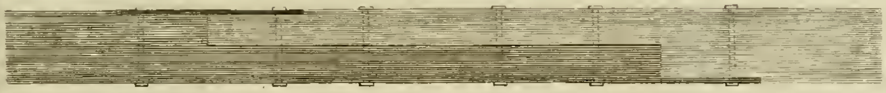

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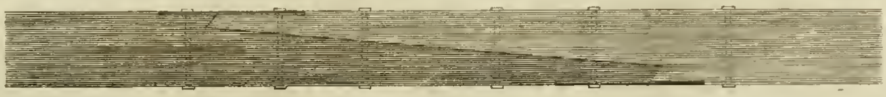

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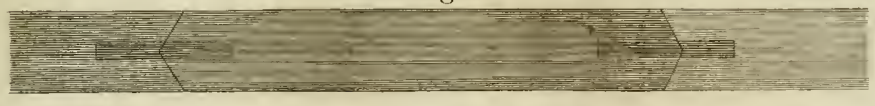

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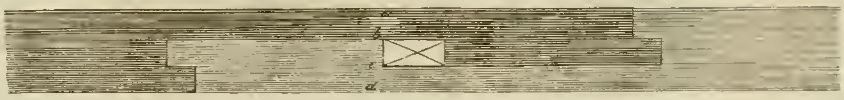

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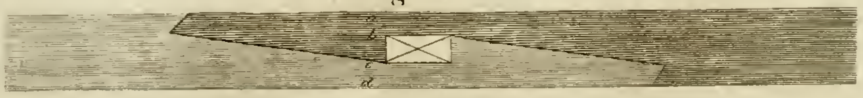

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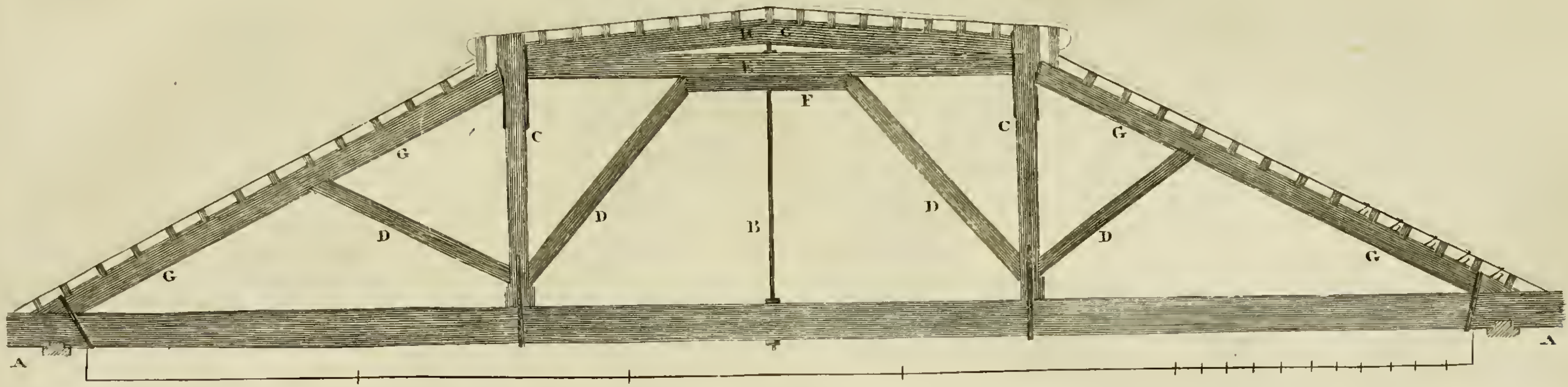
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Fig.39.

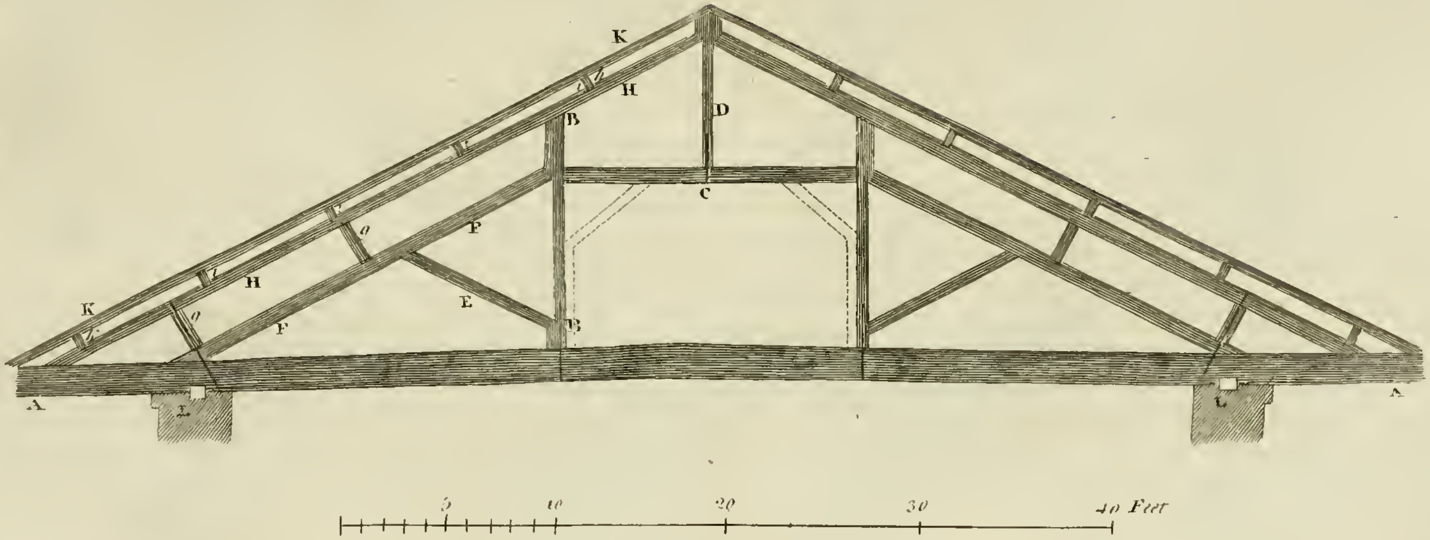
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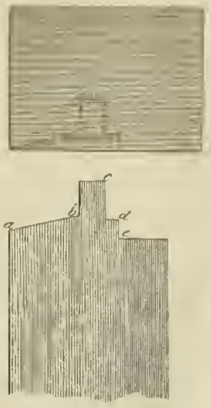
Fig. 27.

Fig. 29.



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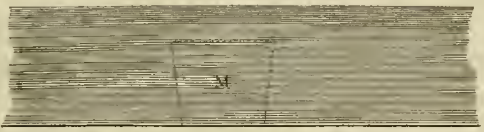

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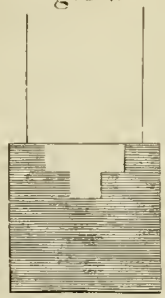

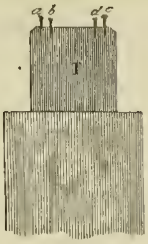

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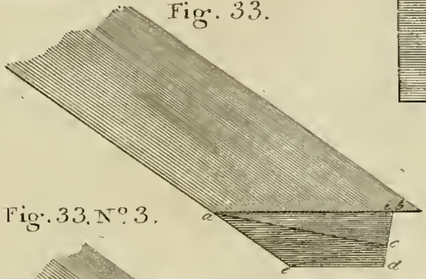

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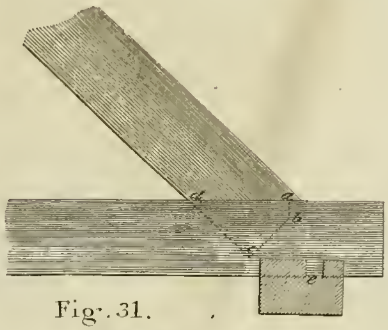

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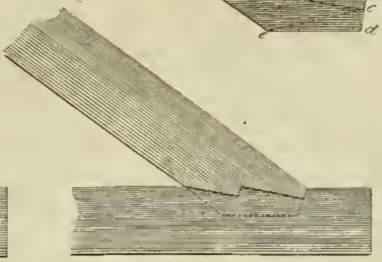

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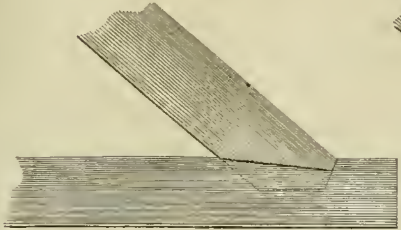

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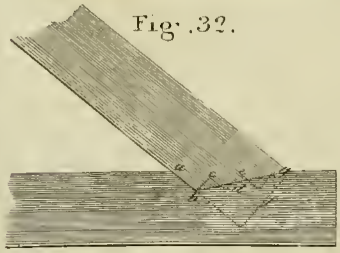

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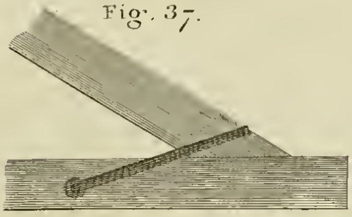

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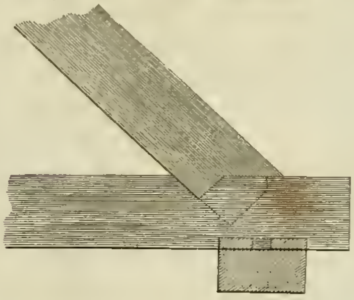

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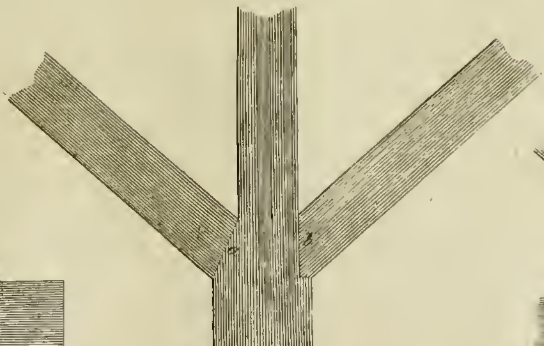

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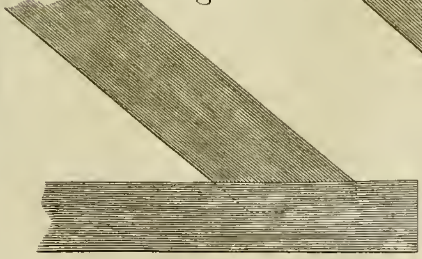

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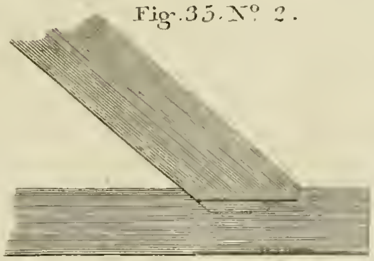

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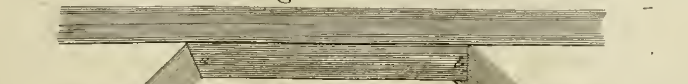

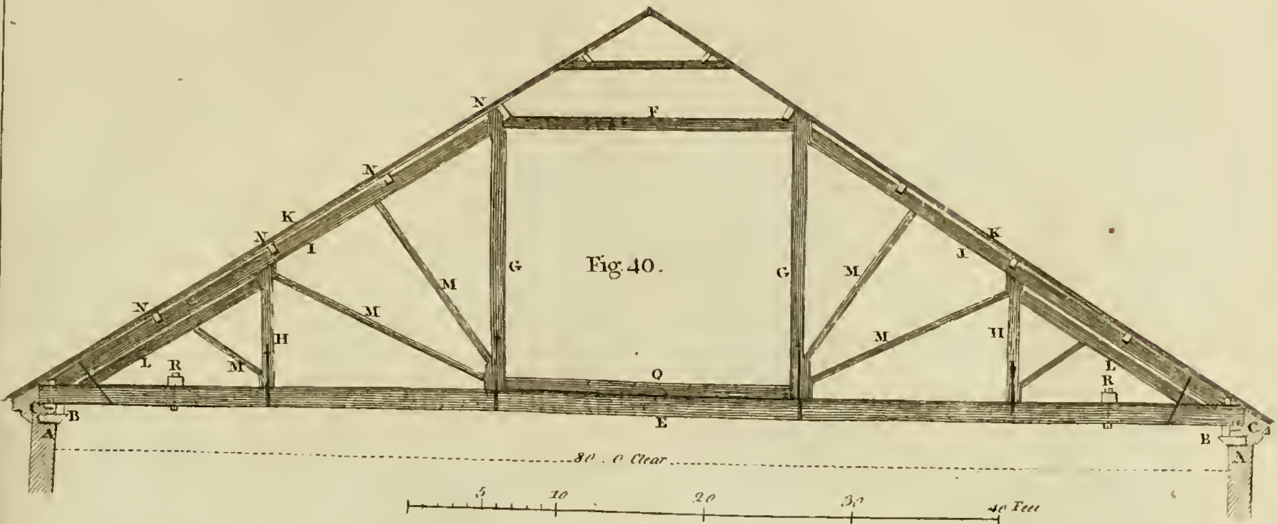

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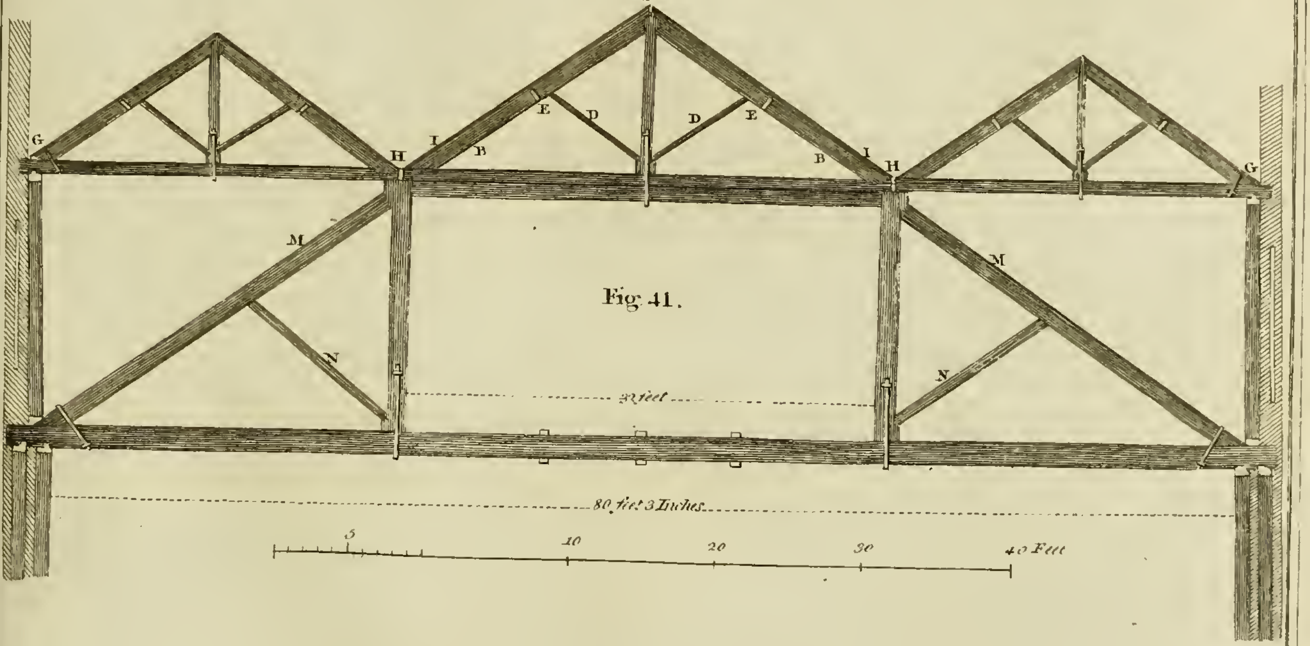
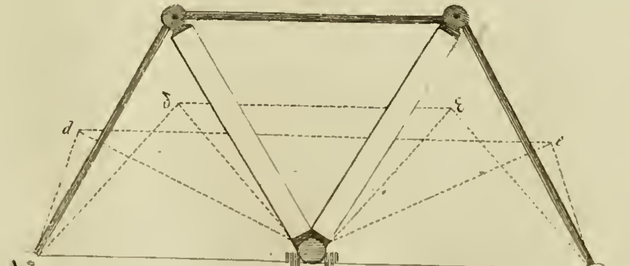


Fig. 41.

Fig. 42.



49 ooden idges. Wooden bridges form another claſs equally difficult and important; but our limits are already overpaſſed, and will not admit them. The principle on which they ſhould all be conſtructed, without exception, is that of a truſs, avoiding all lateral bearings on any of the timbers. In the application of this principle, we muſt farther remark, that the angles of our truſs ſhould be as acute as poſſible; therefore we ſhould make it of as few and as long pieces as we can, taking care to prevent the bending of the truſs beams by bridles, which embrace them, but without preſſing them to either ſide. When the truſs conſiſts of many pieces, the angles are very obtuſe; and the thruſts increaſe nearly in the duplicate proportion of the number of angles. The proper maxims will readily occur to the artiſt who conſiders with attention the ſpecimens of centres or coombs, which we ſhall give in the article Centre.

50 raming of reat levers. With reſpect to the frames of carpentry which occur in engines and great machines, the varieties are ſuch that it would require a volume to treat of them properly. The principles are already laid down; and if the reader be really intereſted in the ſtudy, he will engage in it with ſerіouſneſs, and cannot fail of being inſtructed. We recommend to his conſideration, as a ſpecimen of what may be done in this way, the working beam of Hornblower's ſteam-engine (ſee *Steam-Engine*, n° 84. *Encycl.*) When the beam muſt act by chains hung from the upper end of arch heads, the framing there given ſeems very ſcientifically conſtructed; at the ſame time, we think that a ſtrap of wrought iron, reaching the whole length of the upper bar (ſee the figure), would be vaſtly preferable to thoſe partial plates which the engineer has put there, for the bolts will ſoon work looſe.

But when arches are not neceſſary, the form employed by Mr Watt is vaſtly preferable, both for ſimplicity and for ſtrength. It conſiſts of a ſimple beam AB (fig. 42.), having the gudgeon C on the upper ſide. The two piſton-rods are attached to wrought iron joints A and B. Two ſtrong ſtruts DC, EC reſt on the upper ſide of the gudgeon, and carry an iron ſtring ADEB, conſiſting of three pieces, connected with the ſtruts by proper joints of wrought iron. A more minute deſcription is not needed for a clear conception of the principle. No part of this is expoſed to a croſs ſtrain; even the beam AB might be ſawed through at the middle. The iron ſtring is the only part which is ſtretched; for AC, DC, EC, BC, are all in a ſtate of compreſſion. We have made the angles equal, that all may be as great as poſſible, and the preſſure on the ſtruts and ſtrings a minimum. Mr Watt makes them much lower, as A *de* B, or A δ ε B. But this is for economy, becauſe the ſtrength is almoſt inſuperable. It might be made with wooden ſtrings; but the workmanſhip of the joints would more than compenſate the cheapneſs of the materials.

We offer this article to the public with deference, and we hope for an indulgent reception of our eſſay on a ſubject which is in a manner new, and would require much ſtudy. We have beſtowed our chief attention on the ſtrength of the conſtruction, becauſe it is here that perſons of the profeſſion have the moſt ſcanty information. We beg them not to conſider our obſervations as too refined, and that they will ſtudy them with care. One principle runs through the whole; and when that is clearly conceived and familiar to the mind, we venture to ſay that the practitioner will find it of eaſy application, and that he will improve every performance by a continual reference to it. 51 Concluſion.

If this attempt to inſtruct our moſt valuable and much eſteemed artiſts ſhall appear to meet with their approbation, it may encourage us to engage in the ſerious taſk of compoſing a ſyſtem on the ſubject. But this is a great work, and will require much time and liberal contribution of knowledge from the eminent carpenters who do honour to this country by their works.

CASCABEL, the knob or button of metal behind the breech of a cannon, as a kind of handle by which to elevate and direct the piece; to which ſome add the fillet and ogees as far as the baſe-ring.

CASEMATE, or Cazemate, in fortification, a kind of vault or arch of ſtone-work, in that part of the flank of a baſtion next the curtain; ſerving as a battery to defend the face of the oppoſite baſtion, and the moat or ditch.

It is now ſeldom uſed, becauſe the batteries of the enemy are apt to bury the artillery of the caſemate in the ruins of the vault; beſide, the great ſmoke made by the diſcharge of the cannon renders it intolerable to the men. So that, inſtead of the ancient covered caſemates, later engineers have contrived open ones, only guarded by a parapet, &c.

Casemate is alſo uſed for a well with ſeveral ſubterraneous branches, dug in the paſſage of the baſtion, till the miner is heard at work, and air given to the mine.

CASSINI (James), a celebrated French aſtronomer, was born at Paris February 18. 1677, being the younger ſon of Johannes Dominicus Caſſini, of whom ſome account has been given in the *Encyclopædia*.

After his firſt ſtudies in his father's houſe, in which it is not to be ſuppoſed that mathematics and aſtronomy would be neglected, he was ſent to ſtudy philoſophy at the Mazarine college, where the celebrated Varignon was then profeſſor of mathematics. From the aſſiſtance of this eminent young man Caſſini profited ſo well, that at 15 years of age he ſupported a mathematical theſis with great honour. At the age of 17 he was admitted a member of the Academy of Sciences; and the ſame year he accompanied his father in a journey to Italy, where he aſſiſted him in the verification of the meridian at Bologna and other meaſurements. On his return he performed ſimilar operations in a journey into Holland, where he diſcovered ſome errors in the meaſure of the earth by Snell, the reſult of which was communicated to the Academy in 1702. He made alſo a viſit to England in 1696, where he was made a member of the Royal Society. In 1712 he ſucceeded his father as aſtronomer royal at the obſervatory of Paris. In 1717 he gave to the Academy his reſearches on the diſtance of the fixed ſtars; in which he ſhewed that the whole annual orbit, of near 200 millions of miles diameter, is but as a point in compariſon of that diſtance. The ſame year he communicated alſo his diſcoveries concerning the inclination of the orbits of the ſatellites in general, and eſpecially of thoſe of Saturn's ſatellites and ring. In 1725 he undertook to determine the cauſe of the moon's libration, by which ſhe ſhews ſometimes a little towards one ſide, and ſometimes a little on the other, of that half which is commonly behind or hid from our view.

In 1732 an important queſtion in aſtronomy exerciſed the ingenuity of our author. His father had determined, by his obſervations, that the planet Venus revolved about her axis in the ſpace of 23 hours; and M. Bianchini had publiſhed a work in 1729, in which he ſettled the period of the ſame revolution at 24 days 8 hours. From an examination of Bianchini's obſervations which were upon the ſpots in Venus, he diſcovered that he had intermitted his obſervations for the ſpace of three hours, from which cauſe he had probably miſtaken new ſpots for the old ones, and ſo had been led into the miſtake. The probability is, that both had fallen into ſome miſtake, or that they had proceeded on very different principles; for otherwiſe ſuch different reſults are wholly unaccountable. Dr Herſchel ſeems ſatisfied that the period of the revolution is leſs than Bianchini has made; but he does not ſay what it is, or that it is not much greater than it was ſuppoſed by Caſſini. Our author, after he had convicted Bianchini, as he thought, of error, determined the nature and quantity of the acceleration of the motion of Jupiter at half a ſecond per year, and of that of the retardation of Saturn at two minutes per year; that theſe quantities would go on increaſing for 2000 years, and then would decreaſe again. In 1740 he publiſhed his Aſtronomical Tables, and his Elements of Aſtronomy; very extenſive and accurate works.

Although aſtronomy was the principal object of our author's conſideration, he did not confine himſelf abſolutely to that branch, but made occaſional excurſions into other fields. We owe alſo to him, for example, Experiments on Electricity, or the Light produced by Bodies by Friction; Experiments on the Recoil of Fire-arms; Reſearches on the Riſe of the Mercury in the Barometer at different Heights above the Level of the Sea; Reflections on the perfecting of Burning-glaſſes; and other Memoirs.

The French Academy had properly judged, that one of its moſt important objects was the meaſurement of the earth. In 1669 Picard meaſured a little more than a degree of latitude to the north of Paris; but as that extent appeared too ſmall from which to conclude the whole circumference with ſufficient accuracy, it was reſolved to continue that meaſurement on the meridian of Paris to the north and the ſouth, through the whole extent of the country. Accordingly, in 1683, the late M. de la Hire continued that on the north ſide of Paris, and the older Caſſini that on the ſouth ſide. The latter was aſſiſted in 1700 in the continuation of this operation by his ſon our author. The ſame work was farther continued by the ſame academicians; and, finally, the part left unfiniſhed by De la Hire in the north was finiſhed in 1718 by our author, with the late Maraldi, and De la Hire the younger.

Theſe operations produced a conſiderable degree of preciſion. It appeared alſo, from this meaſured extent of ſix degrees, that the degrees were of different lengths in different parts of the meridian; and in ſuch ſort that our author concluded, in the volume publiſhed for 1718, that they decreaſed more and more towards the pole, and that therefore the figure of the earth was that of an oblong ſpheroid, or having its axis longer than the equatorial diameter. He alſo meaſured the perpendicular to the ſame meridian, and compared the meaſured diſtance with the differences of longitude as before determined by the eclipſes of Jupiter's ſatellites: whence he concluded that the length of the degrees of longitude was ſmaller than it would be on a ſphere, and that therefore again the figure of the earth was an oblong ſpheroid, contrary to the determination of Newton by the theory of gravity. Though Newton was of all men the moſt averſe from controverſy, the other mathematicians in Britain did not tamely ſubmit to concluſions in direct oppoſition to the fundamental doctrine of a philoſopher of whoſe talents the nation was juſtly proud. The conſequence was, that the French government ſent two different ſets of meaſurers, the one to meaſure a degree at the equator, the other at the polar circle; and the compariſon of the whole determined the figure to be an oblate ſpheroid, contrary to Caſſini's determination.

After a long and laborious life, James Caſſini died in April 1756, in conſequence of a fall, and was ſucceeded in the Academy and Obſervatory by the ſubject of the following article. He publiſhed, A Treatiſe on the Magnitude and Figure of the Earth; as alſo, The Elements or Theory of the Planets, with Tables; beſide an infinite number of papers in the Memoirs of the Academy, from the year 1699 to 1755.

Cassini de Thury (Ceſar François), a celebrated French aſtronomer, director of the obſervatory, penſioner aſtronomer, and member of moſt of the learned ſocieties of Europe, was born at Paris June 17. 1714, being the ſecond ſon of James Caſſini, the ſubject of the preceding memoir, whoſe occupations and talents he inherited and ſupported with great honour. He received his firſt leſſons in aſtronomy and mathematics from MM. Maraldi and Camus; and made ſuch a rapid progreſs, that when he was not more than ten years of age he calculated the phaſes of a total eclipſe of the ſun. At the age of eighteen he accompanied his father in his two journeys undertaken for drawing the perpendicular to the obſervatory meridian from Straſbourg to Breſt. From that time a general chart of France was deviſed; for which purpoſe it was neceſſary to traverſe the country by ſeveral lines parallel and perpendicular to the meridian of Paris, and our author was charged with the conduct of this buſineſs; in which he was ſo ſcrupulous as to meaſure again what had been meaſured by his father. This great work was publiſhed in 1740, with a chart ſhewing the new meridian of Paris, by two different ſeries of triangles, paſſing along the ſea coaſts to Bayonne, traverſing the frontiers of Spain to the Mediterranean and Antibes, and thence along the eaſtern limits of France to Dunkirk, with parallel and perpendicular lines deſcribed at the diſtance of 6000 toiſes from one another, from ſide to ſide of the country.

A tour which, in 1741, our author made in Flanders, in the train of the king, gave riſe, at his majeſty's inſtance, to the chart of France; relative to which Caſſini publiſhed different works, as well as a great number of the ſheets of the chart itſelf. In 1761 he undertook an expedition into Germany, for the purpoſe of continuing to Vienna the perpendicular of the Paris

ris meridian; to unite the triangles of the chart of France with the points taken in Germany; to prepare the means of extending into that country the ſame plan as in France; and thus to eſtabliſh ſucceſſively for all Europe a moſt uſeful uniformity.—Our author was at Vienna the 6th of June 1761, the day of the tranſit of the planet Venus over the ſun, of which he obſerved as much as the ſtate of the weather would permit him to do, and publiſhed the account of it in his *Voyage en Allemagne*.

Finally, M. Caſſini, always meditating the perfection of his grand deſign, profited of the peace of 1783 to propoſe the joining of certain points taken upon the Engliſh coaſt with thoſe which had been determined on the coaſt of France, and thus to connect the general chart of the latter with that of the Britiſh iſles, like as he had before united it with thoſe of Flanders and Germany. The propoſal was favourably received by the Engliſh government, and preſently carried into effect under the direction of the Royal Society, the execution being committed to the late General Roy. See the life of that general in this *Supplement*.

Between the years 1735 and 1770, M. Caſſini publiſhed, in the volumes of Memoirs of the French Academy, a prodigious number of pieces, conſiſting chiefly of aſtronomical obſervations and queſtions; among which are obſervable, reſearches concerning the parallax of the ſun, the moon, Mars, and Venus; on aſtronomical refractions, and the effect cauſed in their quantity and laws by the weather; numerous obſervations on the obliquity of the ecliptic, and on the law of its variations. In ſhort, he cultivated aſtronomy for fifty years, the moſt important for that ſcience that ever elapſed for the magnitude and variety of objects, in which he commonly ſuſtained a principal ſhare.

M. Caſſini was of a very ſtrong and vigorous conſtitution, which carried him through the many laborious operations in geography and aſtronomy which he conducted. An habitual retention of urine, however, rendered the laſt twelve years of his life very painful and diſtreſſing, till it was at length terminated by the ſmall-pox the 4th of September 1784, in the 71ſt year of his age. He was ſucceeded in the academy, and as director of the obſervatory, by his only ſon John-Dominic Caſſini, the fourth in order of direct deſcent who has filled that honourable ſtation.

CASTRAMETATION, the art or act of encamping an army.

CATACAUSTICS, or CATACAUSTIC CURVES, in the higher geometry, are the ſpecies of cauſtic curves formed by reflection.

CATACOUSTICS, or CATAPHONICS, is the ſcience of reflected ſounds; or that part of acouſtics which treats of the properties of echoes.

CATALOGUES OF BOOKS, is a ſubject of which a very curious hiſtory has been given to the world by Profeſſor Beckmann. In the Encyclopædia mention has been made of ſome of the moſt valuable catalogues, their defects pointed out, and rules given for making them more perfect; but nothing has there been ſaid of their origin, or of the uſes which might be made of the oldeſt catalogues.

According to the Profeſſor, George Willer, whom ſome improperly call Viller, and others Walter, a bookſeller at Augſburg, who kept a very large ſhop, and frequented the Franckfort fairs, firſt fell upon the plan of cauſing to be printed, before every fair, a catalogue of all the new books, in which the ſize and printers names were marked. Le Mire, better known under the name of Miræus, ſays that catalogues were firſt printed in the year 1554; but Labbe (A), Reimann (B), and Heumann (C), who took their information from Le Mire, make the year erroneouſly to be 1564. Willer's catalogues were printed till the year 1592 by Nicol. Baſſæus, printer at Franckfort. Other bookſellers, however, muſt have ſoon publiſhed catalogues of the like kind, though that of Willer continued a long time to be the principal.

In all theſe catalogues, which are in quarto and not paged, the following order is obſerved. The Latin books occupy the firſt place, beginning with the Proteſtant theological works, perhaps becauſe Willer was a Lutheran; then come the Catholic; and after theſe, books of juriſprudence, medicine, philoſophy, poetry, and muſic. The ſecond place is aſſigned to German books, which are arranged in the ſame manner.

The bookſellers of Leipſic ſoon perceived the advantage of catalogues, and began not only to reprint thoſe of Franckfort, but alſo to enlarge them with many books which had not been brought to the fairs in that city. Our author had for ſome time in his cuſtody, *Catalogus univerſalis pro nundinis Francofurtenſibus vernalibus, de anno* 1600; or, A catalogue of all the books on ſale in Book-ſtreet, Franckfort, and alſo of the books publiſhed at Leipſic, which have not been brought to Franckfort, with the permiſſion of his highneſs the elector of Saxony, to thoſe new works which have appeared at Leipſic. Printed at Leipſic by Abraham Lamberg, and to be had at his ſhop. On the September catalogue of the ſame year, it is ſaid that it is printed from the Franckfort copy with additions. He found an Imperial privilege for the firſt time on the Franckfort September catalogue of 1616: *Cum gratia et privilegio ſpeciali ſ. caeſ. maj. Proſtat apud J. Krugerum Auguſtanum.*

Reimmann ſays, that after Willer's death the catalogue was publiſhed by the Leipſic bookſeller Henning Groſſe, and by his ſon and grandſon. The council of Franckfort cauſed ſeveral regulations to be iſſued reſpecting catalogues; an account of which may be ſeen in D. Orth's *Treatiſe on the Imperial Fairs at Franckfort*. After the buſineſs of bookſelling was drawn from Franckfort to Leipſic, occaſioned principally by the reſtrictions to which it was ſubjected at the former by the cenſors, no more catalogues were printed there; and the ſhops in Book-ſtreet were gradually converted into taverns (D).

“ In the 16th century there were few libraries; and theſe, which did not contain many books, were in monaſteries,

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(A) Labbe, Bibliotheca Bibliothecarum. Lipſiæ, 1682, 12mo, p. 112.

(B) Einleitung in die *Hiſtoriam Literariam*, i. p. 203.

(C) Conſpectus Reip. Litter. c. vi. § 2. p. 316.

(D) Joh. Adolph. Stock, Frankfurter Chronik, p. 77.

Catalogues of Books.

naſteries, and conſiſted principally of theological, philoſophical, and hiſtorical works, with a few, however, on juriſprudence and medicine; while thoſe which treated of agriculture, manufactures, and trade, were thought unworthy of the notice of the learned, or of being preſerved in large collections. The number of theſe works was, nevertheleſs, far from being inconſiderable; and at any rate, many of them would have been of great uſe, as they would have ſerved to illuſtrate the inſtructive hiſtory of the arts. Catalogues which might have given occaſion to inquiries after books, that may be ſtill ſomewhere preſerved, have ſuffered the fate of tomb-ſtones, which, being waſted and crumbled to pieces by the deſtroying hand of time, become no longer legible. A complete ſeries of them perhaps is nowhere to be found, at leaſt I do not remember (ſays the Profeſſor) to have ever ſeen one in any library."

This loſs, however, he thinks, might be in ſome meaſure ſupplied by the catalogues of Cleſs and Draudius; who, by the deſire of ſome bookſellers, collected together all the catalogues which had been publiſhed at the different fairs in different years. The work of Cleſs has the following title: *Unius ſæculi ejuſque virorum litteratorum monumentis tum florentiſſimi, tum fertiliſſimi, ab anno* 1500 *ad* 1602 *nundinarum autumnalium incluſive, elenchus conſummatiſſimus—deſumtus partim ex ſingularum nundinarum catalogis, partim ex bibliothecis.* Auctore Joanne Cleſſio, Wineccenſi, Hannoio, philoſopho ac medico.—By the editor's preface, it appears that the firſt edition was publiſhed in 1592. The order is almoſt the ſame as that obſerved by Willer in his catalogues.

The work of Draudius, which was printed in ſeveral quarto volumes for the firſt time in 1611, and afterwards in 1625, is far larger, more complete, and more methodical. Our author, however, confeſſes, that he never ſaw a perfect copy of either edition. This catalogue conſiſts of three parts; of which the firſt has the title of *Bibliotheca claſſica, ſive Catalogus officinalis, in quo ſinguli ſingularum facultatum ac profeſſionum libri, qui in quavis fere lingua extant—recenſentur; uſque ad annum* 1624 *incluſive.* Auctore M. Georgio Draudio.—It contains Latin works on theology, juriſprudence, medicine, hiſtory, geography, and politics. The copy in the library of the univerſity of Gottingen ends at page 1304, which has, however, a catch-word, that ſeems to indicate a deficiency.—The ſecond part is intitled, *Bibliotheca claſſica ſive Catalogus officinalis, in quo philoſophici artiumque adeo humaniorum, poetici etiam et muſici libri uſque ad annum* 1624 *continentur.* This part, containing Latin books alſo, begins at page 1298, and ends with page 1654, which is followed by an index of all the authors mentioned.—A ſmaller volume, of 302 pages, without an index, has for title, *Bibliotheca exotica, ſive Catalogus officinalis librorum peregrinis linguis uſualibus ſcriptorum.* And a third part, forming 759 pages, beſides an index of the authors, is called, *Bibliotheca librorum Germanicorum claſſica;* that is, A catalogue of all the books printed in the German language till the year 1625.

We have reaſon to believe that there are other editions of this catalogue than thoſe mentioned by Profeſſor Beckmann; and it might become ſome prince or great man, for it is not a work for a bookſeller, to compare all the editions together, and publiſh a new one more correct than any that is at preſent extant. This indeed would be an expenſive and not an eaſy taſk; for our author obſerves, that all the oldeſt catalogues had the ſame faults as thoſe of later date, and that theſe faults have been copied by Draudius. Many books are mentioned which were never printed, and many titles, names, and dates, are given incorrectly; but Draudius nevertheleſs is well worth the attention of any one who may be inclined to employ his time and ingenuity on the hiſtory of literature; and his work certainly was of uſe to Haller when he compoſed his *Bibliotheca.*

Catalogues of the Stars.

Catalogues of the Stars, have uſually been diſpoſed, either as collected into certain figures called *conſtellations*, or according to their right aſcenſions, that is, the order of their paſſing over the meridian.

Of the principal catalogues, according to the firſt of theſe forms, an account has been given in the *Encyclopædia.* The firſt catalogue, we believe, that was printed in the new or ſecond form, according to the order of the right aſcenſions, is that of De la Caille, given in his Ephemerides for the ten years between 1755 and 1765, and printed in 1755. It contains the right aſcenſions and declinations of 307 ſtars, adapted to the beginning of the year 1750. In 1757 De la Caille publiſhed his *Aſtronomiæ Fundamenta*, containing a catalogue of the right aſcenſions and declinations of 398 ſtars, likewiſe adapted to the beginning of 1750. And in 1763, the year after his death, was publiſhed the *Cœlum Auſtrale Stelliferum* of the ſame author; containing a catalogue of the places of 1942 ſtars, all ſituated to the ſouthward of the tropic of Capricorn, and obſerved by him while he was at the Cape of Good Hope in 1751 and 1752; their places being alſo adapted to the beginning of 1750. In the ſame year was publiſhed his Ephemerides for the ten years between 1765 and 1775; in the introduction to which are given the places of 515 zodiacal ſtars, all deduced from the obſervations of the ſame author; the places adapted to the beginning of the year 1765.

In the Nautical Almanac for 1773, is given a catalogue of 387 ſtars, in right aſcenſion, declination, longitude, and latitude, derived from the obſervations of the late celebrated Dr Bradley, and adjuſted to the beginning of the year 1760. This ſmall catalogue, and the reſults of about 1200 obſervations of the moon, are all that the public have yet ſeen of the multiplied labours of this moſt accurate and indefatigable obſerver, although he has now (1798) been dead upwards of 38 years.

In 1775 was publiſhed a thin volume, intitled *Opera Inedita*, containing ſeveral papers of the late Tobias Mayer, and among them a catalogue of the right aſcenſions and declinations of 998 ſtars, which may be occulted by the moon and planets; the places being adapted to the beginning of the year 1756.

At the end of the firſt volume of "Aſtronomical Obſervations made at the Royal Obſervatory at Greenwich," publiſhed in 1776, Dr Maſkelyne, the preſent aſtronomer royal, has given a catalogue of the places of 34 principal ſtars, in right aſcenſion and north polar diſtance, adapted to the beginning of the year 1770.

Theſe being the reſult of ſeveral years repeated obſervations, made with the utmoſt care and the beſt inſtruments, it may be preſumed are exceedingly accurate.

In 1782, M. Bode of Berlin publiſhed a very extenſive catalogue of 5058 of the fixed ſtars, collected from

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from the obſervations of Flamſteed, Bradley, Hevelius, Mayer, De la Caille, Meſſier, Monnier, D'Arqueir, and other aſtronomers; all adapted to the beginning of the year 1780; and accompanied with a celeſtial atlas or ſet of maps of the conſtellations, engraved in a moſt delicate and beautiful manner.

To theſe may be added Dr Herſchel's catalogue of double ſtars, printed in the Phil. Tranſ. for 1782 and 1783; Meſſier's nebulæ and cluſters of ſtars, publiſhed in the *Connoiſſance des Temps* for 1784; and Herſchel's catalogue of the ſame kind, given in the Phil. Tranſ. for 1786.

In 1789 Mr Francis Wollaſton publiſhed "A Specimen of a General Aſtronomical Catalogue, in Zones of North-polar Diſtance, and adapted to January 1. 1790." Theſe ſtars are collected from all the catalogues before-mentioned, from that of Hevelius downwards. This work contains five diſtinct catalogues; viz. Dr Maſkelyne's new catalogue of 36 principal ſtars; a general catalogue of all the ſtars, in zones of north-polar diſtance; an index to the general catalogue; a catalogue of all the ſtars, in the order in which they paſs the meridian; and a catalogue of zodiacal ſtars, in longitude and latitude.

Finally, in 1792, Dr Zach publiſhed at Gotha, *Tabulæ Motuum Solis;* to which is annexed a new catalogue of the principal fixed ſtars, from his own obſervations made in the years 1787, 1788, 1789, 1790. This catalogue contains the right aſcenſions and declinations of 381 principal ſtars, adapted to the beginning of the year 1800.—*Hutton's Mathematical Dictionary*.

Beſides theſe two methods of forming *catalogues* of the ſtars, Dr Herſchel has conceived a new one, in which the comparative brightneſs of the ſtars is accurately expreſſed. It is long ſince aſtronomers were firſt led to arrange the ſtars in claſſes of different magnitudes by their various degrees of brilliancy or luſtre. Brightneſs and ſize have at all times been conſidered as ſynonymous terms; ſo that the brighteſt ſtars have been referred to the claſs comprehending thoſe of the firſt magnitude; and as the ſubſequent orders of ſtars have been ſuppoſed to decreaſe in luſtre, their magnitude has been determined in the ſame decreaſing progreſſion: but the want of ſome fixed and ſatisfactory ſtandard of luſtre has been the ſource of conſiderable confuſion and uncertainty in ſettling the relative magnitudes of the ſtars. A ſtar marked 1. 2m. is ſuppoſed to be between the firſt and ſecond magnitude; but 2. 1m. intimates that the ſtar is nearly of the ſecond magnitude, and that it partakes ſomewhat of the luſtre of a ſtar of the firſt order. Such ſubdiviſions may be of ſome uſe in aſcertaining ſtars of the firſt, ſecond, and third claſſes; but the expreſſions 5m, 5.6m, 6.5m, 6m, muſt be very vague and indefinite. Dr Herſchel obſerves that he has found them ſo in fact; and he therefore conſiders this method of pointing out the different luſtre of ſtars as a reference to an imaginary ſtandard. If any dependence could be placed on this method of magnitudes, "it would follow, that no leſs than eleven ſtars in the conſtellation of the Lion, namely, β σ τ ξ A *b c d* 54, 48, 72, had all undergone a change in their luſtre ſince Flamſteed's time: For if the idea of magnitudes had been a clear one, our author, who marked β 1.2m. and γ 2m. ought to be underſtood to mean that β is larger than γ; but we now find that actually γ is larger than β. Every one of the eleven ſtars (ſays Dr Herſchel) which I have pointed out may be reduced to the ſame contradiction."

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The author has pointed out the inſtances of the inſufficiency of this method, and of the uncertain concluſions that are deduced from it, in determining the comparative brightneſs of ſtars found not only in Mr Flamſteed's catalogue, but alſo in the catalogues of other aſtronomers. It is ſufficiently apparent that the preſent method of expreſſing the brightneſs of the ſtars is very defective. Dr Herſchel therefore propoſes a different mode, that is more preciſe and ſatisfactory.

"I place each ſtar (he ſays), inſtead of giving its magnitude, into a ſhort ſeries, conſtructed upon the order of brightneſs of the neareſt proper ſtars. For inſtance, to expreſs the luſtre of D, I ſay CDE. By this ſhort notation, inſtead of referring the ſtar D to an imaginary uncertain ſtandard, I refer it to a preciſe and determined exiſting one. C is a ſtar that has a greater luſtre than D, and E is another of leſs brightneſs than D. Both C and E are neighbouring ſtars, choſen in ſuch a manner that I may ſee them at the ſame time with D, and therefore may be able to compare them properly. The luſtre of C is in the ſame manner aſcertained by BCD; that of B by ABC; and alſo the brightneſs of E by DEF; and that of F by EFG.

"That this is the moſt natural, as well as the moſt effectual way to expreſs the brightneſs of a ſtar, and by that means to detect any change that may happen in its luſtre, will appear, when we conſider what is requiſite to aſcertain ſuch a change. We can certainly not wiſh for a more deciſive evidence, than to be aſſured, by actual inſpection, that a certain ſtar is now no longer more or leſs bright than ſuch other ſtars to which it has been formerly compared; provided we are at the ſame time aſſured that thoſe other ſtars remain ſtill in their former unaltered luſtre. But if the ſtar D will no longer ſtand in its former order CDE, it muſt have undergone a change; and if that order is now to be expreſſed by CED, the ſtar has loſt ſome part of its luſtre; if, on the contrary, it ought now to be denoted by DCE, its brightneſs muſt have had ſome addition. Then, if we ſhould doubt the ſtability of C and E, we have recourſe to the orders BCD and DEF, which expreſs their luſtre; or even to ABC and EFG, which continue the ſeries both ways. Now having before us the ſeries BCDEF, or if neceſſary even the more extended one ABCDEFG, it will be impoſſible to miſtake a change of brightneſs in D, when every member of the ſeries is found in its proper order except D."

In the author's journal or catalogue, in which the order of the luſtre of the ſtars is fixed, each ſtar bears its own proper name or number, *e. g.* "the brightneſs of the ſtar δ Leonis may be expreſſed by β δ ι Leonis, or better by 94—68—17 Leonis; theſe being the numbers which the three above ſtars bear in the Britiſh catalogue of fixed ſtars."

This method of arrangement occurred to Dr Herſchel ſo early as the year 1782; but he was diverted from the regular purſuit of it by a variety of other aſtronomical engagements. After many trials, he propoſed, in the Tranſactions of the Royal Society of London for 1796, the plan which appeared to him the moſt eligible. It is as follows:—Inſtead of denoting particular ſtars by letters, he makes uſe of numbers; and in his choice of the ſtars which are to expreſs the luſtre of any particular one, he directs his firſt view to perfect equality. When two ſtars ſeem to be ſimilar both in brightneſs and magnitude, he puts down their numbers together, ſeparated merely by a point, as 30.24 Leonis; but if two ſtars, which at firſt ſeemed alike in their luſtre, appeared on a longer inſpection to be different, and the preference ſhould be always decidedly in favour of the ſame ſtar, he ſeparates theſe ſtars by a comma, thus, 41,94 Leonis. This order muſt not be varied; nor can three ſuch ſtars, as 20, 40, 39, Libræ, admit of a different arrangement. If the ſtate of the heavens ſhould be ſuch as to require a different order in theſe numbers, we may certainly infer that a change has taken place in the luſtre of one or more of them. When two ſtars differ very little in brightneſs, but ſo that the preference of the one to the other is indiſputable, the numbers that expreſs them are ſeparated by a ſhort line, as 17—70 Leonis, or 68—17—70 Leonis. When two ſtars differ ſo much in brightneſs, that one or two other ſtars might be interpoſed between them, and ſtill leave ſufficient room for diſtinction, they are diſtinguiſhed by a line and comma, thus, —, or by two lines, as 32— —41 Leonis. A greater difference than this is denoted by a broken line, thus — — —29 Bootis. On the whole, the author obſerves, the marks and diſtinctions which he has adopted cannot poſſibly be miſtaken; "a point denoting equality of luſtre; a comma indicating the leaſt perceptible difference; a ſhort line to mark a decided but ſmall ſuperiority; a line and comma, or double line, to expreſs a conſiderable and ſtriking exceſs of brightneſs; and a broken line to mark any other ſuperiority which is to be looked upon as of no uſe in eſtimations that are intended for the purpoſe of directing changes."

The difficulties that attend this arrangement are not diſguiſed; but the importance and utility of it more than compenſate for the labour which it muſt neceſſarily require. By a method of this kind, many diſcoveries of changeable and periodical ſtars might probably have been made, which have eſcaped the moſt diligent and accurate obſervers. We might then, as the author ſuggeſts, be enabled to reſolve a problem in which we are all immediately concerned.

"Who, for inſtance, would not wiſh to know what degree of permanency we ought to aſcribe to the luſtre of our ſun? Not only the ſtability of our climates, but the very exiſtence of the whole animal and vegetable creation itſelf, is involved in the queſtion. Where can we hope to receive information upon this ſubject but from aſtronomical obſervations? If it be allowed to admit the ſimilarity of ſtars with our ſun as a point eſtabliſhed, how neceſſary will it be to take notice of the fate of our neighbouring *ſuns*, in order to gueſs at that of our own? That *ſtar*, which among the multitude we have dignified by the name of *ſun*, to-morrow may ſlowly begin to undergo a gradual decay of brightneſs, like β Leonis, α Ceti, α Draconis, δ Urſæ majoris, and many other diminiſhing ſtars that will be mentioned in my catalogues. It may ſuddenly increaſe, like the wonderful ſtar in the back of Caſſiopea's chair, and the no leſs remarkable one in the foot of Serpentarius; or gradually come on like β Geminorum, β Ceti, ζ Sagittarii, and many other increaſing ſtars, for which I alſo refer to my catalogues; and, laſtly, it may turn into a periodical one of 25 days duration, as Algol is one of three days, δ Cephei of five, β Lyræ of ſix, η Antinoi of ſeven days, and as many others as are of various periods."

Having thus explained the general principle on which this catalogue is formed, as we find it in the author's firſt memoir on the ſubject, we muſt refer the reader to the Doctor's own account for its particular arrangement; obſerving only that the catalogue ſubjoined comprehends nine conſtellations, which are arranged in alphabetical order, with the comparative brightneſs of the ſtars accurately ſtated. In a ſubſequent paper, publiſhed in the ſame volume, he has completely verified the utility of his method by experience, and ſhewn that there is no permanent change of luſtre in the ſtars. In the notes to his firſt catalogue he mentioned α Herculis as a periodical ſtar. By a ſeries of obſervations on this ſtar, compared with κ Ophiuchi, which was moſt conveniently ſituated for his purpoſe, he has been able not only to confirm this opinion, but to aſcertain its period. His obſervations are arranged in a table, by means of which he determines that this ſtar had gone through four ſucceſſive changes in an interval of 241 days; and therefore the duration of its period muſt be about 60 days and a quarter. This fact concurs with other circumſtances in evincing the rotatory motion of the ſtars on their axes. "Dark ſpots, or large portions of the ſurface, leſs luminous than the reſt, turned alternately in certain directions, either towards or from us, will account for all the phenomena of periodical changes in the luſtre of the ſtars, ſo ſatisfactorily, that we certainly need not look out for any other cauſe." If it be alledged that the periods in the change of luſtre of ſome ſtars, ſuch as Algol, β Lyræ, δ Cephei, and η Antinoi, are ſhort, being only 3, 5, 6, and 7 days reſpectively; while thoſe of *o* Ceti, and of the changeable ſtar in Hydra, and that in the neck of the Swan, are long, amounting to 331, 394, and 497 days; and that we cannot aſcribe phenomena ſo different in their duration to the ſame cauſe—it may be anſwered to this objection, that the force of it is founded on our limited acquaintance with the ſtate of the heavens. To the 7 ſtars, the periodical changes of which were before known, we may now add α Herculis, which performs a revolution of its changes in 60 days.

"The ſtep from the rotation of α Herculis to that of *o* Ceti is far leſs conſiderable than that from the period of Algol to the rotation of α Herculis; and thus a link in the chain is now ſupplied, which removes the objection that aroſe from the vacancy." The rotation of the fifth ſatellite of Saturn is proved by the change obſervable in its light; and "this variation of light, owing to the alternate expoſition of a more or leſs bright hemiſphere of this periodical ſatellite, plainly indicates that the ſimilar phenomenon of a changeable ſtar ariſes from the various luſtre of the different parts of its ſurface, ſucceſſively turned to us by its rotatory motion."

Beſides, we perceive a greater ſimilarity between the ſun and the ſtars, by means of the ſpots that muſt be admitted to exiſt on their ſurfaces, as well as on that of the ſun.

Dr Herſchel farther obſerves, that the ſtars, beſides a rotatory motion on their axes, may have other movements; "ſuch as nutations or changes in the inclination of their axes; which, added to bodies much flattened by quick rotatory motions, or ſurrounded by rings like Saturn, will eaſily account for many new phenomena that may then offer themſelves to our extended views." To this paper is likewiſe ſubjoined a catalogue of nine conſtellations; and the author promiſes to give the whole of them in ſucceſſive ſhort catalogues on the ſame plan.

CATENARIA, or CATENARY CURVE. See *Encycl.* and ARCH in this *Supplement*.

CATHARINE II Empreſs of all the Ruſſias, acted ſo conſpicuous a part on the theatre of the world; poſſeſſed ſuch uncommon powers of mind, highly cultivated by ſcience and literature; and was ſuch a patroneſs of ſcience and literature in others—that it cannot be deemed foreign from a work of this nature to give ſome account of the principal events of her more private life.

SOPHIA AUGUSTA FREDERICA, who, upon her marriage to the grandſon of Peter the great, aſſumed the name CATHARINA ALEXIEVNA, was born at *Stettin* on the 2d of May 1729. Her father was Chriſtian Auguſtus, prince of Anhalt Zerbſt Dornburg, at that time major general in the Pruſſian ſervice, commander in chief of the regiments of infantry, and governor of the town and fortreſs of Stettin. Her mother, who was born princeſs of Holſtein Eutin, was a woman of great parts and beauty, of nearly the ſame age with the prince-royal of Pruſſia, afterwards Frederic the Great, with whom ſhe kept up a regular correſpondence, and who afterwards contributed to the aggrandiſement of her daughter. This accompliſhed princeſs took upon herſelf the care of educating the young Sophia, whom ſhe brought up in the ſimpleſt manner, and would not ſuffer to exhibit the leaſt ſymptoms of that pride to which ſhe had ſome propenſity from her earlieſt childhood. The conſequence of this ſalutary reſtraint was, that good humour, intelligence, and ſpirit, were even then the ſtriking features of her youthful character. Being naturally addicted to reading, to reflection, to learning, and to employment, ſhe was taught the French and other faſhionable languages; and was inſtructed to read ſuch books chiefly as might make her acquainted with hiſtory and with the principles of ſcience; whilſt the doctrines of the Lutheran religion were carefully explained to her by a divine, who little thought how ſoon his illuſtrious pupil would embrace another faith.

The Empreſs Elizabeth, who then ſwayed the ſceptre of Ruſſia, had in early life been promiſed in marriage to the young prince of Holſtein Eutin, brother to the princeſs of Anhalt Zerbſt; but at the inſtant when the marriage was about to be celebrated, the prince fell ſick and died. Elizabeth, who loved him to exceſs, became inconſolable, and in the bitterneſs of her grief made a vow of celibacy. This vow, though ſenſual, and even laſcivious, ſhe kept ſo far as never publicly to acknowledge any man as a huſband; and upon her aſcending the throne of her anceſtors, ſhe called her nephew the Duke of Holſtein Gottorp to her court, where he was ſolemnly proclaimed, when fourteen years of age, Grand Duke, with the title of Imperial Highneſs, and declared ſucceſſor to the Empreſs Elizabeth. To ſecure the ſucceſſion in the family of Peter the Great, the Empreſs was very deſirous to have her nephew married; and the princeſs of Anhalt Zerbſt, not ignorant of the tender remembrance which ſhe ſtill preſerved for her brother, conceived the idea of placing, by means of it, her daughter on the throne of Ruſſia. She communicated her plan to the king of Pruſſia, who not only applauded it, but lent her his aſſiſtance to carry it into execution.

Full of ambitious hopes, therefore, the princeſs repaired with her daughter to St Peterſburg, where ſhe was received with friendſhip by Elizabeth, and where the young Sophia ſoon made a conſiderable impreſſion on the mind of the Grand Duke. As Peter was well made, of a good figure, and, though uneducated, not deſtitute of natural talents, the attachment became reciprocal; and the princeſs of Zerbſt, throwing herſelf at the feet of the empreſs, aſſured her, that the two lovers were attached to each other by a paſſion unconquerable; and, calling to her mind the love which ſhe had herſelf borne to the prince of Holſtein, conjured her to promote the happineſs of that prince's niece. The ſtratagem ſucceeded. The choice of Elizabeth was next day announced to the council and to the foreign miniſters; and preparations were made for celebrating the marriage with a magnificence worthy of the heir of the throne of the Ruſſias. In the mean time the Grand Duke was ſeized with the ſmall-pox, from which, tho' he recovered, it was with ſuch a change of features, as rendered him, from being comely, almoſt hideous, and converted the love of the young princeſs of Anhalt, if indeed ſhe ever felt for him that paſſion, into horror and diſguſt. She was not, however, of a diſpoſition to let a disfigured countenance frighten her from a throne. She embraced the Greek religion, changed her name from Sophia Auguſta Frederica to CATHARINA ALEXIEVNA, and with the entire approbation of Elizabeth was married to her nephew the Grand Duke.

For ſome time this ill-matched pair lived together, though without love, yet on terms apparently decent; but a mutual diſlike gradually took place between them, which the courtiers quickly diſcovered, and were at pains to foment into hatred. Peter was now ugly, and his mind was uninformed. Catharine, if not a beauty, was at leaſt a lovely woman, and highly accompliſhed. She could find no entertainment in his converſation, and he felt himſelf degraded by her ſuperiority. A faction was formed at court, headed by the great chancellor Beſtucheff, to exclude the Grand Duke from the throne, and to place Catharine at the head of affairs; and to accompliſh this end, every art was employed to fill the feeble mind of the empreſs with jealouſies of her nephew, and with a contempt of his character. He was repreſented at one time as extremely ambitious, and capable of the moſt daring enterpriſes, to get immediate poſſeſſion of the throne; and at another, as a wretch given up to drunkenneſs and to every unprincely vice.

The conſequence of the firſt of theſe accuſations was, that he was kept at a diſtance from his aunt, and a ſtranger to public affairs; and being wholly unemployed, that time which his education had not fitted him to fill up with reading, reflection, and rational converſation, hung ſo heavy on his mind, that it was no difficult matter for thoſe diſſipated young men, who were placed about him for that very purpoſe, to initiate him in the habits of drunkenneſs, and the other mean practices to which it was pretended he had long been devoted. In ſuch a ſchool, it was no wonder that he became a proficient in grovelling diſſipation; or that, being unpoliſhed, and even of rude manners, he choſe for his companions ſome of the loweſt of the people.

Catharine, in the mean time, languiſhed for that happineſs which ſhe could not find in the ſociety of her huſband. She was fond of pleaſure ; but it was that comparatively refined pleaſure which ſhe had enjoyed at the court of Berlin. She loved balls, muſic, and elegant converſation, and could take no ſhare in the drunken revels of Peter. Among the young men with whom he was ſurrounded, his chamberlain Soltikoff was particularly remarked for the elegance of his taſte and the graces of his perſon ; and though yet ſcarcely more than a boy in years, he was ſaid to have obtained the favours of ſeveral ladies of the court. Succeſs had made him confident and ambitious ; and his ambition prompted him to aſpire at making a conqueſt even of the Grand Ducheſs. By ſtudying her taſte, and contriving to amuſe her, he was at laſt ſucceſsful ; and obtained from her Imperial Highneſs every favour which he could wiſh : but he enjoyed not his fortune with moderation, and his enemies contrived to get him placed in an honourable office at a diſtance from the court. He was commiſſioned to repair to Stockholm, with the title of Envoy Extraordinary, to notify to the king of Sweden the birth of Paul Petrovitch, of whom the Grand Ducheſs had juſt been delivered *. The preſumptuous Soltikoff, proud of the employment, ſet off with haſte to Sweden, and left it with equal ſpeed. But ſcarcely had he quitted Stockholm, on the wings of love and ambition, when he was ſtopped on the road by a courier, who put into his hands an order for him to go immediately to Hamburg, and there to reſide in the quality of miniſter plenipotentiary from the court of Ruſſia.

Catharine for ſome time preſerved her attachment to the exiled chamberlain ; but all at once the preſence of a ſtranger, whom fortune had brought to the court of Ruſſia, made her forget the lover whom ſhe no longer ſaw. This perſon was Staniſlaus Poniatowſky, the late king of Poland, who firſt made his appearance at St Peterſburg in the train of the Britiſh ambaſſador, and very quickly gained the affections of the Grand Ducheſs. In carrying on this intrigue, the lovers were not ſo cautious as to deceive the eyes of the envious courtiers, who reported to the empreſs not only all that they ſaw, but whatever they ſuſpected. Elizabeth was incenſed, and commanded Poniatowſky to quit without delay the dominions of Ruſſia. The accompliſhed Pole obeyed ; but ſoon returned clothed with a character which made him in ſome degree independent of the empreſs.

The Count de Bruhl, then prime miniſter to the king of Poland, ſaw of what importance it was to his maſter to have a powerful intereſt at the court of Ruſſia. He was likewiſe no ſtranger to the paſſion which the Grand Ducheſs entertained for Poniatowſky ; and having got that nobleman decorated with the order of the White Eagle, he ſent him back to St Peterſburgh in the quality of miniſter plenipotentiary from the republic and king of Poland. Nor was this all that Bruhl did for the two lovers. Being informed by the chancellor Beſtucheff, that the Grand Duke and Grand Ducheſs were languiſhing in a penury unworthy of their rank, he remitted to Poniatowſky 6000 ducats, to be employed, in ſuch a manner as he might judge beſt, for ſecuring the favour of the prince and his conſort. The ambaſſador profited by theſe counſels and benefactions. He was already ſure of the Grand Ducheſs's heart, and he very quickly gained the favour of her huſband. He talked Engliſh and German with him ; drank, ſmoked, abuſed the French, and extolled the king of Pruſſia with unlimited praiſe.

The Grand Ducheſs was ſo blinded by her paſſion, that ſhe was never without Poniatowſky in her company. She devoted to him the whole of her time ; and ſhe made this intimacy ſo little a ſecret, that public report was loud to her prejudice. In the mean time ſhe was delivered of the Princeſs Anne†, who lived only fifteen months. The Grand Duke was the only perſon about court who ſeemed to know nothing of what was paſſing. His whole time was occupied in copying, with ſervile affectation, the air, the manners, the tone of the king of Pruſſia ; and in dreſſing a little army at Oranianbaum in the Pruſſian uniform. His eyes, however, were at laſt opened. Some of the courtiers, from hatred to the chancellor, who countenanced the intrigue between the Grand Ducheſs and the Poliſh ambaſſador, rouſed his jealouſy in order to deſtroy their enemy. They ſucceeded. He forbade his wife to be ſeen with Poniatowſky, and prevailed with the empreſs to deprive the chancellor of his office, and to baniſh him to an eſtate which he had 120 verſts beyond Moſcow.

Catharine had now to ſupport at once the averſion of her huſband, the indignation of the empreſs, the inſulting diſdain of a court, which a few days before was laviſh of its aſſiduities and ſmiles; and what afflicted her moſt of all, the dread of loſing for ever her favourite Poniatowſky. Her courage, however, did not forſake her. Poniatowſky was indeed recalled, and left Ruſſia, after ſuffering ſome deſerved indignities from the Grand Duke, who about this time formed a connection with one of the daughters of the Senator Vorontzoff, brother to the new chancellor. This lady, Elizabeth Romanovna Vorontzoff, was elder ſiſter to the Princeſs Daſhkoff, who acted ſo conſpicuous a part in the revolution which ſet the crown on the head of Catharine. She was beautiful, but vain ; and poſſeſſed not either the wit or the underſtanding of her ſiſter.

In the mean time the health of the empreſs viſibly declining, Catharine was very deſirous of being reconciled to her : but the irritated ſovereign would liſten to no accommodation, except on terms too humiliating for the haughty ſpirit of the Grand Ducheſs. Catharine, therefore, abſented herſelf from court, and aſked permiſſion to retire into Germany. This, as ſhe had foreſeen, was refuſed. Elizabeth was too fond of the young Paul Petrovitch to permit the departure of his mother, and thereby expoſe him to the danger of being at ſome future period declared illegitimate. She took the Grand Ducheſs again into favour ; and it is thought, that had ſhe lived a little longer than ſhe did, ſhe would have excluded Peter from the throne, and declared Paul her immediate ſucceſſor.

Whilſt the empreſs was meditating the aggrandiſement of the young prince and his mother, the Grand Duke had conceived a plan for degrading them both. He had reſolved, at the moment his aunt ſhould cloſe her eyes, to aſſemble his troops, to get himſelf proclaimed emperor, to repudiate the Grand Ducheſs, to declare the young Paul Petrovitch illegitimate, and publicly to marry his miſtreſs Elizabeth Romanovna Vorontzoff. We have ſhewn elſewhere (ſee Russia, n° 72. *Encycl.*) how this plan, when almoſt ready to be carried into execution, was betrayed to Catharine, who, ever ſince her caballing with the Chancellor Beſtucheff, had

reſolved,

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* Oct. 1. 1754.

† February 1758.

reſolved, by ſome means or other, to ſnatch the ſceptre from the feeble hand of her huſband. At preſent, we believe ſhe was not acquainted with it; and though ſhe had, ſhe could not now have turned it to her advantage, as her party, ever ſince the diſgrace of Beſtucheff, was without a leader of any abilities.

Amid theſe diſtractions, cauſed by the proſpect of the death of the empreſs, and the known hatred of the Grand Duke and Ducheſs to each other, Count Panin, preceptor to the young prince, devoted himſelf entirely to Catharine. He wiſhed to ſee her poſſeſſed of all the power of the empire; but he was afraid to proceed to the extremity to which ſhe propoſed to go, and to deprive Peter of the name of Emperor. He contrived therefore to procure an apparent reconciliation between the Grand Duke and his conſort, as well as between him and his aunt Elizabeth; and he had almoſt perſuaded the ſilly prince not to aſſume the ſovereign power on the death of the empreſs, till he ſhould be ſolemnly inveſted with it by a decree of the ſenate. Could he obtain this point, he knew that the power of Peter would be limited, and the authority ſecured to his wife and his ſon. He was, however, diſappointed. Catharine herſelf diſapproved of this plan, and concurred with the real friends of her huſband in adviſing him "to conform to eſtabliſhed cuſtom in aſſuming the reins of empire."

He had hardly received this advice when word was brought him that the Empreſs Elizabeth was dead (A); and the courtiers preſſed in crowds about him. He accoſted them with dignity, received the oaths of the officers of his guard, and ſeemed at once to have laid aſide his weakneſs. In an hour he got on horſeback, traverſed the ſtreets of St Peterſburgh, and diſtributed money among the multitude and the ſoldiers. He had been ſo treated by his aunt, that he could not poſſibly be grieved at her death; but in paying the laſt duties to her remains, he betrayed no indecent elation. The firſt actions of his reign were prudent and patriotic, and ſuch as would have done honour to a greater prince. He appeared to be reconciled to his wife, in whoſe company he ſpent much of his time; he recalled from priſon and baniſhment 17,000 perſons, ſome of them of rank and of great talents, who had been the victims of Elizabeth's jealous timidity; he permitted the nobility to bear arms or not at their own diſcretion, freeing them at the ſame time from the extreme ſervitude under which they had been held by his immediate predeceſſors; and he aboliſhed *the ſecret committee*, an infamous inquiſitorial tribunal, which ever ſince the reign of the father of Peter the Great had been the chief engine of Ruſſian deſpotiſm.

He neglected, however, one thing; which, among the people over whom he was appointed to reign, would have contributed more to the ſecurity of his throne than all the wiſe and beneficent edicts which he had publiſhed. He made no preparations to be crowned at Moſcow. Inſtead of complying with this ancient ceremony, and humouring the prejudices of his ſuperſtitious ſubjects, he thought of nothing but of war with Denmark, and of a perſonal interview with the king of Pruſſia in Germany. His admiration of that great monarch hurried him indeed into the moſt extravagant follies. Not contented with giving him peace, and entering into an offenſive and defenſive alliance with him, he had the meanneſs to ſolicit a commiſſion in his army, and to accept of the rank of major-general. Of this title he ſeemed more vain than of that of Emperor of all the Ruſſias. He conſtantly wore the Pruſſian uniform; introduced among his troops the Pruſſian diſcipline, which, though better than their own, was diſagreeable, becauſe it was new, and much more becauſe it was German; and he raiſed his uncle, a man of no military talents, and a foreigner, to the dignity of generaliſſimo of the Ruſſian armies; giving him at the ſame time the particular command of the horſe-guards, a body of men which had never before been under any command but that of the ſupreme head of the empire. Nor did his infatuated predilection for Germany, a country abhorred by the Ruſſians, ſtop even here: He diſbanded the noble guards which had placed Elizabeth on the throne, diſmiſſed the horſe-guards from the ſervice which they performed at court, and ſubſtituted his Holſtein guards in their place.

Whilſt he was thus alienating from himſelf the affections of the army, he contrived to diſguſt another order of men, whoſe attachment he ſhould have laboured above all things to retain. He was at pains to ſhew his preference of the Lutheran faith and worſhip to the doctrines and ceremonies of the Greek church; he attempted to make ſome alterations in the dreſs of the monks; he annexed great part of the poſſeſſions of the church to the domains of the crown; and he baniſhed the archbiſhop of Novogorod, who oppoſed theſe innovations; and found himſelf obliged ſuddenly to recal him.

He had now returned to his former courſes. He ſhut himſelf up for whole days with his miſtreſs and drunken companions; he compelled the nobility and ladies of the court to ſit in company with buffoons and comedians; he inſulted every foreign miniſter but the miniſters of Great Britain and Pruſſia; and he made no ſecret of his intention to repudiate the empreſs, declare Paul Petrovitch illegitimate, and marry the Counteſs Vorontzoff. Convinced, however, as it would ſeem, that he could not be a father, he reſolved to adopt Prince Ivan, the deſcendant of the elder brother of Peter the Great, whom Elizabeth had dethroned and confined in priſon; to declare him his ſucceſſor; and to unite him in marriage with the young princeſs of Holſtein Beck, who was then at St Peterſburgh, and whom he cheriſhed as his daughter.

This inconſiſtent and weak conduct of the emperor turned the attention of all orders of men to the empreſs, who made it her ſole employment to gain thoſe hearts which he was loſing. Inſtructed from her infancy in the arts of diſſimulation, it was not difficult for her to affect, in the ſight of the multitude, ſentiments the moſt foreign to her mind. The pupil of the French philoſophers put on the air of a bigot to the moſt ſuperſtitious ceremonies of the Greek religion, and treated the miniſters of that religion with the profoundeſt reverence. And whilſt her huſband was getting drunk

amidſt

(A) Chriſtmas-day 1761 according to the Ruſſian calendar, or the 5th of January 1762 according to ours.

amidſt a rabble of buffoons, and diſguſting every perſon of decency who approached him, ſhe kept her court with a mixture of dignity and affability, which attracted to her all who, by capacity, courage, or reputation, were capable of ſerving her.

Correct, however, as her public conduct appeared, her private life was not leſs licentious than formerly. While yet Grand Ducheſs, ſhe had formed a very tender connection with Gregory Orloff, a man of mean birth, and of no education, but poſſeſſed at once of perſonal beauty and the moſt daring courage. He had an inferior commiſſion in the artillery, while his two brothers were common ſoldiers in the regiments of guards. The intrigue which ſhe carried on with him was known only to one of her women named Catharine Ivanovna; nor did Orloff himſelf for ſome time ſuſpect the rank of the lady who ſo laviſhly conferred upon him her favours in ſecret. At laſt, finding him intrepid and diſcreet, ſhe diſcovered herſelf, unveiled to him all her ambitious deſigns, and eaſily prevailed with him and his brothers to enter with zeal into her conſpiracy againſt the emperor. Orloff likewiſe gained over Bibikoff his friend, a Lieutenant Paſſick, with other officers; and by their means eaſily ſeduced ſome regiments of the guards. The Princeſs Daſhkoff was ſtrongly attached to Catharine, we believe, from worthy motives, and had frequent meetings with Orloff on the buſineſs of the conſpiracy, without ſuſpecting that he was ſo much as known to the empreſs. Count Panin, too, and the Hetman of the Koſacks, were determined to tumble Peter from the throne; but they were not inclined to go all the lengths propoſed by Catharine and her two favourites. Hoping to enjoy the actual power of the empire themſelves, they were for declaring Paul Petrovitch emperor in the room of his father, and conferring upon his mother the name and authority only of regent; while the princeſs and Orloff, knowing the ſentiments and wiſhes of the empreſs, were reſolved to veſt her with ſovereign power, or to periſh themſelves in the hazardous attempt.

In the mean time the anniverſary of the patron ſaints of Ruſſia was at hand, when Peter had determined, at the concluſion of the feſtival, to divorce the empreſs, ſhut her up in priſon, declare her ſon illegitimate, and publicly marry his miſtreſs. As they who plan a conſpiracy are always more vigilant than thoſe againſt whom it is directed, the friends of Catharine were carefully informed of all that paſſed about the emperor, whilſt he was kept in total ignorance of their proceedings. It was therefore neceſſary for them to unite in the ſame plan, and to carry it quickly into execution; for delay or diviſions would involve them all in one common ruin. The empreſs contrived to bring over the Hetman entirely to her views; and the Princeſs Daſhkoff, by the ſacrifice, it has been ſaid, of her charms, found little difficulty in reconciling Count Panin to the ſame meaſures. They now agreed to ſeize the Tzar on his arrival at Peterhoff, an Imperial palace on the ſhore of the Gulf of Cronſtedt, where he propoſed to celebrate the approaching feſtival; and they were waiting impatiently for the moment of action, when all at once their plot was diſcovered.

Paſſick, who has been mentioned among the conſpirators, had gained the ſoldiers of the company of guards in which he was a lieutenant; but one of them, who thought that his captain was in the ſecret, aſked that officer one evening, When they were to take up arms againſt the emperor? The captain, ſurpriſed, had recourſe to diſſimulation, and eaſily drew from the ſoldier all that he knew of the conſpiracy. It was nine o'clock at night. Paſſick was put under arreſt; but found means to ſlip into the hands of a man who had been placed as a ſpy over him by the Princeſs Daſhkoff, a ſcrap of paper containing theſe words, "Proceed to execution this inſtant, or we are undone." The man was deſired to carry it to the Hetman, by whom he would be handſomely rewarded; but he hurried with it to the princeſs, who inſtantly communicated the intelligence to the other conſpirators. She herſelf put on man's apparel, and haſtened to the place where ſhe was accuſtomed to meet Orloff and his friends; where ſhe found them, as impatient as herſelf to carry their plot into immediate execution.

During this awful criſis the empreſs was at Peterhoff, at the diſtance of 25 verſts from St Peterſburgh; and one of the brothers of Gregory Orloff, named Alexius, undertook to find her out, whilſt he himſelf, with his other brother and Bibikoff his friend, repaired to the barracks for the purpoſe of inſtructing the ſoldiers of their party how to act on the firſt ſignal. Alexius Orloff carried with him a ſhort note from the Princeſs Daſhkoff, but neglected to deliver it; and the empreſs, being ſuddenly rouſed from a ſound ſleep, was much alarmed, when ſhe ſaw at the ſide of her bed a ſoldier of whom ſhe knew nothing. Her alarm was increaſed when the ſtranger ſaid, "Your majeſty has not a moment to loſe; get ready to follow me;" and inſtantly diſappeared. She roſe, however, and calling her woman Ivanovna, they diſguiſed themſelves in ſuch a manner that they could not be known by the ſentinels about the palace; and the ſoldier returning, they hurried with him to a coach which was waiting at the garden gate. Orloff took the reins, but drove with ſuch fury that the horſes ſoon fell down; and they were obliged to travel part of the way on foot. They had not, however, gone far, when they met a light country cart; and ſhe who was aſpiring to the throne of the greateſt empire in the world, was glad to enter the capital of that empire in this humble vehicle.

It was ſeven in the morning when ſhe arrived in St Peterſburgh: and to the ſoldiers, who gathered about her in great numbers, ſhe ſaid, that "her danger had driven her to the neceſſity of coming to aſk their aſſiſtance; that the Tzar had intended, that very night, to put her and her ſon to death; and that ſhe had ſo great confidence in their diſpoſitions, as to put herſelf entirely into their hands." They immediately ſhouted, "Long live the empreſs!" And the chaplain of one of the regiments fetching a crucifix, received their oaths of fidelity.

The troops, however, were not unanimous in this revolt. Though Gregory Orloff was treaſurer of the artillery, and well enough beloved by the ſoldiers, that corps refuſed to follow him until he ſhould produce the orders of Villebois their general: and that officer, withheld either by fidelity to the emperor or by fear, preſumed to ſpeak to Catharine of the obſtacles which yet remained for her to ſurmount; adding, that ſhe ought to have foreſeen them. She haughtily replied, that "ſhe had not ſent for him to aſk what ſhe ought to have foreſeen,

foreſeen, but to know how he intended to act." "To obey your Majeſty," returned Villebois; and putting himſelf at the head of his regiment, he immediately joined the conſpirators. So ripe indeed were the minds of all men for this revolt, that in the ſpace of two hours the empreſs found herſelf ſurrounded by 2000 warriors, together with great part of the inhabitants of Peterſburgh: and with that numerous train of attendants ſhe repaired to the church of Kaſan, where the archbiſhop of Novogorod, ſetting the Imperial crown on her head, proclaimed her ſovereign of all the Ruſſias, declaring, at the ſame time, Paul Petrovitch her ſucceſſor.

Matters had now proceeded by much too far to admit of any compromiſe between Catharine and her huſband: but had the infatuated Tzar put his affairs wholly into the hands of Marſhal Munich, that intrepid veteran would have tumbled the empreſs from her throne almoſt as quickly as ſhe had got poſſeſſion of it. He acted, however, a very different part. Upon receiving intelligence of what had been done at St Peterſburgh, he aſked indeed the Marſhal's advice, but ſuffered himſelf to be guided by his miſtreſs and timid companions. Through their terrors and his own irreſolution opportunities were loſt which could never be recovered; for though his Holſtein guards, with tears in their eyes, ſwore that they were all ready to ſacrifice their lives in his ſervice, and though the old Marſhal offered to lead them againſt the rebels, ſaying to the emperor, "I will go before you, and their ſwords ſhall not reach you till they have pierced my body," he was perſuaded to treat with the empreſs, to acknowledge his miſconduct, and to offer to ſhare with her the ſovereign power. At laſt he was weak enough to abandon his troops, and to ſurrender at diſcretion to his conſort; whoſe creatures hurried him from Oranienbaum to Peterhoff, ſtripped him of all his clothes, and, after leaving him for ſome time in his ſhirt, a butt to the outrages of an inſolent ſoldiery, threw over him an old morning-gown, and ſhut him up alone, with a guard at the door of his wretched apartment. On the 29th of June, O. S.* 1762, Count Panin was ſent to him by the empreſs; and after a long conference, prevailed with him to write and ſign a ſolemn reſignation of his crown, and a declaration of his utter incapacity to govern ſo great an empire.

The revolution was now complete, and Peter ſeemed to enjoy ſome compoſure of mind; but in the evening he was carried a priſoner to Ropſcha, a ſmall Imperial palace, at the diſtance of 20 verſts from Peterhoff, where he was murdered on the 17th of July, juſt one week after his depoſition. Of the manner of his death different accounts have been given. By ſome he is ſaid to have been poiſoned; by others, to have been ſtrangled by one of the Orloffs; and a few have thought that he periſhed by the ſame means as Edward II. of England. Whether the empreſs was acceſſory to his death is not known; though it is certain, that ſo far from making any inquiry after his murderers, ſhe affected to believe that he had died naturally of the *piles!*

The firſt care of Catharine was to reward thoſe who had been the principal actors in the revolt. Panin was made prime miniſter; the Orloffs received the title of Count; and the favourite Gregory was appointed lieutenant-general of the Ruſſian armies, and knight of the order of St Alexander Neſky, the ſecond order of the empire. Several officers of the guards were promoted, of whom 24 received conſiderable eſtates; and among the ſoldiers, whom ſhe treated with the greateſt affability, brandy and beer were liberally diſtributed. The Chancellor Beſtucheff, who had been the moſt inveterate enemy of Peter, was recalled from his exile, reſtored to his rank of field-marſhal, and had an annual penſion ſettled upon him of 20.000 rubles. To the friends of the emperor ſhe behaved with great moderation. Prince George, whom he had conſtituted Duke of Courland, was indeed obliged to renounce his title; but the adminiſtration of Holſtein was committed to him, and he ever after ſerved the empreſs with zeal and fidelity.

The news of the revolution was ſoon ſpread over Europe; and none of the ſovereigns, though they knew by what ſteps Catharine had mounted the throne, heſitated for a moment to acknowledge her title. She was not, however, at perfect eaſe in her own mind; nor was her right recogniſed by all her ſubjects. Though ſhe publiſhed manifeſtoes, ſetting forth the intentions of the late emperor towards her and her ſon, which made reſiſtance neceſſary; though in theſe papers ſhe attributed her elevation to the wiſhes of her people and the providence of God; and though ſhe called upon all who were ſincerely attached to the orthodox faith of the Greek church, to conſider the ſudden death of Peter as the judgment of heaven in favour of the revolution—yet in the diſtant provinces no exultations were heard; both ſoldiers and peaſants obſerved a gloomy ſilence. Even at Moſcow, ſo great was the diſaffection to Catharine's government, that it was ſome time before ſhe could venture to go to that city to be crowned; and ſhe found in it at laſt ſo cold a reception, that ſhe very quickly returned to St Peterſburgh.

Nor was this the only cauſe of her uneaſineſs. The connection between Orloff and her became viſible, and gave juſt offence to her other friends. The princeſs of Daſhkoff firſt perceived it; and when ſhe preſumed to expoſtulate with the empreſs on the meanneſs and imprudence of her paſſion, ſhe was baniſhed from the court to Moſcow. Count Panin and the Hetman ſaw with indignation that they had dethroned the grandſon of Peter the Great, to aggrandiſe a rude and low born upſtart. Cabals and conſpiracies were entered into by high and low, both againſt Catharine and againſt her favourite; and it required all her abilities and firmneſs to preſerve at once her throne and her lover. On one occaſion ſhe hoped to obtain from the Princeſs Daſhkoff ſufficient proof that Panin and the Hetman of the Koſacks were concerned in a plot which had juſt been diſcovered; and with this view ſhe wrote to her a letter of four pages, filled with the moſt tender epithets and the moſt magnificent promiſes, conjuring her in the name of their long-ſtanding friendſhip, to reveal what ſhe knew of the recent conſpiracies. With becoming magnamity, the princeſs replied, "Madam, I have heard nothing; but if I had heard any thing, I ſhould take good care how I ſpoke of it. What is it you require of me? That I ſhould expire upon a ſcaffold? I am ready to mount it."

Catharine, deſpairing of conquering ſuch a ſpirit, attempted to attach to her thoſe whom ſhe dared not to puniſh. Some of the inferior conſpirators were baniſhed to Siberia, while Panin and the Hetman, whom ſhe moſt dreaded, received additional marks of her favour. In the mean time, to gain the affections of the people

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* July 10.

at large, ſhe paid the utmoſt attention to the adminiſtration of juſtice; formed magnificent eſtabliſhments for the education of the youth of both ſexes: founded hoſpitals for orphans, for the ſick, and for lying-in women; invited foreigners of all nations, poſſeſſed of any merit, to ſettle in different parts of her vaſt territories; increaſed the naval force of the empire; and gave ſuch encouragement to the cultivation of every elegant and uſeful art, that in the ſhort ſpace of a year and a half from her acceſſion to the throne, the national improvement of Ruſſia was viſible.

In the good fortune and glory of Catharine, no one rejoiced more ſincerely than Count Poniatowſky. He approached towards the confines of Ruſſia, and wrote to her in the tendereſt ſtyle of congratulation, requeſting permiſſion to pay his reſpects to her in the capital of her empire. It is not improbable that he flattered himſelf with the hopes that ſhe would give him her hand in marriage, and thus raiſe him to the throne of the Tzars; but ſhe had promiſed to the Empreſs Elizabeth, that ſhe would never again ſee the count; and to that promiſe ſhe at preſent adhered. She wrote to him, however, in the moſt affectionate terms; and tho' ſhe gave him no encouragement to repair to St Peterſburgh, ſhe aſſured him that ſhe had other proſpects in view for his aggrandiſement, and that he might depend upon her perpetual friendſhip: and ſhe ſoon appeared to be as good as her word. On the death of Auguſtus III. ſhe raiſed her former favourite to the throne of Poland, in oppoſition to the wiſhes of the courts of Vienna and Verſailles, as well as of a great majority of the Poliſh nobles. She defeated the intrigues of the two foreign courts by more ſkilfully conducted intrigues of her own; and by pouring her armies into the republic, ſhe ſo completely overawed the nuncios, that Poniatowſky was choſen by the unanimous ſuffrages of the diet which met for the election of a ſovereign; and, on the 7th of September 1764, was proclaimed King of Poland and Grand Duke of Lithuania, by the name of Staniſlaus Auguſtus.

Whilſt ſhe was thus diſpoſing of foreign kingdoms, ſhe was kept under perpetual dread of being tumbled from the throne of her own vaſt empire. Her want of title to that throne was now ſeen by all ranks of her ſubjects: the good qualities of Peter the third were remembered, and his failings and faults forgotten. His fate was univerſally lamented; and, except the conſpirators, who may be ſaid to have embrued their hands in his blood, there was hardly a Ruſſian who did not regret that the ſovereignty had paſſed from the ancient family of the Tzars to a foreigner, allied only by marriage to the blood royal. Even the conſpirators themſelves had loſt much of their regard for Catharine. The princeſs of Daſhkoff was a ſecond time baniſhed to Moſcow; and, to magnify her own importance, ſhe ſpoke freely of the means by which the empreſs, whom ſhe accuſed of ingratitude, had been raiſed to the throne. The inhabitants of Moſcow, who never favoured the uſurpation, were thus made ripe for a revolt. At St Peterſburgh, Count Panin felt himſelf uneaſy under the predominant influence of the favourite, and tried in vain to divert Catharine's affections to a new object. She received a few ſecret viſits from a handſome young man, and then appointed him to a lucrative and honourable employment in ſome diſtant province of the empire; when Orloff recovered his former aſcendency, which through his own careleſſneſs he had nearly loſt. In this ſtate of the public mind, conſpiracies were very frequent; and as the general object of them was to place on the throne Prince Ivan, who was again languiſhing in the dungeon from which Peter had taken him, the empreſs had given to his guard an order, ſigned by her own hand, to put that unfortunate prince to death, ſhould any attempt be made to liberate him from his priſon. An attempt was made by a very inferior officer, as ſome have ſuppoſed, by the inſtructions of Catharine, and her bloody order was inſtantly obeyed. The aſſaſſins were rewarded, and promoted in the army; but the officer who attempted to reſcue the prince was condemned to death, and ſuffered unexpectedly the ſentence of the law. The brothers and ſiſters of Ivan, who had been kept in a priſon different from his, were ſent to Denmark; and, to provide them with neceſſaries ſuitable to their rank, the empreſs made them a preſent of 200,000 rubles, and paid annually, to the maintenance of their dignity, a penſion of thirty thouſand.

The throne of Catharine was now firmly eſtabliſhed, by the death or renunciation of every perſon who was deſcended of the imperial family; and ſhe had leiſure to turn her thoughts to the aggrandiſement of the empire. It was ſoon ſeen that this was the object which ſhe had in view when ſhe raiſed Count Poniatowſky to the throne of Poland, and that ſhe was not actuated on that occaſion by any remains of her former attachment. We have elſewhere ſhewn (ſee POLAND, *Encycl.* n° 98—115) under what pretences ſhe invaded the kingdom of him who had formerly been one of her moſt favoured lovers, and by what means ſhe annexed great part of it to the territories of Ruſſia. But it is not through her wars that in this article we mean to trace her character: It is not as a ſovereign and heroine that her life is entitled to a place in a general repoſitory of arts, ſciences, and miſcellaneous literature, but as a patroneſs of art and of ſcience, and as the legiſlatrix of a vaſt empire, who employed all her talents and all her power for the civilization of a great part of the human race.

Under the article RUSSIA (*Encycl.*), we have mentioned the famous *code of laws for a great empire*, and the propoſed *convention of deputies from all the claſſes*, which Catharine and the Princeſs Daſhkoff ſo artfully employed as means to bring about the revolution which ſeated the former on the throne. The ſtates actually met in the ancient capital of the empire, and the ſovereign's inſtructions for framing a new code of laws was read amidſt reiterated burſts of applauſe. All preſent extolled the ſagacity, the wiſdom, the humanity of the empreſs; but fear and flattery had a greater ſhare in theſe exclamations than any juſt knowledge of the ſubject. The deputies of the Samoides alone had the courage to ſpeak freely. One of them ſtood up, and, in the name of himſelf and his brethren, ſaid, "We are a ſimple and honeſt people. We quietly tend our reindeer. We are in no want of a new code; but make laws for the Ruſſians, our neighbours, that may put a ſtop to their depredations." The following ſittings did not paſs ſo quietly. A debate about the liberation of the boors was carried on with ſuch warmth, that fatal conſequences were to be apprehended; and the deputies were diſmiſſed to their reſpective provinces in the manner which we have elſewhere related. Previous, however, to the diſſolution of this aſſembly, the members were required to ſignalize the meeting by ſome conſpicuous act of gratitude; and, by a general acclamation, the titles of GREAT, WISE, PRUDENT, and MOTHER OF THE COUNTRY, were decreed to the empreſs. With aſſumed modeſty ſhe accepted only of the laſt, "as the moſt benign and glorious recompence for her labours and ſolicitudes in behalf of a people whom ſhe loved."

For that people ſhe did indeed labour, and labour moſt uſefully. She introduced into the adminiſtration of juſtice the greateſt reformation of which the half-civilized ſtate of Ruſſia would perhaps admit. She ſpared neither trouble nor expence to diffuſe over the empire the light of ſcience, and the benefits of uſeful and elegant arts; and ſhe protected, as far as ſhe could, the poor from the oppreſſions of the rich. About the middle of 1767, ſhe conceived the idea of ſending ſeveral learned men to travel through the interior of her vaſt dominions, to determine the geographical poſition of the principal places, to mark their temperature, and to examine into the nature of their ſoil, their vegetable and mineral productions, and the manners of the people by whom they were inhabited. To this employment ſhe appointed Pallas, Gmelin, Euler, and many others of the higheſt eminence in the republic of letters; from whoſe journals of theſe intereſting travels large additions have been made to the general ſtock of uſeful knowledge. This ſurvey of the empire, and the maps made from it, had Catharine done nothing elſe, would alone have been ſufficient to render her name immortal. Well convinced in her own mind, that it is not ſo much by the power of arms, as by precedence in ſcience, that nations obtain a conſpicuous place in the annals of the world, with a laudable zeal ſhe encouraged artiſts and ſcholars of all denominations. She granted new privileges to the two academies of ſciences and the arts; encouraged ſuch of the youth as had behaved well in theſe national inſtitutes, to travel for farther improvement over Europe, by beſtowing upon them, for three years, large penſions to defray their expence; and, to remove as much as poſſible the Ruſſian prejudice againſt all kinds of learning, ſhe granted patents of nobility to thoſe who, during their education, had conducted themſelves with propriety, and become proficients in any branch of uſeful or elegant knowledge. Still farther to encourage the fine arts in her dominions, ſhe aſſigned an annual ſum of 5000 rubles for the tranſlation of foreign literary works into the Ruſſian language.

In the year 1768, the ſmall-pox raged at St Peterſburgh, and proved fatal to vaſt numbers of all ranks and of every age. The empreſs was deſirous to introduce the practice of inoculation among her ſubjects; and reſolved to ſet the example by having herſelf and her ſon inoculated, With this view, ſhe applied for a phyſician from England: and Dr Thomas Dimſdale of Hertford being recommended to her, he repaired with his ſon to the capital of Ruſſia, where he inoculated firſt the empreſs, then the grand duke, and afterwards many of the nobility. The experiment proving ſucceſsful, he was created a baron of the empire, appointed actual counſellor of ſtate, and phyſician to her imperial majeſty, with a penſion of L. 500 ſterling a-year, to be paid him in England, beſides L. 10,000 which he immediately received. So popular was the empreſs at this period, that, by a decree of the ſenate, the anniverſary of her recovery from the ſmall pox was enjoined to be celebrated as a religious feſtival; and it has ever ſince been obſerved as ſuch.

She was now engaged in war with the Turks, of which a ſufficient account for a work of this nature has been given under the title TURKEY *(Encycl)*; but there was one tranſaction of her and her friends, of which no mention was made in that article, though it is of importance to him who would form a juſt eſtimate of her perſonal character.

We have noticed the ſenſuality of the empreſs Elizabeth. She bore three children to the grand veneur Alexey Gregorievitch Razumoffſky, to whom, indeed, ſhe is ſaid to have been clandeſtinely married. Of theſe children the youngeſt was a girl, brought up under the name of Princeſs Tarrakanoff. Prince Radzivil, who has been mentioned in the article POLAND *(Encycl.)*, irritated at Catharine's cruelties to his countrymen, conceived the project of placing the young princeſs on the throne of her anceſtors; and, having gained over the perſons to whom her education was intruſted, he carried her off to Rome as a place of ſafety. Catharine, in return, ſeized his large eſtates; and he and the princeſs were reduced to extreme poverty. Radzivil repaired to Poland in order to learn what could be done to forward his great enterpriſe; and ſcarcely had he arrived there when an offer was made to reſtore to him his poſſeſſions, upon condition of his carrying his ward to St Peterſburgh. This he refuſed: but had the baſeneſs to promiſe, that he would give himſelf no farther concern about the daughter of Elizabeth; and he was put in poſſeſſion of all his eſtates.

By the inſtructions of the empreſs, Alexius Orloff, who nominally commanded the Ruſſian fleet at the Dardanelles, repaired to Rome, got acceſs to young Tarrakanoff, and found means to perſuade her that all Ruſſia was ready to revolt from Catharine, and place her on the throne of her mother. To convince her of his ſincerity, he pretended to feel for her the tendereſt and moſt reſpectful paſſion; and the unſuſpicious lady was induced to accept of him as a huſband. The ruffian who had aſſaſſinated the grandſon of Peter the Great, did not heſitate to ſeduce and betray his grand daughter. Under pretence of having the marriage ceremony performed according to the rites of the Greek church, he ſuborned ſome ſubaltern villains to perſonate prieſts and lawyers; thus combining profanation with impoſture againſt the unprotected and too confident Tarrakanoff.

Having been treated for ſome days, both at Rome and at Leghorn, with all the reſpect due to a ſovereign, the unſuſpecting princeſs expreſſed a wiſh to go on board a Ruſſian ſhip of war. This was juſt what Orloff wanted. Attended by a numerous and obſequious train, ſhe was rowed from the ſhore in a boat with magnificent enſigns, hoiſted upon the deck of the ſhip in a ſplendid chair, and immediately handcuffed. In vain did ſhe throw herſelf at the feet of her pretended huſband, and conjure him by every thing tender which had paſſed between them. She was carried down into the hold; the next day the veſſel ſailed for St Peterſburgh; where, upon her arrival, the princeſs was ſhut up in the fortreſs; and what became of her ſince was never known. Such were the means which Catharine ſcrupled not to employ in order to get rid of all pretenders to her throne.

Soon after this ſervice rendered to her by Alexius Orloff, ſhe diſmiſſed his brother Gregory from her favour, and connected herſelf with Vaſſiltchikoff, a ſublieutenant of the guards. The former favourite had indeed become inſolent, and, as Catharine thought, ungrateful. He aſpired to nothing leſs than the throne. From love to himſelf, and to a ſon which ſhe had born to him, ſhe offered to enter into a ſecret marriage; but with this propoſal the proud prince (A) was not ſatisfied, and hoped that his refuſal would impel her to receive him publicly as her huſband and partner in power. He was miſtaken. She diveſted him of all his employments; but gave him a penſion of 150,000 rubles, a handſome ſervice of plate, and an eſtate with 6000 peaſants upon it; and, thus enriched, he ſet out upon a journey through various parts of Europe. He returned, however, much ſooner than was expected; the new favourite was handſomely rewarded, and ſent to a diſtance; Orloff was reſtored to all his offices, and his baleful influence was again felt.

He attempted to perſuade the empreſs to diſmiſs Panin from the court; but the grand duke interpoſed in behalf of his old preceptor; and, for once, Catharine liſtened to the entreaties of her ſon. When a dreadful rebellion, under a Koſak of the name of Pugetſhoff, who pretended to be Peter III. eſcaped from his aſſaſſins, was ſhaking the throne to its foundation—the influence of Orloff was ſuch as to prevent the empreſs, for ſome time, from employing her ableſt general againſt the rebels, becauſe that general was Panin, brother to the miniſter. Danger, however, at laſt prevailed over the favourite: Panin was ſent againſt Pugetſhoff; the rebellion was cruſhed; and Catharine found leiſure to give ſomething like a legal conſtitution to the empire. In that work, the laws and regulations eſtabliſhed for the government of the various provinces, and for the equitable adminiſtration of juſtice through the whole of her vaſt dominions, evinces the greateſt wiſdom and ſagacity in their author, as well as a proper regard to the practicable liberties and rights of men. In the capital, ſhe eſtabliſhed the moſt perfect police, by which the internal tranquillity of a great city was, perhaps, ever maintained; and whilſt her private conduct was far from correct, ſhe was acting in the capacity of ſovereign, ſo as to deſerve, indeed, the appellation of *Mother of her people*.

To follow her through all her wars and intrigues with foreign courts, would ſwell this article to the ſize of a volume. Such a narrative, too, belongs rather to the hiſtory of Ruſſia than to the memoirs of Catharine; in which it is the buſineſs of the biographer to develop the private character of the woman, rather than to detail the exploits of the ſovereign. Her partition of Poland, and afterwards the annihilation of it as an independent republic; her encroachments on the territories of the grand ſignior; her formation of the armed neutrality; the influence which ſhe maintained over the courts of Sweden and Denmark; and the art with which ſhe threw the weight of Ruſſia ſometimes into the ſcale of Auſtria, and ſometimes into that of Pruſſia, juſt as the intereſts of her own dominions required the one or the other to preponderate—ſhew how admirably ſhe was qualified to guide the helm of a great empire in all its tranſactions with foreign ſtates. We ſpeak not of the equity of her proceedings; for it muſt be confeſſed, that equity formed no barrier againſt her ambition; and that ſhe never failed to ſubjugate thoſe whom ſhe pretended to take under her protection. Her ruling paſſion was to enlarge her own territories, already ſo very extenſive; and, for the attainment of that object, ſhe contrived the moſt judicious plans, which ſhe executed with vigour. In this part of her conduct, however, ſhe has been equalled by other monarchs; but in the zeal and the wiſdom with which ſhe endeavoured to introduce among her half-ſavage ſubjects the bleſſings of knowledge and induſtry, ſhe ſtands unrivalled, except, perhaps, by her predeceſſor Peter the Great. Of this we need bring no other proof, in addition to what has been already ſtated, than that ſhe founded in St Peterſburgh alone thirty-one ſeminaries, where 6800 children of both ſexes were educated at the annual expence to the government of 754,335 rubles. She ſuperintended herſelf the education of her grandchildren, and wrote for them books of inſtruction. If it be true, that "every man acquainted with the common principles of human action, will look with veneration on the writer who is at one time combating Locke, and at another making a catechiſm for children in their fourth year;" with what veneration ſhould we look upon the empreſs of Ruſſia, could we forget the means by which ſhe obtained that elevation from which ſhe frequently deſcended for a ſimilar employment: This ſhe did, not for her own deſcendants alone, but alſo for the children of others; of whom ſhe had always a great number in her apartments, who ſhared in the inſtruction given to her grandchildren, and whoſe careſſes ſhe returned with extreme complaiſance.

Her greateſt weakneſs was ſurely that groſs paſſion which her panegyriſts have dignified with the name of love; but to ſuch an appellation it had no claim, if love be any thing more than a ſexual appetite. Beſides Gregory Orloff, ſhe had not fewer than ten favourites after the death of her huſband; and of theſe ſhe ſeems to have felt a refined affection for none but Lanſkoi, a young Pole of a very ancient family, and of elegant manners, and the famous Potemkin, to whom ſhe is ſaid ſecretly to have given her hand, and who preſerved her friendſhip, if not her affection, to the end of his life. To Lanſkoi, whoſe education had been much neglected, ſhe condeſcended to become preceptrix; and, as he made great progreſs in the acquiſition of uſeful knowledge, ſhe admired in him her own creation. Potemkin, though not amiable, deſerved her favour for the fidelity and abilities with which he ſerved her, both in the council and in the field; and in him, when ſhe had ceaſed to look on him with the eyes of love, ſhe reſpected the intriguing politician and intrepid commander, who had formed plans for driving the Turks out of Europe, and ſetting her on the throne of Byzantium. Her other favourites had nothing to recommend

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(A) She had ſome time before obtained for him a patent, creating him a prince of the Roman empire.

mend them but maſculine beauty and corporeal ſtrength. One of them, however, thought it neceſſary to have a library in the grand houſe, of which the empreſs, upon receiving him into favour, had made him a preſent; and deſired the principal bookſeller to fill his ſhelves. The man aſked him what books he would pleaſe to have. "You underſtand that better than I (replied the favourite); that is your buſineſs. You know the proper aſſortments; I have deſtined a large room to receive them. Let there be large books at the bottom, and ſmaller and ſmaller up to the top; that is the way they ſtand in the empreſs's library!" In the converſation of ſuch men the cultivated mind of Catharine could enjoy no interchange of ſentiments.

We know not whether that more than Aſiatic magnificence, which ſhe diſplayed on every public occaſion, ſhould be conſidered as an inſtance of weakneſs or of wiſdom. If ſhe delighted in balls, and maſquerades, and ſumptuous entertainments, and dreſs loaded with jewels, and every kind of ſplendid ornament, for their own ſakes, ſhe betrayed a weakneſs unworthy of that ſovereign who held in her hand the balance of Europe, and at whoſe nod the greateſt powers of Aſia trembled: but if ſhe introduced ſuch ſplendor into her court merely to divert the attention of the Ruſſians from the means by which ſhe got poſſeſſion of the throne, and to ween them from their own ſavage and ſlovenly manners; even this may perhaps be conſidered as one of her moſt maſterly ſtrokes in politics.

Her ambition was boundleſs; but, if ſuch a phraſe may be allowed, it was not always true ambition. When the French republic had eſtabliſhed itſelf on the ruins of monarchy, and was propagating new theories of government through all Europe, true ambition would ſurely have led the autocratrix of the north to unite her forces with thoſe of the coaleſced powers, in order to cruſh the horrid hydra, before its anarchical principles could be introduced among her own barbarous ſubjects. Such would certainly have been the advice of her favourite Potemkin, who longed to lead a Ruſſian army into France, even before the murder of the unfortunate Lewis. That general, however, had died in October 1791; and when Britain, Auſtria, and Pruſſia, were leagued againſt the new republic, Catharine looked coolly on, in hopes, it is probable, of availing herſelf of their weakneſs, when exhauſted by a long and bloody war. She gave refuge, indeed, in her dominions to many emigrants from France, and ſent a ſquadron of ſhips to co-operate with the navy of England: but in this laſt meaſure ſhe regarded merely her own immediate intereſt; for her crazy ſhips were repaired by Britiſh carpenters at the expence of the Britiſh government, and her officers had an opportunity of learning the evolutions of the Britiſh navy. She had likewiſe other proſpects in view when ſhe lent to the allies this ſlender aid. She meditated a new war with Turkey; and, depending upon meeting with no oppoſition, if ſhe ſhould not receive aſſiſtance from England and Auſtria, ſhe flattered herſelf with accompliſhing her darling project of driving the Ottomans out of Europe, and of reigning in Conſtantinople. But ſhe was diſappointed. On the morning of the 9th of November 1796, ſhe was ſeized with what her principal phyſician judged a fit of apoplexy; and, at 10 o'clock in the evening of the following day, expired, in the 68th year of her age, leaving behind her the character of one of the greateſt ſovereigns that ever ſwayed a ſceptre.

After this long detail of the incidents of her life, it is needleſs to inform the reader that Catharine II. had no religion, and, of courſe, no principles of morality, which could induce her in every inſtance to do to others as ſhe would have them do to her. She was a profeſſed diſciple of the French philoſophers; by ſome of whom ſhe was ridiculed, and by others cheated. The incenſe which ſhe paid to the genius of Voltaire did not hinder him from frequently breaking his jeſts upon the autocratrix of Ruſſia and her ſucceſſive favourites; and Diderot, whom ſhe careſſed, ſold to her an immenſe library, when he poſſeſſed hardly a book, and was obliged to ranſack Germany and France for volumes to enable him to fulfil his bargain. Such is the friendſhip, and ſuch the gratitude, which ſubſiſts among the amiable pupils of nature, and the philanthropic advocates for the rights of man.

CAUDA *Capricorni*, a fixed ſtar of the fourth magnitude, in the tail of Capricorn; called alſo, by the Arabs, *Dineb Algedi;* and γ by Bayer.

Cauda *Ceti*, a fixed ſtar of the third magnitude; called alſo, by the Arabs, *Dined Kaetos;* marked β by Bayer.

Cauda *Cygni*, a fixed ſtar of the ſecond magnitude, in the Swan's tail; called by the Arabs *Dineb Adigege*, or *Eldegiagich;* and marked α by Bayer.

Cauda *Delphini*, a fixed ſtar of the third magnitude, in the tail of the Dolphin; marked ε by Bayer.

Cauda *Draconis*, or Dragon's tail, the moon's ſouthern or deſcending node.

Cauda *Leonis*, a fixed ſtar of the firſt magnitude, in the Lion's tail; called alſo, by the Arabs, *Dineb Eleced;* and marked β by Bayer. It is called alſo *Lucida Cauda.*

Cauda *Urſæ Majoris*, a fixed ſtar of the third magnitude, in the tip of the Great Bear's tail; called alſo, by the Arabs, *Alalioth*, and *Benenath;* and marked η by Bayer.

Cauda *Urſæ Minoris*, a fixed ſtar of the third magnitude, at the end of the Leſſer Bear's tail; called alſo the *Pole Star*, and, by the Arabs, *Alrukabah;* and marked α by Bayer.

CAUSE has been defined, we think, with accuracy in the Encyclopædia, and the doctrine ſtated which we believe to be true. Objections however have been made to that doctrine, of which we have endeavoured to remove ſome, under the title Action, in this Supplement; and the doctrine itſelf has been well illuſtrated (at leaſt ſuch is our opinion) in the ſupplementary article Astronomy. We have, therefore, very little to add here on the ſubject of cauſes, though it is the moſt important ſubject which can employ the mind of man. What is the relation between a phyſical cauſe and that which is termed its effect—between heat, for inſtance, and the fuſion of metals? Is it a *neceſſary connection*, or only a *conjunction*, diſcovered by experience to be *conſtant?*

If by *neceſſary* connection be meant that kind of connection of which the contrary cannot be conceived, we do not think that the connection of any phyſical cauſe with its effect can be called neceſſary. We ſee no difficulty in conceiving, that fire, inſtead of fuſing gold, might fix mercury. This *may* indeed be impoſſible; and

and we might perhaps ſee the impoſſibility, did we as completely know the nature of fire and of metals, as we know the relations of pure geometry. We know that the three angles of a plain triangle cannot poſſibly be either greater or leſs than two right angles; for in this compariſon nothing is hid from our mental view. We do not, however, perceive the impoſſibility of mercury being fixed, as clay is hardened, by heat: for of *heat*, and mercury, and clay, we know very little, and that little is the offspring of experience.

But if the connection between cauſe and effect be not *neceſſary*, are we not deprived of the means of demonſtrating the great fundamental truth of religion? We have nowhere ſaid, that the connection between cauſe and effect is not neceſſary; but only, that we do not perceive the neceſſary connection between what are called *phyſical* cauſes and their effects. That every event is, and muſt be, brought about by *ſome cauſe* or ſome *agency*, we hold to be a ſelf-evident truth, which no man can deny who underſtands the terms in which it is expreſſed; but what or where the agency is, we can very ſeldom, if ever, know, except when we think of our own voluntary actions. When a change is obſerved, we cannot doubt of its being produced by ſomething: either the thing changed is animated, and has produced the change by its own agency, juſt as we move our heads and legs by an act of volition; or if it be inanimated, and of itſelf incapable of agency, the change has been produced by ſomething external, denominated a *cauſe*. But all external cauſes, which are not likewiſe agents, in the proper ſenſe of the word, may be traced, we think, as effects up to ſome agency; and therefore, in our opinion, there is no real, ultimate, efficient cauſe but mind, or that which is endued with power. In proof of this doctrine, if it need any proof, we can only refer to what has been ſaid elſewhere on our notions of *power* and of *phyſical cauſes*. See (*Encycl.*) METAPHYSICS, n° 109, &c.—PHILOSOPHY and PHYSICS, *paſſim*—and (*Suppl.*) ACTION and ASTRONOMY.

1
Definition.

CENTER, or CENTRE, a word borrowed from the French name *ceintre* or *cintre*, given to the frame of timber, by which the brick or ſtone of arched vaulting is ſupported during its erection, and from which it receives its form and curvature.

2
Purpoſe of this article.

It is not our intention to deſcribe the variety of conſtructions which may be adopted in eaſy ſituations, where the arches are of ſmall extent, and where ſufficient foundation can be had in every part of it for ſupporting the frame. In ſuch caſes, the frequency of the props which we can ſet up diſpenſes with much care; and a frame of very ſlight timbers, connected together in an ordinary way, will ſuffice for carrying the weight, and for keeping it in exact ſhape. But when the arches have a wide ſpan, and conſequently a very great weight, and when we cannot ſet up intermediate pillars, either for want of a foundation in the ſoft bottom of a river, or becauſe the arch is turned between two lofty piers, as in the dome of a ſtately cathedral—we are then obliged to reſt every thing on the piers themſelves; and the framing which is to ſupport our arch before the keyſtone is ſet, muſt itſelf be an arch, depending on the mutual abutment of its beams. One ſhould think that this view of the conſtruction of a centre would offer itſelf at the firſt, naturally derived from the erection it was to aſſiſt: but it has not been ſo. When intermediate pillars were not employed, it was uſual to frame the mould for the arch with little attention to any thing but its ſhape, and then to croſs it and recroſs it in all directions with other pieces of timber, till it was thought ſo bound together that it could be lifted in any poſition, and, when loaded with any weight, could not change its ſhape. The frame was then raiſed in a lump, like any ſolid body of the ſame ſhape, and ſet in its place. This is the way ſtill practiſed by many country artiſts, who, having no clear principles to guide them, do not ſtop till they have made a load of timber almoſt equal to the weight which it is to carry.

But this artleſs method, beſides leading the employer into great expence, is frequently fatal to the undertaker, from the unſkilfulneſs of the conſtruction. The beams which connect its extremities are made alſo to ſupport the middle by means of poſts which reſt on them. They are therefore expoſed to a tranſverſe or croſs ſtrain, which they are not able to bear. Their number muſt therefore be increaſed, and this increaſes the load. Some of theſe croſs ſtrains are derived from beams which are preſſed very obliquely, and therefore exert a prodigious thruſt on their ſupports. The beams are alſo greatly weakened by the mortiſes which are cut in them to receive the tenons of the croſſing beams: and thus the whole is exceedingly weak, in proportion to what the ſame quantity of timber may be made by a proper diſpoſition of its parts.

3
General principles of conſtruction.

The principles from which we are to derive this diſpoſition are the general mechanical principles of carpentry, of which we have given ſome account in that article. Theſe furniſh one general rule: When we would give the utmoſt ſtrength poſſible to a frame of carpentry, every piece ſhould be ſo diſpoſed that it is ſubject to no ſtrain but what either puſhes or draws it in the direction of its length: and, if we would be indebted to timber alone for the force or ſtrength of the centre, we muſt reſt all on the firſt of theſe ſtrains; for when the ſtraining force tends to *draw* a beam out of its place, it muſt be held there by a mortiſe and tenon, which poſſeſſes but a very trifling force, or by iron ſtraps and bolts. Caſes occur where it may be very difficult to make every ſtrain a thruſt, and the beſt artiſts admit of ties; and indeed where we can admit a tie-beam connecting the two feet of our frame, we need ſeek no better ſecurity. But this may ſometimes be very inconvenient. When it is the arch of a bridge that we are to ſupport, ſuch a tie-beam would totally ſtop the paſſage of ſmall craft up and down the river. It would often be in the water, and thus expoſed to the moſt fatal accidents by freſhes, &c. Interrupted ties, therefore, muſt be employed, whoſe joint or meetings muſt be ſupported by ſomething analogous to the king-poſts of roofs. When this is judiciouſly done, the ſecurity is abundantly good. But great judgment is neceſſary, and a very ſcrupulous attention to the diſpoſition of the pieces. It is by no means an eaſy matter to diſcern whether a beam, which makes a part of our centre, is in a ſtate of compreſſion or in a ſtate of extenſion. In ſome works of the moſt eminent carpenters even of this day, we ſee pieces conſidered as ſtruts (and conſiderable dependence had on them in this capacity), while they are certainly performing the office of tie-beams, and ſhould be ſecured accordingly. This was the caſe in the boldeſt centre (we think) that has been

been executed in Europe, that of the bridge of Orleans, by Mr Hupeau. Yet it is evidently of great conſequence not to be miſtaken in this point; for when we are miſtaken, and the piece is ſtretched which we imagine to be compreſſed, we not only are deprived of ſome ſupport that we expected, but the expected ſupport has become an additional load.

4
How to diſtinguiſh a ſtrut from a tie.

To aſcertain this point, we may ſuppoſe the piers to yield a little to the preſſure of the archſtones on the centre frames. The feet, therefore, fly outwards, and the ſhape is altered by the ſinking of the crown. We muſt draw our frame anew for this new ſtate of things, and muſt notice what pieces muſt be made longer than before. All ſuch pieces have been acting the part of tie-beams.

But a centre has ſtill another office to ſuſtain; it muſt keep the arch in its form; that is, while the load on the centre is continually increaſing, as the maſons lay on more courſes of arch ſtones, the frame muſt not yield and go out of ſhape, ſinking under the weight on the haunches, and riſing in the crown, which is not yet carrying any load. The frame muſt not be ſupple; and muſt derive its ſtiffneſs, not from the cloſeneſs and ſtrength of its joints, which are quite inſignificant when ſet in competition with ſuch immenſe ſtrains, but from ſtruts or ties, properly diſpoſed, which hinder any of the angles from changing its amplitude.

5
How to ſecure ſtiffneſs and ſtrength.

It is obvious, from all that has been ſaid, that the ſtrength and ſtiffneſs of the whole muſt be found in the triangles into which this frame of carpentry may be reſolved. We have ſeen that the ſtrains which one piece produces on two others, with which it meets in one point, depends on the angles of their interſection; and that it is greater as an obtuſe angle is more obtuſe, or an acute angle more acute. And this ſuggeſts to us the general maxim, "to avoid as much as poſſible all very obtuſe angles." Acute angles, which are not neceſſarily accompanied by obtuſe ones, are not ſo hurtful; becauſe the ſtrain here can never exceed the ſtraining force; whereas, in the caſe of an obtuſe angle, it may ſurpaſs it in any degree.

Such are the general rules on this ſubject. Although ſomething of the mutual abutment of timbers, and the ſupport derived from it, has been long perceived, and employed by the carpenters in roofing, and alſo (doubtleſs) in the forming of centres, yet it is a matter of hiſtorical fact, that no general and diſtinct views had been taken of it till about the beginning of this century, or a little earlier. Fontana has preſerved the figure of the frames on which the arches of St Peter's at Rome were turned. The one employed for the dome is conſtructed with very little ſkill; and thoſe for the arches of the nave and tranſepts, though incomparably ſuperior, and of conſiderable ſimplicity and ſtrength, are yet far inferior to others which have been employed in later times. It is much to be regretted that no trace remains of the forms employed by the great architect and conſummate mechanician Sir Chriſtopher Wren. We ſhould doubtleſs have ſeen in them every thing that ſcience and great ſagacity could ſuggeſt. We are told, indeed, that his centering for the dome of St Paul's was a wonder of its kind; begun in the air at the height of 160 feet from the ground, and without making uſe of even a projecting corniche whereon to reſt it.

6
The earlieſt theory, on ſcientific principles,

The earlieſt theory of the kind that we have met with, that is propoſed on ſcientific principles, and with the expreſs purpoſe of ſerving as a leſſon, are two centres by Mr Pitot of the Academy of Sciences, about the beginning of this century. As they have conſiderable merit (greatly reſembling thoſe employed by Michael Angelo in the nave of St Peter's), and afford ſome good maxims, we ſhall give a ſhort account of them. We crave the excuſe of the artiſts if we ſhould employ their terms of art ſomewhat aukwardly, not being very familiarly acquainted with them. Indeed, we obſerve very great differences, and even ambiguity, in the terms employed.

What we ſhall deſcribe under the name of a *centre* is (properly ſpeaking) only one frame, truſs, or rib, of a centre. They are ſet up in vertical planes, parallel to each other, at the diſtance of 5, 6, 7, or 8 feet, like the truſſes or main couples of a roof. Bridging joiſts are laid acroſs them.—In ſmaller works theſe are laid ſparingly, but of conſiderable ſcantling, and are boarded over; but for great arches, a bridging joiſt is laid for every courſe of archſtones, with blockings between to keep them at their proper diſtances. The ſtones are not laid immediately on theſe joiſts, but beams of ſoft wood are laid along each joiſt, on which the ſtone is laid. Theſe beams are afterwards cut out with the chiſſel, in order to ſeparate the centre from the ring of ſtones, which muſt now ſupport each other by their mutual abutment.

7
Illuſtrated.
Plate XIV.

The centre is diſtinguiſhable into two parts, ALLB (fig. 1.) and LDL, which are pretty independent of each other, or at leaſt act ſeparately. The horizontal STRETCHER LL cuts the ſemicircle ADB half way between the ſpring and the crown of the arch; the arches AL, LD, being 45° each. This ſtretcher is divided in the ſame proportion in the points G and H; that is, GH is one half of LL, and LG, HL are each one-fourth of LL nearly. Each end is ſupported by two STRUTS EI, GI, which reſt below on a SOLE or BED properly ſupported. The interval between the heads of the ſtruts GI, HK is filled up by the STRAINING BEAM GH, abutting in a proper manner on the ſtruts (ſee CARPENTRY, *Supplement*). The extremities L, L, are united in like manner by butting joints, with the heads of the outer ſtruts. The ARCH MOULDS AP, BP, are connected with the ſtruts by croſs pieces PQ, which we ſhall call BRIDLES, which come inwards on each ſide of the ſtruts (being double), and are bolted to them. This may be called the lower part of the frame. The upper part conſiſts of the king poſt DR, ſupported on each ſide by the two ſtruts or braces ML, ON, mortiſed into the poſt, and alſo mortiſed into the ſtretcher, at the points L, N, where it is ſupported by the ſtruts below. The arches LD, LD are connected with the ſtruts by the bridles PQ, in the ſame manner as below.

8
Propriety of this arrangement.

There is a great propriety in many parts of this arrangement. The lower parts or haunches of the arch preſs very lightly on the centres. Each archſtone is lying on an inclined plane, and tends to ſlide down only with its relative weight; that is, its weight is to its tendency to ſlide down the joint as radius to the ſine of elevation of the joint. Now it is only by this tendency to ſlide down the joint that they preſs on the centering, which in every part of the arch is perpendicular to the joint: But the preſſure on the joint, ariſing from this cauſe, is much leſs than this, by reaſon of the friction of the joints. A block of dry freeſtone will not ſlide down at all; and therefore will not preſs on the centering, if the joint be not elevated 35 degrees at leaſt. But the archſtones are not laid in this manner, by ſliding them down along the joint, but are laid on the centres, and ſlide down *their* ſlope, till they touch the blocks on which they are to reſt; ſo that, in laying the archſtones, we are by no means allowed to make the great deduction from their weight juſt now mentioned, and which Mr Couplet preſcribes (Mem. Acad. Sciences, 1729). But there is another cauſe which diminiſhes the preſſure on the centres; each block ſlides down the planks on which it is laid, and preſſes on the block below it, in the direction of the tangent to the arch. This preſſure is tranſmitted through this block, in the ſame direction, to the next, and through it to the third, &c. In this manner it is plain that, as the arch advances, there is a tangential preſſure on the lower archſtones, which diminiſhes their preſſure on the frame, and, if ſufficiently great, might even puſh them away from it. Mr Couplet has given an analyſis of this preſſure, and ſhews, that in a ſemicircular arch of uniform thickneſs none of the arch ſtones below 30° preſs on the frames. But he (without ſaying ſo) calculates on the ſuppoſition that the blocks deſcend along the circumference of this frame in the ſame manner as if it were perfectly ſmooth. As this is far from being the caſe, and as the obſtructions are to the laſt degree various and irregular, it is quite uſeleſs to inſtitute any calculation on the ſubject. A little reflection will convince the reader, that in this caſe the obſtruction ariſing from friction *muſt* be taken into account, and that it *muſt not* be taken into account in eſtimating the preſſure of each ſucceſſive courſe of ſtones as they are laid. It is enough that we ſee that the preſſure of the lower courſes of archſtones on the frame is diminiſhed. Mr Couplet ſays, that the whole preſſure of a ſemicircular arch is but $\frac{4}{9}$ths of its weight; but it is much greater, for the reaſon juſt now given. We have tried, with a well made wooden model (of which the circumference was rubbed with black lead to render it more ſlippery), whether *ony* part of the wooden blocks repreſenting the archſtones were detached from the frame by the tangential preſſure of the ſuperior blocks; but we could not ſay confidently that any were ſo detached. We perceived that all kept hold of a thin ſlip of Chineſe paper (alſo rubbed with black lead) between them and the frame, ſo that a ſenſible force was required to pull it out. From a combination of circumſtances, which would be tedious to relate, we believe that the centres carry more than two-thirds of the weight of the arch before the keyſtone is ſet. In elliptical and lower pitched circular arches, the proportion is ſtill greater.

9
By a centre of M. Pitot's.

It ſeems reaſonable enough, therefore, to diſpoſe the framing in the manner propoſed by Pitot, directing the main ſupport to the upper maſs of the arch, which preſſes moſt on the frame. We ſhall derive another advantage from this conſtruction, which has not occurred to Mr Pitot.

There is an evident propriety in the manner in which he has diſtributed the ſupports of the upper part. The ſtruts which carry the king poſt ſpring from thoſe points of the ſtretcher where it reſts on the ſtruts below: thus the ſtretcher, on which all depends, bears no tranſverſe ſtrains. It is ſtretched by the ſtrut above it, and it is compreſſed in a ſmall degree between the ſtruts below it, at leaſt by the outer ones. Mr Pitot propoſes the ſtraining beam GH as a lateral ſupport to the ſtretcher, which may therefore be of two pieces: but although it *does* augment its ſtrength, it does not ſeem neceſſary for it. The ſtretcher is abundantly carried by the ſtrap, which may and ſhould ſuſpend it from the king poſt. The great uſe of the ſtraining piece is to give a firm abutment to the inner ſtruts, without allowing any lateral ſtrain on the ſtretcher. *N. B.* Great care muſt be taken to make the hold ſufficiently firm and extenſive between the ſtretcher and the upper ſtruts, ſo that its coheſion to reſiſt the thruſts from theſe ſtruts may be much employed.

The only imperfection that we find in this frame is the lateral ſtrains which are brought upon the upper ſtruts by the bridles, which certainly tranſmit to them part of the weight of the archſtones on the curves. The ſpace between the curves and ML ſhould alſo have been truſſed. Mr Pitot's form is, however, extremely ſtiff; and the cauſing the middle bridle to reach down to the ſtretcher, ſeems to ſecure the upper ſtruts from all riſk of bending.

This centre gives a very diſtinct view of the offices of all the parts, and makes therefore a proper introduction to the general ſubject. It is the ſimpleſt that can be in its principle, becauſe all the eſſential parts are ſubjected to one kind of ſtrain. The ſtretcher LL is the only exception, and its extenſion is rather a collateral circumſtance than a ſtep in the general ſupport. 10

The ſtrength of this frame

The examination of the ſtrength of the frame is extremely eaſy. Mr Pitot gives it for an arch of 60 feet ſpan, and ſuppoſes the archſtones 7 feet long, which is a monſtrous thickneſs for ſo ſmall an arch; 4 feet is an abundant allowance, but we ſhall abide by his conſtruction. He gives the following ſcantlings of the parts:

The ring or circumference conſiſts of pieces of oak 12 inches broad and 6 thick.

The ſtretcher LL is 12 inches ſquare.

The ſtraining piece GH is alſo 12 by 12.

The lower ſtruts 10 by 8.

The king poſt 12 by 12.

The upper ſtruts 10 by 6.

The bridles 20 by 8.

Theſe dimenſions are French, which is about $\frac{1}{17}$th larger than ours, and the ſuperficial dimenſions (by which the ſection and the abſolute ſtrength is meaſured) is almoſt $\frac{1}{8}$th larger than ours. The cubic foot, by which the ſtones are meaſured, exceeds ours nearly $\frac{1}{5}$th. The pound is deficient about $\frac{1}{13}$th. But ſince very nice calculation is neither eaſy nor neceſſary on this ſubject, it is needleſs to depart from the French meaſures, which would occaſion many fractional parts and a troubleſome reduction.

The arch is ſuppoſed to be built of ſtone which weighed 160 pounds per foot. Mr Pitot, by a computation (in which he has committed a miſtake), ſays, that only $\frac{11}{14}$ths of this weight is carried by the frame. We believe, however, that this is nearer the truth than Mr Couplet's aſſumption of $\frac{4}{9}$ths already mentioned.

Mr Pitot farther aſſumes, that a ſquare inch of ſound oak will carry 8640 pounds. By his language we ſhould imagine that it will not carry much more: but this is very far below the ſtrength of any Britiſh oak that we have tried; ſo far, indeed, that we rather imagine

gine that he means that this load may be laid on it with perfect ſecurity for any time. But to compenſate for knots and other accidental imperfections, he aſſumes 7200 as the meaſure of its abſolute force.

He computes the load on each frame to be 707520 pounds, which he reduces to $\frac{11}{14}$ths, or 555908 pounds.

The abſolute force of each of the lower ſtruts is 576000 (at 7200 per inch), and that of the curves 518400. Mr Pitot, conſidering that the curves are kept from bending outwards by the arch-ſtones which preſs on them, thinks that they may be conſidered as acting preciſely as the outer ſtruts EI. We have no objection to this ſuppoſition.

11 Computed.

With theſe data we may compute the load which the lower truſs can ſafely bear by the rule delivered in the article Carpentry. We therefore proceed as follows:

Meaſure off by a ſcale of equal parts as, at, each 576000, and add tv 518400. Complete the parallelogram $avxs$, and draw the vertical xc, meeting the horizontal line aC in c. Make cb equal to ca. Join xb, and complete the parallelogram $axby$. It is evident that the diagonal xy will repreſent the load which theſe pieces can carry; for the line av is the united force of the curve AP and the ſtrut IE, and as is the ſtrength of IG. Theſe two are equivalent to ax. xb is, in like manner, equivalent to the ſupport on the other ſide, and xy is the load which will juſt balance the two ſupports ax and bx.

When xy is meaſured on the ſame ſcale, it will be found = 2850000 pounds. This is more than five times the load which actually lies on the frame. It is therefore vaſtly ſtronger than is neceſſary. Half of each of the linear dimenſions would have been quite ſufficient, and the ſtruts needed only to be 5 inches by 4. Even this would have carried twice the weight, and would have borne the load really laid on it with perfect ſafety.

We proceed to meaſure the ſtrength of the upper part. The force of each ſtrut is 432000, and that of the curve is 518400; therefore, having drawn Mv parallel to the ſtrut ON, make Mv = 432000, and Ms = 432000 + 518400. Complete the parallelogram Msrv. Draw the horizontal line rk, cutting the vertical MC in k, and make ky = Mk. It is plain, from what was done for the lower part, that My will meaſure the load which can be carried by the upper part. This will be found = 1160000. This is alſo greatly ſuperior to the load; but not in ſo great a proportion as the other part. The chief part of the load lies on the upper part; but the chief reaſon of the difference is the greater obliquity of the upper ſtruts. This ſhortens the diagonal My of the parallelogram of forces. Mr Pitot ſhould have adverted to this; and inſtead of making the upper ſtruts more ſlender than the lower, he ſhould have made them ſtouter.

The ſtrain on the ſtretcher LL is not calculated. It is meaſured by $r'k'$, when My is the load actually lying on the upper part. Leſs than the ſixth part of the coheſion of the ſtretcher is more than ſufficient for the horizontal thruſt; and there is no difficulty of making the foot joints of the ſtruts abundantly ſtrong for the purpoſe.

The reader will perceive that the computation juſt now given does not ſtate the proportions of the ſtrains *actually exerted* on the different pieces, but the load on the whole, on the ſuppoſition that each piece is ſubjected to a ſtrain proportioned to its ſtrength. The other calculation is much more complicated, but is not neceſſary here.

This centre has a very palpable defect. If the piers ſhould yield to the load, and the feet of the centre fly out, the lower part will exert a very conſiderable ſtrain on the ſtretcher, tending to break it acroſs between N and L, and on the other ſide. HKF of the lower part is firmly bound together, and cannot change its ſhape, and will therefore act like a lever, turning round the point F. It will draw the ſtrut HK away from its abutment with GH, and the ſtretcher will be ſtrained acroſs at the place between H and F, where it is bolted with the bridle. This may be reſiſted in ſome degree by an iron ſtrap uniting ON and HK; but there will ſtill be a want of proportional ſtrength. Indeed, in an arch of ſuch height (a ſemicircle), there is but little riſk of this yielding of the piers; but it is an imperfection.

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

The centre (fig. 2.) is conſtructed on the ſame principle preciſely for an elliptical arch (A). The calculation of its ſtrength is nearly the ſame alſo; only the two upper ſtruts of a ſide being parallel, the parallelogram Msrv (of fig. 1.) is not needed, and in its ſtead we meaſure off on ON a line to repreſent twice its ſtrength. This comes in place of Mr' of fig. 1.—*N. B.* The calculation proceeds on the ſuppoſition that the ſhort ſtraining piece MM makes but one firm body with the king-poſt. Mr Pitot employed this piece (we preſume) to ſeparate the heads of the ſtruts, that their obliquity might be leſſened thereby: and this is a good thought; for when the angle formed by the ſtruts on each ſide is very open, the ſtrain on them becomes very great.

The ſtretcher of this frame is ſcarfed in the middle. Suppoſe this joint to yield a little, there is a danger of the lower ſtrut ON loſing its hold, and ceaſing to join in the ſupport: for when the crown ſinks by the lengthening of the ſtretcher, the triangle ORN of fig. 2. will be more diſtorted than the ſpace above it, and ON will be looſened. But this will not be the caſe when the ſinking of the crown ariſes from the mere compreſſion of the ſtruts. Nor will it happen at all in the centre, fig. 1. On the contrary, the ſtrut ON will abutt more firmly by the yielding of the foot of ML.

The figure of this arch of Mr Pitot's conſiſts of three arches of circles, each of 60 degrees. As it is elegant, it will not be unacceptable to the artiſt to have a conſtruction for this purpoſe.

13 How to conſtruct ſuch an arch.

Make BY = CD, and CZ = $\frac{1}{2}$ CY. Deſcribe the ſemicircle ZÆY, and make ZS = ZÆ. S is the centre of the ſide arches, each of 60 degrees. The centre T of

the

(A) It is the middle arch of the bridge at Liſle Adam, of which Mr Pitot had the direction. It is of 80 feet ſpan, and riſes 31 feet.

the arch, which unites theſe two, is at the angle of an equilateral triangle STS.

This conſtruction of Mr Pitot's makes a handſome oval, and very near an ellipſis, but lies a little without it. We ſhall add another of our own, which coincides with the ellipſe in eight points, and furniſhes the artiſt, by the way, a rule for drawing an infinite variety of ovals.

Let AB, DE (fig. 2. N° 2.) be the axes of an ellipſe, C the centre, and F, f the two foci. Make $Cb = CD$, and deſcribe a circle $ADbe$ paſſing through the three given points A, D, and b. It may be demonſtrated, that if from any point P of the arch AD be drawn a chord PD, and if a line PRr be drawn, making the angle $DPR = PDC$, and meeting the two axes in the points R and r, then R and r will be the centres of circles, which will form a quarter APD of an oval, which has AB and DE for its two axes.

We want an oval which ſhall coincide as much as poſſible with an ellipſis? The moſt likely method for this is to find the very point P where the ellipſis cuts the circle $ADbe$. The eaſieſt way for the artiſt is to deſcribe an arch of a circle am, having AB for its radius, and the remote focus f for its centre. Then ſet one foot of the compaſſes on any point P, and try whether the diſtance PF from the neareſt focus F is exactly equal to its diſtance Pm from that circle. Shifting the foot of the compaſſes from one point of the arch to another, will ſoon diſcover the point. This being found, draw PD, make the angle $DPr = PDr$, and R and r are the centres wanted. Then make $Cs = CR$, and we get the centres for the other ſide.

The geometer will not reliſh this mechanical conſtruction. He may therefore proceed as follows: Draw Dd parallel to AB, cutting the circle in d. Draw ed, cutting AC in N. Draw CG parallel to Ae, and make the angle $CGi = ADe$. Biſect CN in O, and join Oi. Make OM, $OM' = Oi$, and draw MP, M'P perpendicular to AB. Theſe ordinates will cut the circle $ADbe$ in the points P and P', where it is cut by the ellipſe. We leave the demonſtration as a geometrical exerciſe for the dilettante.

14 Centre for the nave of St Peter's.

We ſaid, that this centering of Mr Pitot's reſembled in principle the one employed by Michael Angelo for the nave and tranſepts of St Peter's church at Rome. Fontana, who has preſerved this, aſcribes the conſtruction of it to one of the name of San Gallo. A ſketch of it is given in fig. 3. It is, however, ſo much ſuperior, and ſo different in principle, from that employed for the cupola, that we cannot think it the invention of the ſame perſon. It is, like Pitot's, not only diviſible, but really divided into two parts, of which the upper carries by much the greateſt part of the load. The pieces are judiciouſly diſpoſed, and every important beam is amply ſecured againſt all tranſverſe ſtrains. Its only fault is a great profuſion of ſtrength. The innermoſt polygon $aghb$ is quite ſuperfluous, becauſe no ſtrain can force in the ſtruts which reſt on the angles. Should the piers yield outwards, this polygon will be looſe, and can do no ſervice. Nor is the triangle gib of any uſe, if the king-poſt above it be ſtrapped to the tie-beam and ſtraining ſill. Perhaps the inventor conſidered the king-poſt as a pillar, and wiſhed to ſecure the tie-beam againſt its croſs ſtrain. This centering, however, muſt be allowed to be very well compoſed; and we expect that the well-informed reader will join us in preferring it to Mr Pitot's, both for ſimplicity of principle, for ſcientific propriety, and for ſtrength.

There is one conſiderable advantage which may be derived from the actual diviſion of the truſs into two parts. If the tie-beam LL, inſtead of reſting on the ſtretcher EF, had reſted on a row of chocks formed like double wedges, placed above each other, head to point, the upper part of the centering might be ſtruck independent of the lower, and this might be done gradually, beginning at the outer ends of the ſtretcher. By this procedure, the joints of the arch-ſtones will cloſe on the haunches, and will almoſt relieve the lower centering, ſo that all can be pulled out together. Thus may the arch ſettle and conſolidate in perfect ſafety, without any chance of breaking the bond of the mortar in any part; an accident which frequently happens in great arches. This procedure is peculiarly adviſable for low pitched or elliptical arches. But this will be more clearly ſeen afterwards, when we treat of the internal movements of an arch of maſonry.

This may ſuffice for an account of the more ſimple conſtruction of truſſed centres; and we proceed to ſuch as have a much greater complication of principle. We ſhall take for examples ſome conſtructed by Mr Perronet, a very celebrated French architect.

15 Perronet's maxim of conſtruction.

Mr Perronet's general maxim of conſtruction is to make the truſs conſiſt of ſeveral courſes of ſeparate truſſes, independent (as he thinks) of each other, and thus to employ the joint ſupport of them all. In this conſtruction it is not intended to make uſe of one truſs, or part of one truſs, to ſupport another, as in the former ſet, and as is practiſed in the roofs of St Paul's church, Covent Garden, and in Drury Lane theatre. Each truſs ſpans over the whole diſtance of the piers, and would ſtand alone (having, however, a tottering equilibrium). It conſiſts of a number of ſtruts, ſet end to end, and forming a polygon. Theſe truſſes are ſo arranged, that the angles of one are in the middle of the ſides of the next, as when a polygon is inſcribed in a circle, and another (of the ſame number of ſides) is circumſcribed by lines which touch the circle in the angles of the inſcribed polygon. By this conſtruction the angles of the alternate truſſes lie in lines pointing towards the centre of the curve. King-poſts are therefore placed in this direction between the adjoining beams of the truſſes. Theſe king-poſts conſiſt of two beams, one on each ſide of the truſs, and embrace the truſs-beams between them, meeting in the middle of their thickneſs. The abutting beams are mortiſed, half into each half of the poſt. The other beam, which makes the baſe of the triangle, paſſes through the poſt, and a ſtrong bolt is driven through the joint, and ſecured by a key or a nut. In this manner is the whole united; and it is expected, that when the load is laid on the uppermoſt truſs, it will all butt together, forcing down the king-poſts, and therefore preſſing them on the beams of all the inferior truſſes, cauſing them alſo to abutt on each other, and thus bear a ſhare of the load. Mr Perronet does not aſſume the invention to himſelf; but ſays that it was invented and practiſed by Mr Manſard de Sagonne at the great bridge of Moulins. It is much more ancient, and is the work of the celebrated phyſician and architect Perrault; as may be ſeen in the collection of machines and inventions of that gentleman publiſhed after

ter his death, and alſo in the great collection of inventions approved of by the Academy of Sciences. It is this which we propoſe to examine.

16 Centering employed for the bridge of Cravant,

Fig 4. repreſents the centering employed for the bridge of Cravant. The arches are elliptical, of 60 feet ſpan and 20 feet riſe. The archſtones are four feet thick, and weigh 176 pounds per foot. The truſs-beams were from 15 to 18 feet long, and their ſection was 9 inches by 8. Each half of the king poſts was about 7 feet long, and its ſection 9 inches by 8. The whole was of oak. The five truſſes were 5½ feet aſunder. The whole weight of the arch was 1350000 lbs. which we may call 600 tons (it is 558). This is about 112 tons for each truſs. We muſt allow near 90 tons of this really to preſs the truſs. A great part of this preſſure is borne by the four beams which make the feet of the truſs, coupled in pairs on each ſide. The diagonal of the parallelogram of forces drawn for theſe beams is, to one of the ſides, in the proportion of 360 to 285. Therefore ſay, as 360 to 285 ; ſo is 90 to 71¼ tons, the thruſt on each foot. The ſection of each is 144 inches. We may with the utmoſt ſafety lay three tons on every inch for ever. This amounts to 432 tons, which is more than ſix times the ſtrain really preſſing the foot beams in the direction of their length ; nay, the upper truſs alone is able to carry much more than its load. The abſolute ſtrength of its foot-beam is 216 tons. It is much more advantageouſly placed ; for the diagonal of the parallelogram of forces correſponding to its poſition is to the ſide as 438 to 285. This gives $58\frac{6}{10}$ tons for the ſtrain on each foot; which is not much above the fourth part of what it is able to carry for ever. No doubt can therefore be entertained of the ſuperabundant ſtrength of this centering. We ſee that the upper row of ſtruts is quite ſufficient, and all that is wanted is to procure ſtiffneſs for it ; for it muſt be carefully kept in mind, that this upper row is not like an equilibrated arch. It will be very unequally loaded as the work advances. The haunches of the frame will be preſſed down, and the joints at the crown raiſed up. This muſt be reſiſted.

Here then we may gather, by the way, a uſeful leſſon. Let the outer row of ſtruts be appropriated to the carriage of the load, and let the reſt be employed for giving ſtiffneſs. For this purpoſe let the outer row have abundant ſtrength. The advantages of this method are conſiderable. The poſition of the beams of the exterior row is more advantageous, when (as in this example) the whole is made to reſt on a narrow foot : for this obliges us to make the laſt angle, at leaſt of the lower row, more open, which increaſes the ſtrain on the ſtrut ; beſides, it is next to impoſſible to diſtribute the compreſſing thruſts among the different rows of the truſs beams ; and a beam which, during one period of the maſon work, is acting the part of a ſtrut, in another period is bearing no ſtrain but its own weight, and in another it is ſtretched as a tie. A third advantage is, that, in a caſe like this, where all reſts on a narrow foot, and the lower row of beams are bearing a great part of the thruſt, the horizontal thruſt on the pier is very great, and may puſh it aſide. This is the moſt ruinous accident that can happen. An inch or two of yielding will cauſe the crown of the arch to ſink prodigiouſly, and will inſtantly derange all the bearings of the abutting beams : but when the lower beams already act as ties, and are quite adequate to their office, we render the frame perfectly ſtiff or unchangeable in its form, and take away the horizontal thruſt from the piers *entirely*. This advantage is the more valuable, becauſe the very circumſtance which obliges us to reſt all on a narrow foot, places this foot on the very top of the pier, and makes the horizontal thruſt the more dangerous.

But, to proceed in our examination of the centering of Cravant bridge, let us ſuppoſe that the king poſts are removed, and that the beams are joined by compaſs joints. If the pier ſhall yield in the ſmalleſt degree, both rows of ſtruts muſt ſink ; and ſince the angles (at leaſt the outermoſt) of the lower row are more open than thoſe of the upper row, the crown of the lower row will ſink more than that of the upper.

The angles of the alternate rows muſt therefore ſeparate a little. Now reſtore the king poſts ; they prevent this ſeparation. Therefore *they are ſtretched ;* therefore the beams of the lower row are alſo ſtretched; conſequently they no longer butt on their mortiſes, and muſt be held in their places by bolts. Thus it appears that, in this kind of ſagging, the original diſtribution of the load among the different rows of beams is changed, and the upper row becomes loaded beyond our expectation.

If the ſagging of the whole truſs proceed only from the compreſſion of the timbers, the caſe is different, and we *may* preſerve the original diſtribution of mutual abutment more accurately. But in this caſe the ſtiffneſs of the frame ariſes chiefly from croſs ſtrains. Suppoſe that the frame is loaded with archſtones on each ſide up to the poſts HC, *h c* ; the angles E and *e* are preſſed down, and the beams EOF, *e o* F puſh up the point F. This cannot riſe without bending the beams EOF, *e o* F; becauſe O and *o* are held down by the double king poſts, which graſp the beams between them. There is therefore a croſs ſtrain on the beams. Obſerve alſo, that the triangle EHF does not preſerve its ſhape by the connection of its joints ; for although the ſtrut beams are mortiſed into the king poſt, they are in very ſhallow mortiſes, rather for ſteadying them than for holding them together. Mr Perronet did not even pin them, thinking that their abutment was very great. The triangle is kept in ſhape by the baſe EF, which is firmly bolted into the middle poſt at O. Had theſe interſections not been ſtrongly bolted, we imagine that the centres of ſome of Mr Perronet's bridges would have yielded much more than they did ; yet ſome of them yielded to a degree that our artiſts would have thought very dangerous. Mr Perronet was obliged to load the crown of the centering with very great weights, increaſing them as the work advanced, to prevent the frames from going out of ſhape : in one arch of 120 feet he laid on 45 tons. Notwithſtanding this imperfection, which is perhaps unavoidable, this mode of framing is undoubtedly very judicious, and perhaps the beſt which can be employed without depending on iron-work.

17 For the bridge of Nogent,

Fig. 5. repreſents another, conſtructed by Perronet for an arch of 90 feet ſpan and 28 feet riſe. The truſſes were 7 feet apart, and the arch was 4½ thick ; ſo that the unreduced load on each frame was very nearly 235 tons. The ſcantling of the ſtruts was 15 by 12 inches. The principle is the ſame as that of the former. The chief difference is, that in this centre the outer truſs-beam of the lower row is not coupled with the middle row,

row, but kept nearly parallel to the outer beam of the upper row. This adds greatly to the ſtrength of the foot, and takes off much of the horizontal thruſt from the pier.

Mr Perronet has ſhewn great judgment in cauſing the polygon of the inner row of truſs beams gradually to approach the polygon of the outer row. By this diſpoſition, the angles of the inner polygon are more acute than thoſe of the outer. A little attention will ſhew, that the general ſagging of all the polygons will keep the abutments of the lower one nearer, or exactly, to their original quantity. We muſt indeed except the foot-beam. It is ſtill too oblique; and, inſtead of converging to the foot of the upper row, it ſhould have diverged from it. Had this been done, this centre is almoſt perfect in its kind. As it is, it is at leaſt ſix times ſtronger than was abſolutely neceſſary. We ſhall have occaſion to refer to this figure on another occaſion.

18 St Maxence,

This maxim is better exemplified by Mr Perronet in the centering of the bridge of St Maxence, exhibited in fig. 5 n° 2. than in that of Nogent, fig. 5. n° 1. But we think that a horizontal truſs-beam *a b* ſhould have been inſerted (in a ſubordinate manner) between the king-poſts next the crown on each ſide. This would prevent the crown from riſing while the haunches only are loaded, without impairing the fine abutments of *c d*, *c d*, when the arch is nearly completed. This is an excellent centering, but is not likely to be of much uſe in theſe kingdoms; becauſe the arch itſelf will be conſidered as ungraceful and ugly, looking like a huge lintel. Perronet ſays, that he preferred it to the ellipſe, becauſe it was lighter on the piers, which were thin. But the failure of one arch muſt be immediately followed by the ruin of all. We know much better methods of lightening the piers.

19 Neuilly, and

Fig. 6 repreſents the centering of the bridge of Neuilly, near Paris, alſo by Perronet. The arch has 120 feet ſpan, and 30 feet riſe, and is 5 feet thick. The frames are 6 feet apart, and each carries an abſolute (that is, not reduced to $\frac{11}{14}$ or to $\frac{4}{9}$) load of 350 tons. The ſtrut beams are 17 by 14 inches in ſcantling. The king poſts are of 15 by 9 each half; and the horizontal bridles, which bind the different frames together in five places, are alſo 15 by 9 each half. There are eight other horizontal binders of 9 inches ſquare.

This is one of the moſt remarkable arches in the world; not altogether on account of its width (for there are ſeveral much wider), but for the flatneſs at the crown; for about 26 feet on each ſide of the middle it was intended to be a portion of a circle of 150 feet radius. An arch (ſemicircular) of 300 feet ſpan might therefore be eaſily conſtructed, and would be much ſtronger than this, becauſe its horizontal thruſt at the crown would be vaſtly greater, and would keep it more firmly united.

The bolts of this centre are differently placed from thoſe of the former; and the change is judicious. Mr Perronet had doubtleſs found by this time, that the ſtiffneſs of his framing depended on the tranſverſe ſtrength of the beams; and therefore he was careful not to weaken them by the bolts. But notwithſtanding all his care, the framing ſunk upwards of 13 inches before the keyſtones were laid; and during the progreſs of the work, the crown roſe and ſunk, by various ſteps, as the loading was extended along it. When 20 courſes were laid on each ſide, and about 16 tons laid on the crown of each frame, it ſunk about an inch. When 46 courſes were laid, and the crown loaded with 50 tons, it ſunk about half an inch more. It continued ſinking as the work advanced; and when the keyſtone was ſet it had ſunk 13½ inches. But this ſinking was not general; on the contrary, the frame had riſen greatly at the very haunches, ſo as to open the upper part of the joints, many of which gaped an inch; and this opening of the joints gradually extended from the haunches towards the crown, in the neighbourhood of which they opened on the under ſide. This evidently aroſe from a want of ſtiffneſs in the frame. But theſe joints cloſed again when the centres were ſtruck, as will be mentioned afterwards.

☞ We have taken particular notice of the movements and twiſting of this centre, becauſe we think that they indicate a deficiency, not only of ſtiffneſs, but of abutment among the truſs beams. The whole has been too flexible, becauſe the angles are too obtuſe: This ariſes from their multiplicity. When the intercepted arches have ſo little curvature, the power of the load to preſs it inward increaſes very faſt. When the intercepted arch is reduced to one half, this power is more than doubled; and it is alſo doubled when the radius of curvature is doubled. The king-poſts ſhould have been farther apart near the crown, ſo that the quantity of arch between them ſhould compenſate for its diminiſhed curvature.

The power of withſtanding any given inequality of load would therefore have been greater, had the centre conſiſted of fewer pieces, and their angles of meeting been proportionally more acute. The greateſt improvement would have been, to place the foot of the lower tier of truſs-beams on the very foot of the pier, and to have alſo ſeparated it at the head from the reſt with a longer king-poſt, and thus to have made the diſtances of the beams on the king-poſts increaſe gradually from the crown to the ſpring. This would have made all the angles of abutment more acute, and would have produced a greater preſſure on all the lower tiers when the frame ſagged.

Fig. 7. repreſents the centering of the bridge of Orleans. The arch has 100 feet ſpan, and riſes 30, and the arch-ſtones are 6 feet long. It is the conſtruction of Mr Hupeau, the firſt architect of the bridge. It is the boldeſt work of the kind that we have ſeen, and is conſtructed on clear principles. The main abutments are few in number. Becauſe the beams of the outer polygon are long, they are very well ſupported by ſtraining beams in the middle; and the ſtruts or braces which ſupport and butt on them, are made to reſt on points carried entirely by *ties*. The inventor, however, ſeems to have thought that the angles of the inner polygon were ſupported by mutual compreſſion, as in the outer polygon. But it is plain that the whole inner polygon may be formed of iron rods. Not but that both polygons *may* be in a ſtate of compreſſion (this is very poſſible); but the ſmalleſt ſagging of the frame will change the proportions of the preſſures at the angles of the two polygons. The preſſures on the exterior angles will increaſe, and thoſe on the lower or interior angles will diminiſh moſt rapidly; ſo that the abutments in the lower polygon will be next to nothing. 20 Orleans.

thing. Such points could bear very little preſſure from the braces which ſupport the middle of the long bearings of the upper beams, and their preſſures muſt be borne chiefly by the joints ſupported by the king-poſts. The king-poſts would then be in a ſtate of extenſion. It is difficult, however, to decide what is the preciſe ſtate of the preſſure at theſe interior angles.

21 Inſtructive hiſtory of this centre

The hiſtory of the erection of this bridge will throw much light on this point, and is very inſtructive. Mr Hupeau died before any of the arches were carried farther than a very few of the firſt courſes. Mr Perronet ſucceeded to the charge, and finiſhed the bridge. As the work advanced, the crown of the frame roſe very much. It was loaded; and it ſunk as remarkably. This ſhewed that the lower polygon was giving very little aid. Mr Perronet then thought the frame too weak, and inſerted the long beam DE, making the diagonal of the quadrangle, and very nearly in the direction of the lower beam *a b*, but falling rather below this line. He now found the frame abundantly ſtrong. It is evident that the truſs is now changed exceedingly, and conſiſts of only the two long ſides, and the ſhort ſtraining beam lying horizontally between their heads. The whole centering conſiſts now of one great truſs *a* E *e b*, and its long ſides *a* E, *e b*, are truſſed up at B and *f*. Had this ſimple idea been made the principle of the conſtruction, it would have been excellent. The angle *a* DE might have been about 176°, and the polygon D *c h g* employed only for giving a ſlight ſupport to this great angle, ſo as not to allow it to exceed 180°. But Mr Perronet found, that the joint *c*, at the foot of the poſt E *c*, was about to *draw looſe*, and he was obliged to bolt long pieces of timber on each ſide of the joint, embracing both beams. Theſe were evidently acting the ſame part as iron ſtraps would have done; a complete proof that, whatever may have been the original preſſures, there was no abutment now at the point *c*, and that the beams that met there were not in a ſtate of compreſſion, but were on the ſtretch. Mr Perronet ſays that he put theſe cheeks to the joints *to ſtiffen* them. But this was not their office; becauſe the adjoining beams were not ſtruts, but ties, as we have now proved.

We may therefore conclude, that the outer polygon, with the aſſiſtance of the pieces *a b*, DE, were carrying the whole load. We do not know the diſtance between the frames; but ſuppoſing them ſeven feet apart, and the arch 6 feet thick, and weighing 170 pounds per foot, we learn the load. The beams were 16 inches ſquare. If we now calculate what they would bear at the ſame very moderate rate allowed to the other centres, we find that the beams AB and *a b* are not loaded to one-ſixth of their ſtrength.

We have given this centre as a fine example of what carpentry is able to perform, and becauſe, by its ſimplicity, it is a ſort of text on which the intelligent artiſt may make many comments. We may ſee plainly that, if the lower polygon had been formed of iron rods, firmly bolted into the feet of the king-poſts, it would have maintained its ſhape completely. The ſervice done by the beam DE was not ſo much an increaſe of abutment as a diſcharge of the weight and of the *pull* at the joint *c*. Therefore, in caſes where the feet of the truſs are *neceſſarily* confined to a very narrow ſpace, we ſhould be careful to make the upper polygon ſufficient to carry the whole load (ſay by doubling its beams), and we may then make the lower polygon of ſlender dimenſions, provided we ſecure the joints on the king-poſts by iron ſtraps which embrace a conſiderable portion of the tie on each ſide of the joint.

22 All theſe centres good in their kind.

We are far from thinking that theſe centres are of the beſt kind that could be employed in their ſituation; but they are excellent in their kind: and a careful ſtudy of them will teach the artiſt much of his profeſſion. When we have a clear conception of the ſtate of ſtrain in which the parts of a frame really are, we know what ſhould be done in order to draw all the advantage poſſible from our materials. We have ſaid in another place, that where we can give our joints ſufficient connection (as by ſtraps and bolts, or by cheeks or fiſhes), it is better to uſe ties than ſtruts, becauſe ties never bend.

We do not approve of Mr Perronet's practice of giving his truſſes ſuch narrow feet. By bringing the foot of the lower polygon farther down, we greatly diminiſh all the ſtrains, and throw more load on the lower polygon: and we do not ſee any of Mr Perronet's centres where this might not have been done. He ſeems to affect a great ſpan, to ſhew the wonders of his art; but our object is to teach how to make the beſt centre of a given quantity of materials; and how to make the moſt perfect centre, when we are not limited in this reſpect, nor in the extent of our fixed points.

23 Excellence of the centre employed for Blackfriars bridge.

We ſhall conclude this ſeries of examples with one where no ſuch affectation takes place. This is the centering of the bridge at Blackfriars, London. The ſpan of the arch is 100 feet, and its height from the ſpring is about 43. The drawing fig. 8. is ſufficiently minute to convey a diſtinct notion of the whole conſtruction. We need not be very particular in our obſervations, after what has been ſaid on the general principles of conſtruction. The leading maxim, in the preſent example, ſeems to be, *that every part of the arch ſhall be ſupported by a ſimple truſs of two legs reſting, one on each pier.* H, H, &c. are called APRON PIECES, to ſtrengthen the exterior joints and to make the RING as ſtiff in itſelf as poſſible. From the ends of this apron-piece proceed the two legs of each truſs. Theſe legs are 12 inches ſquare: They are not of an entire piece, but of ſeveral, meeting in firm abutment. Some of their meetings are ſecured by the double king-poſts, which graſp them firmly between them, and are held together by bolts. At other interſections, the beams appear halved into each other; a practice which cannot but weaken them much, and would endanger their breaking by croſs ſtrains, if it were poſſible for the frame to change its ſhape. But the great breadth of this frame is an effectual ſtop to any ſuch change. The fact was, that *no ſinking or twiſting whatever* was obſerved during the progreſs of the maſon work. Three points in a ſtraight line were marked on purpoſe for this obſervation, and were obſerved every day. The arch was more than ſix feet thick; and yet the ſinking of the crown, before ſetting the key-ſtones, did not amount to one inch.

The centre employs about one-third more timber than Perronet's great centre in proportion to the ſpan of the arch; but the circumference increaſes in a greater proportion than this, becauſe it is more elevated. In every way of making a compariſon of the dimenſions, Mr Mylne's arch employs more timber; but it is *beyond all compariſon* ſtronger. The great elevation is partly the reaſon of this. But the diſpoſition of the timbers is alſo much more advantageous, and may be copied even in the low pitched arches of Neuilly. The ſimple truſs, reaching from pier to pier for the middle point of the arch, gives the ſtrong ſupport where it is moſt of all wanted; and in the lateral points H, although one leg of the truſs is very oblique, the other compenſates for it by its upright poſition.

The chief peculiarity of this centre is to be ſeen in its baſe. This demands a more particular attention: but we muſt firſt make ſome obſervations on the condition of an arch, as it reſts on the centering after the keyſtones are all ſet, and on the gradual transference of the preſſure from the boards of the centering to the joints of the archſtones.

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

While all the archſtones lie on the centering, the lower courſes are alſo leaning pretty ſtrongly on each other. But the mortar is hardly compreſſed in the joints; and leaſt of all in the joints near the crown. Suppoſe the arch to be catenarian, or of any other ſhape that is perfectly equilibrated: When the centering is gradually withdrawn, all the archſtones follow it. Their wedge-like form makes this impoſſible, without the middle ones ſqueezing the lateral ones aſide. This compreſſes the mortar between them. As the ſtones thus come nearer to each other, thoſe near the crown muſt deſcend more than thoſe near the haunches, before every ſtone has leſſened its diſtance from the next by the ſame quantity; for example, by the hundredth part of an inch. This circumſtance alone muſt cauſe a ſinking in the crown, and a change of ſhape. But the joints near the crown are *already* more open than thoſe near the haunches. This produces a ſtill greater change of form before all is ſettled. Some maſons endeavour to remedy, or at leaſt to diminiſh, this, by uſing no mortar in the joints near the crown. They lay the ſtones dry, and even force them together by wedges and blocks laid between the ſtones on oppoſite ſides of the crown: They afterwards pour in fine cement. This appears a good practice. Perronet rejects it, becauſe the wedging ſometimes breaks the ſtones. We ſhould not think this any great harm; becauſe the fracture will make them cloſe where they would otherwiſe lie hollow. But, after all our care, there is ſtill a ſinking of the crown of the arch. By gradually withdrawing the centering, the joints cloſe, the archſtones begin to butt on each other, and to force aſide the lateral courſes. This abutment gradually increaſing, the preſſure on the haunches of the centering is gradually diminiſhed by the mutual abutment, and ceaſes entirely in that courſe, which is the loweſt that formerly preſſed it: it then ceaſes in the courſe above, and then in the third, and ſo on. And, in this manner, not only the centering quits the arch, gradually, from the bottom to the top, *by its own retiring from it*, but the arch alſo quits the centering *by changing its ſhape*. If the centering were now puſhed up again, it would touch the arch firſt at the crown; and it muſt *lift up* that part gradually before it come again in contact with the haunches. It is evident, therefore, that an arch, built on a centre of a ſhape perfectly ſuited to equilibration, will not be in equilibrio when the centering is removed. It is therefore neceſſary to form the centering in ſuch a manner (by raiſing the crown), that it ſhall *leave* the arch of a proper form. This is a very delicate taſk, requiring a previous knowledge of the enſuing change of form. This cannot be aſcertained by the help of any theory we are acquainted with.

But, ſuppoſe this attained, there is another difficulty: While the work advances, the centering is warped by the load laid on it, and continually increaſing on each ſide. The firſt preſſure on the centering forces down the haunches, and raiſes the crown. The arch is therefore leſs curved at the haunches than is intended: the joints, however, accommodate themſelves to this form, and are cloſe, and filled with mortar. When the maſons approach the middle of the arch, the frame ſinks there, and riſes up at the haunches. This opens all the joints in that place on the *upper* ſide. By the time that the keyſtones are ſet, this warping has gone farther; and joints are opened on the *under* ſide near the crown. It is true we are here ſpeaking rather of an extreme caſe, when the centering is *very* flexible; but this occurred to Mr Perronet in the two great bridges of Neuilly and of Mantz. In this laſt one, the crown ſunk above a foot before the key was ſet, and the joints at the haunches opened above an inch *above*, while ſome nearer the crown opened near a quarter of an inch *below*.

25
A delicate buſineſs to ſtrike the centering.

In this condition of things, it is a delicate buſineſs to ſtrike the centering. Were it removed in an inſtant, all would probably come down; for the archſtones are not yet abutting on each other, and the joints in the middle are open below. Mr Perronet's method appears to us to be very judicious. He began to detach the centering at the very bottom, on each ſide equally, where the preſſure on the centering is very ſlight. He cut away the blocks which were immediately under each archſtone. He proceeded gradually upwards in this way with ſome ſpeed, till all was detached that had been put out of ſhape by the bending of the centering. This being no longer ſupported, ſunk inward, till it was ſtopped by the abutment which it found on the archſtones near the crown, which were ſtill reſting on their blocks. During part of this proceſs, the open joints opened ſtill more, and looked alarming. This was owing to the removal of the load from the haunches of the centering. This allowed the crown to ſink ſtill more, by forcing out the arch ſtones at the haunches. He now pauſed ſome days; and during this time the two haunches, now hanging in the air, gradually preſſed in toward the centering, their outer joints cloſing in the meanwhile. The haunches were now preſſing pretty hard on the archſtones nearer the crown. He then proceeded more ſlowly, deſtroying the blocks and bridgings of theſe upper archſtones. As ſoon as he deſtroyed the ſupport of one, it immediately yielded to the preſſure of the haunch; and if the joint between it and the one adjoining toward the crown happened to be open, whether on the under or the upper ſide, it immediately cloſed on it. But in proceeding thus, he found every ſtone ſink a little while it cloſed on its neighbour; and this was like to produce a ragged ſoffet, which is a deformity. He therefore did not allow them to ſink ſo much. In the places of the blocks and bridgings which he had cut away, he ſet ſmall billets, ſtanding on their ends, between the centering and the archſtones. Theſe allowed the pendulous arch to puſh toward the crown without ſenſibly deſcending; for the billets were puſhed out of the perpendicular, and ſome of them tumbled down. Proceeding

ing in this way, he advanced to the very next courſe to the keyſtone on each ſide, the joints cloſing all the way as he advanced. The laſt job was very troubleſome; we mean the detaching the three uppermoſt courſes from the centering: for the whole elaſticity of the centering was now trying to unbend, and preſſing hard againſt them. He found that they were lifted up; for the joints beyond them, which had cloſed completely, now opened again below; but this job was finiſhed in one day, and the centre ſprung up two or three inches, and the whole arch ſunk about ſix inches. This was an anxious time; for he dreaded the great momentum of ſuch a vaſt maſs of matter. It was hard to ſay where it would ſtop. He had the pleaſure to ſee that it ſtopped very ſoon, ſettling ſlowly as the mortar was compreſſed, and after one or two days ſettling no more. This ſettling was very conſiderable both in the bridge at Neuilly and in that at Mantz. In the former, the ſinking during the work amounted to 13 inches. It ſunk ſix inches more when the blocks and bridgings were taken out, and 1½ when the little ſtandards were deſtroyed, and 1¼ more next day; ſo that the whole ſinking of the *pendulous* arch was 9½ inches, beſides what it had ſunk by the bending and compreſſion of the centering.

The crown of the centering was an arch of a circle deſcribed with a radius of 150 feet; but by the ſinking of the arch its ſhape was conſiderably changed, and about 60 feet of it formed an arch of a circle whoſe radius was 244 feet. Hence Mr Perronet infers, that a ſemicircle of 500 feet ſpan may be erected. It would no doubt be ſtronger than this arch, becauſe its greater horizontal thruſt would keep the ſtones firmer together. The ſinking of the arches at Mantz was not quite ſo great, but every thing proceeded in the ſame way. It amounted in all to 20½ inches, of which 12 inches were owing to the compreſſion and bending of the centering.

26 The foregoing obſervations exemplified.

In fig. 5. n° 1. may be obſerved an indication of this procedure of the maſonry. There may be noticed a horizontal line *a c*, and a diagonal *a b*. Theſe are ſuppoſed to be drawn on the maſonry as it would have ſtood had the frames not yielded during the building. The dotted line A*b' c'* ſhews the ſhape which it took by the ſinking of the centering. The dotted line on the other ſide was actually drawn on the maſonry when the keyſtone was ſet; and the wavy black line on the ſame ſide ſhews the form which the dotted line took by the ſtriking of the centering. The undulated part of this line cuts its former poſition a little below the middle, going without it below, and falling within it above. This ſhews very diſtinctly the movement of the whole maſonry, diſtinguiſhing the parts that were forced out and the parts which ſunk inward.

We preſume that the practical reader will think this account of the internal movements of a ſtupendous arch very inſtructive and uſeful. As Mr Perronet obſerved it to be uniformly the ſame in ſeveral very large arches which he erected, we may conclude that it is the general proceſs of nature. We by no means have the confidence in the durability or ſolidity of his arches which he prudently profeſſes to have. We have converſed with ſome very experienced maſons, who have alſo erected very great arches, and in very difficult ſituations, which have given univerſal ſatisfaction; and we have found them uniformly of opinion, that an arch which has ſettled to ſuch a proportion of its curvature as to change the radius from 150 to 244 feet, is in a very hazardous ſituation. They think the hazard the greater, becauſe the ſpan of the arch is ſo great in proportion to its weight (as they expreſs it very emphatically) or its height. The weight, ſay they, of the haunches is too ſmall for forcing together the keyſtones, which have ſcarcely any wedge-like form to keep them from ſliding down. This is very good reaſoning, and expreſſes very familiar notions. The mechanician would ſay, that the horizontal thruſt at the crown is too ſmall. When we queſtioned them about the propriety of Mr Perronet's method of removing the centering, they unanimouſly approved of its general principle, but ſaid that it was very ticklish indeed in the execution. The caſes which he narrates were new to them. They ſhould have almoſt deſpaired of ſucceſs with arches which had gone ſo much out of ſhape by the bending of the centres; becauſe, ſaid they, the ſlope of the centering, to a great diſtance from the crown, was ſo little, that the archſtones could not ſlide outwards along it, to cloſe even the under ſide of the joints which had opened above the haunches; ſo that *all* the archſtones were at too great a diſtance from each other; and a great and *general* ſubſiding of the whole was neceſſary for bringing them even to touch each other. They had *never* obſerved ſuch bendings of the centerings which they had employed, having never allowed themſelves to contract the feet of their truſſes into ſuch narrow ſpaces. They obſerved, that nothing but lighters with their maſts down can paſs under the truſſes, and that the ſides muſt be ſo protected by advanced works from the accidental ſhock of a loaded boat, that there cannot be left room for more than one. They added, that the bridges of communication, neceſſary for the expeditious conducting of the work, made all this ſuppoſed roomineſs uſeleſs: beſides, the buſineſs can hardly be ſo urgent and crowded anywhere, as to make the paſſage through every arch indiſpenſably neceſſary. Nor was the inconvenience of this obſtruction greatly complained of during the erection of Weſtminſter or Blackfriars bridges. Nothing ſhould come in competition with the *undoubted* ſolidity of the centering and the future arch; and all boaſting diſplay of talent and ingenuity by an engineer, in the exhibition of the wonders of his art, is miſplaced here.

Theſe appeared to us good reaſons for preferring the more cautious, and incomparably more ſecure, conſtruction of Mr Mylne, in which the breadth given to each baſe of the truſſes permitted a much more effective diſpoſition of the abutting timbers, and alſo enabled the engineer to make it incomparably ſtiffer; ſo that no change need be apprehended in the joints which have already cloſed, and in which the mortar has already taken its ſet, and commenced an union that never can be reſtored if it be once broken in the ſmalleſt degree, no not even by greater compreſſion.

27 The connection that is formed by mortar of lime, &c.

Here we beg leave to mention our notions of the connection that is formed by mortar compoſed of lime or gypſum. We conſider it as conſiſting chiefly, if not ſolely, in a cryſtallization of the lime or gypſum and water. As much water is taken up as is neceſſary for the formation of the cryſtals during their gradual converſion into mild calcareous earth or alabaſter, and the reſt evaporates. When the free acceſs of air is abſolutely prevented, the cryſtallization never proceeds to that ſtate, even although the mortar becomes extremely dry and hard. We had an opportunity of obſerving this accidentally, when paſſing through Maeſtricht in 1770, while they were cutting up a maſſy revetment of a part of the fortifications more than 300 years old. The mortar between the bricks was harder than the bricks (which were Dutch clinkers, ſuch as are now uſed only for the greateſt loads); but when mixed with water it made it lime-water, ſeemingly as ſtrrong as if freſh lime had been uſed. We obſerved the ſame thing in one ſmall part of a huge maſs of ancient Roman work near Romney in Kent; but the reſt, and all the *very old* mortar that we have ſeen, was in a mild ſtate, and was generally much harder than what produced any lime-water. Now when the mortar in the joints has begun its firſt cryſtallization, and is allowed to remain in perfect reſt, we are confident that the ſubſequent cryſtals, whether of lime, or of calcareous earth, or of gypſum, will be much larger and ſtronger than can ever be produced if they are once broken; and the farther that this cryſtallization has been carried, that is, the harder that the mortar has become, leſs of it remains to take any new cryſtallization. Why ſhould it be otherwiſe here than in every other cryſtallization that we are acquainted with?

28
Neceſſity of keeping the joints in their firſt ſtate.

We think therefore that it is of great conſequence to keep the joints in their *firſt* ſtate if poſſible; and that the ſtrength (as far as it depends on the mortar) is greatly diminiſhed by their opening; eſpecially when the mortar has acquired conſiderable hardneſs, which it will do in a month or ſix weeks, if it be good. The coheſion given by mortar is indeed a mere trifle, when oppoſed to a force which tends to open the joints, acting, as it generally does, with the tranſverſe force of a lever: but in ſituations where the overload on any particular archſtones tends to puſh them down through between their neighbours, like wedges, the coheſion of the mortar is then of very great conſequence.

We muſt make another obſervation. Mr Perronet's ingenious proceſs tended very effectually to cloſe the joints. It doing this, the forces which he brought into action had little to oppoſe them; but as ſoon as they were cloſed, the contact of the parts formerly open oppoſed an obſtruction incomparably greater, and immediately balanced a force which was but juſt able to turn the ſtone gently about the two edges in which it touched the adjoining ſtones. This is an important remark, though ſeemingly very trifling; and we wiſh the practitioner to have a very clear conception of it; but it would take a multitude of words to explain it. It is worth an experiment. Form a little arch of wooden blocks; and form one of theſe ſo, that when they are all reſting on the centering, it may be open at the outer joint—Remove the centering—Then preſs on the arch at ſome diſtance from the open joint.—You will find that a very ſmall preſſure will make the arch bend till that joint cloſes.—Preſs a little harder, and the arch will bend more, and the next joint will open.—Thus you will find that, by preſſing alternately on each ſide of the open joint, that ſtone can eaſily be made to flap over to either ſide; and that immediately after this is done the reſiſtance increaſes greatly. This ſhews clearly, that a very moderate force, judiciouſly employed, will cloſe the joints, but will not preſs the parts ſtrongly together. The joints therefore are *cloſed*, but *no more than cloſed*, and are hanging only by the edges by which they were hanging while the joints were open. The arch, therefore, though apparently cloſe and firm, is but looſe and tottering. Mr Perronet ſays, that his arches were firm, becauſe hardly a ſtone was obſerved to chip or ſplinter off at the edges by the ſettlement. But he had done every thing to prevent this, by digging out the mortar from between the headers, to the depth of two inches, with ſaws made on purpoſe. But we are well informed, that before the year 1791 (twenty years after the erection) the arches at Neuilly had ſunk very ſenſibly, and that very large ſplinters had flewn off in ſeveral places. It could not be otherwiſe. The original conſtruction was too bold; we may ſay needleſsly and oſtentatiouſly bold. A very gentle ſlope of the roadway, which would not have ſlackened the mad gallop of a ducal carriage, nor ſenſibly checked the laborious pull of a loaded waggon, and a proper difference in the ſize of the arches, would have made this wonderful bridge incomparably ſtronger and alſo much more elegant and pleaſing to the eye. Indeed, it is far from being as handſome as it might have been. The ellipſe is a moſt pleaſing figure to every beholder; but this is concealed as much as poſſible, and it is attempted to give the whole the appearance of a tremendous lintel. It has the oppreſſive look of danger. It will not be of long duration. The bridge at Mantz is ſtill more exceptionable, becauſe its piers are tall and ſlender. If any one of the arches fails, the reſt muſt fall in a moment. An arch of Blackfriars Bridge might be blown up without diſturbing its neighbours.

9
Mr Perronet's conſtructions too bold.

30
A bad method of ſtriking the centre.

Mr Perronet mentions another mode of ſtriking the centering, which he ſays is very uſual in France. Every ſecond bridging is cut out. Some time after, every ſecond of the remainder; after this, every ſecond of the remainder; and ſo on, till all are removed. This is never practiſed in this country, and is certainly a very bad method. It leaves the arch hanging by a number of diſtant points; and it is wonderful that any arch can bear this treatment.

31
The common method in Britain.

Our architects have generally proceeded with extreme caution. Wherever they could, they ſupported the centering by intermediate pillars, even when it was a truſſed centre, having a tie-beam reaching from ſide to ſide. The centre was made to reſt, not immediately on theſe pillars, but on pieces of timber formed like acute wedges, placed in pairs, one above the other, and having the point of the one on the thick end of the other. Theſe wedges were well ſoaped and rubbed with black lead, to make them ſlippery. When the centres are to be ſtruck, men are ſtationed at each pair of the wedges with heavy malls. They are directed to ſtrike together on the oppoſite wedges. By this operation, the whole centering deſcends together; or, when any part of the arch is obſerved to have opened its joints on the upper ſide, the wedges below that part are ſlackened. The framing may perhaps bend a little, and allow that part to ſubſide. If any part of the arch is obſerved to open its joints on the under ſide, the wedges below that part are allowed to ſtand after the reſt have been ſlackened. By this proceſs, the whole comes down gradually, and as ſlowly as we pleaſe, and the defects of every part of the arch may be attended to. Indeed the caution and moderation of our builders have commonly been ſuch, that few defects have been allowed to ſhew themſelves. We are but little acquainted with joints opening to the extent of two inches, and in ſuch a caſe would probably lift every ſtone of the arch again (b). We have not employed truſſed centerings ſo much perhaps as we ſhould have done; nor do we ſee their advantage (ſpeaking as mere builders) over centres ſupported all over, and unchangeable in their form. Such centres muſt bend a little, and require loading on the middle to keep them in ſhape. Their compreſſion and their elaſticity, are very troubleſome in the ſtriking of the centres in Mr Perronet's manner. The elaſticity is indeed of uſe when the centres are ſtruck in the way now deſcribed.

Theſe obſervations on the management of the internal movements of a great arch will enable the reader to appreciate all the merit of Mr Mylne's very ingenious conſtruction. We proceed therefore to complete our deſcription.

32 The excellence of Mr Mylne's method.

The gradual enlargement of the baſe of the piers of Blackfriars bridge enabled the architect to place a ſeries of five poſts *c*, *c*, *c*, *c*, *c*, one on each ſtap of the pier; the ingenious contexture of which made it like one ſolid block of ſtone (ſee Arch, *Supplement*). Theſe ſtruts were gradually more and more oblique, till the outer one formed an obtuſe angle with the loweſt ſide of the interior polygon of the truſs. On the top of theſe poſts was laid a ſloping SEAT or beam D of ſtout oak, the upper part of which was formed like a zig-zag ſcarfing. The poſts were not perpendicular to the under ſide of the ſeat. The angles next the pier were ſomewhat obtuſe. Short pieces of wood were placed between the heads of the poſts (but not mortiſed into them), to prevent them from ſlipping back. Each face of the ſcarf was covered with a thick and ſmooth plate of copper. The feet of the truſs were mortiſed into a ſimilar piece F, which may be called the SOLE of the truſs, having its lower ſide notched in the ſame manner with the upper ſide of D, and like it covered with copper. Between theſe two lay the STRIKING WEDGE E, the faces of which correſponded exactly with the ſlant faces of the ſeat and the ſole. The wedge was ſo placed, that the correſponding faces touched each other for about half of their length. A block of wood was put in at the broad end or baſe of this wedge, to keep it from ſlipping back during the laying the arch-ſtones. Its outer end E was bound with iron, and had an iron bolt ſeveral inches long driven into it. The head of this bolt was broad enough to cover the whole wood of the wedge within the iron ferule.

We preſume that the reader, by this time, foreſees the uſe of this wedge. It is to be driven in between the ſole and the ſeat (having firſt taken out the block at the baſe of the wedge). As it advances into the wider ſpaces, the whole truſs muſt deſcend, and be freed from the arch; but it will require prodigious blows to drive it back. Mr Mylne did not think ſo, founding his expectation on what he ſaw in the launching of great ſhips, which ſlide very eaſily on a ſlope of 10 or 12 degrees. He rather feared, that taking out the block behind would allow the wedge to be puſhed back at once, ſo that the deſcent of the truſs would be too rapid. However, to be certain of the operation, he had prepared an abundant force in a very ingenious manner. A heavy beam of oak, armed at the end with iron, was ſuſpended from two points of the centre like a battering ram, to be uſed in the ſame manner. Nothing could be more ſimple in its ſtructure, more powerful in its operation, or more eaſy in its management. Accordingly the ſucceſs was to his wiſh. The wedge did not ſlip back of itſelf; and very moderate blows of the ram drove it back with the greateſt eaſe. The whole operation was over in a very few minutes. The ſpectators had ſuſpected, that the ſpace allowed for the receſs of the wedge was not ſufficient for the ſettlement of the arch; but the architect truſted to the precautions he had taken in its conſtruction. The reader, by turning to the article Arch in this *Supplement*, will ſee that there was only the arch LY which could be expected to ſettle: accordingly, the receſs of the wedge was found to be much more than was neceſſary. However, had this not been the caſe, it was only neceſſary to take out the pieces between the poſts below the ſeat, and then to drive back the heads of the ſtruts; but this was not needed (we believe) in any of the arches. We are well aſſured that none of the arches ſunk an inch and a half. The great arch of 100 feet ſpan did not ſink one inch at the crown. It could hardly be perceived whether the arch quitted the centering gradually or not, ſo ſmall had been the changes of ſhape.

33 The great ſuperiority of the centering uſed by him.

We have no heſitation in ſaying, that (if we except ſome waſte of great timber by uncommon joggling) the whole of this performance is the moſt perfect of any that has come to our knowledge. We doubt not but that ſeveral have equalled it, or may have excelled it; but we do not know of them: and we think that the bringing forward ſuch performances is no leſs ſerviceable to the public, than it is honourable to the inventor. Nor do we ſuppoſe that any views of intereſt can be ſo powerful as to prevent an ingenious architect from communicating to the public ſuch honourable ſpecimens of his own talents. We ſhould be happy to communicate more of this kind; for we conſider it as a very important article of practical mechanics, and think that it is of conſequence to the nation that it ſhould be very generally underſtood. In every corner of the country bridges are to be built—we have everywhere good *maſons*, who are fully able to execute any practicable project, but too little acquainted with principle to invent, or to accommodate even what they know to local circumſtances, and are very apt to be duped by appearances of ingenuity, or miſled by erroneous notions of the ſtrains which are excited. We profeſs more ſcience, and

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(b) The writer of this article can only ſay, that, after much inquiry, he has no information of any arch being received from the builder as ſufficient that had ſuffered half the change of ſhape mentioned by Mr Perronet. The arch of Dublin bridge, built by an excellent, but a very private, maſon, Mr Steeven, is 105 feet wide, with only 22 feet of riſe. It was erected (but not on a truſſed centering) without changing one full inch in its elevation; and when the centering was removed, it ſunk only $1\frac{1}{4}$th inches, and about half an inch more when the parapets were added and the bridge completely finiſhed.

and to treat the ſubject with the aſſiſtance of accurate principles: But while we are certain that every circumſtance is ſuſceptible of the moſt accurate determination, we muſt acknowledge that we have by no means attained an accurate knowledge of all the ſtrains which are produced and excited in a frame of carpentry, which is ſettling and changing its ſhape, even though it be not very complicated; far leſs are we poſſeſſed of a clear view of what happens in a maſs of maſonry in ſimilar conditions. Therefore, though we ſpeak with the ſtrong belief of our being right, we ſpeak with a ſenſe of our fallibility, and with great deference to the judgment of eminent and experienced architects and engineers. We ſhould conſider their free and candid criticiſms as the higheſt favour; and we even ſolicit them, with aſſurances of thanks, and that we will take ſome opportunity, before the cloſe of this work, to acknowledge and correct our miſtakes. We even preſume to hope, that the liberal-minded artiſt will be pleaſed with this opportunity which we give him of increaſing the national ſtock of knowledge. Let mutual jealouſy and rivalſhip reign in the breaſts, and prompt the exertions, of our reſtleſs neighbours on the continent—let them think that the dignity of man conſiſts in perpetual warfare, in which every individual feels himſelf indebted only to himſelf, freed from all the ſweet ties of domeſtic partiality, of friendſhip, and of patriotic attachment. We hope that the hearts of Britons will long continue to be warmed and *fortified* by the thoughts of mutual aſſiſtance, mutual co-operation, mutual attachment, and a patriotic preference of their countrymen to all other men. While theſe ſentiments are regulated by unſhaken honeſty, by candour, and by Chriſtian charity, we ſhall be ſecured from the *errors* of partial attachments, and yet enjoy all the pleaſures of unſophiſticated nature. Families will ſtill be bound together by the affectionate ties of blood; and the whole frame of Britiſh ſociety will be in harmony with the bonds which connect the members of each family, by their endleſs croſſings and intermixings. In this ſtate, the ſtate of ſocial nature, the man of talents will not lock up all the fruits of his exertions in his own breaſt, but will feel a pleaſure in imparting them to a ſociety that is dear to him, and on which he depends for all his beſt enjoyments. Nothing will hold the good man back when this is in his power, but the virtuous uſe which he can make of his ſuperiority in the diſcharge of his own little circle of duties. This is all that is required of true patriotiſm; and it is not too much to be expected from Britons, who feel a pleaſure in viewing their country as the great ſchool of the arts, under the patronage of a ſovereign who has done more for their improvement than all the other princes of Europe, and who (we are well aſſured) is now meditating a plan which muſt be highly gratifying to every eminent profeſſor of the arts.

34
The ſubject of this article connected with the conſtruction of wooden bridges.

THE ſubject which we have been conſidering is very cloſely connected with the conſtruction of wooden bridges. Theſe are not always conſtructed on the ſole principles of equilibrium, by means of mutual abutment. They are ſtiff frames of carpentry, where, by a proper diſpoſition, beams are put into a ſtate of extenſion, as well as of compreſſion, ſo as to ſtand in place of ſolid bodies as big as the ſpaces which the beams encloſe; and thus we are enabled to couple two, three, or four of theſe together, and ſet them in abutment with each other like mighty arch-ſtones. We ſhall cloſe this article, therefore, with two or three ſpecimens of wooden bridges, diſpoſed in a ſeries of progreſſive compoſition, ſo as to ſerve as a ſort of introduction to the art in general, and furniſh a principle which will enable the intelligent and cautious artiſt to puſh it with confidence as far as it can go.

Plate XVII.

The general problem is this. Suppoſe that a bridge is to be thrown over the ſpace AB (fig. 9.), and that this is too wide for the ſtrength of the ſize of timber which is at our command; how may this beam AB be ſupported with ſufficient effect? There are but two ways in which the middle point C (where the greateſt ſtrain is) can be ſupported: 1. It may be ſuſpended by two ropes, iron rods, or wooden ties, DC, EC, made faſt to two firm points, D, E, above it; or it may reſt on the ridge of two rafters *d*C, *e*C, which reſt on two firm points *d*, *e*, below it 2. It may be ſupported by connecting it with a point ſo ſupported; and this connection may be formed, either by ſuſpending it from this point, or by a poſt reſting on it. Thus it may hang, by means of a rod or a king-poſt FC, from the ridge F of two rafters AF, BF; or it may reſt on the ſtrut C*f*, whoſe lower extremity *f* is carried by the ropes, rods, or wooden ties A*f*, B*f*.

Whichſoever of theſe methods we employ, it follows, from the principles of carpentry, that the ſupport given to the point C is ſo much the more powerful, as we make the angle DCE, or *d*C*e*, or the equivalent angles AFB, or A*f*B, more acute.

35
The uſual and ſimpleſt method of conſtructing ſuch bridges.

Each of theſe methods may be ſuppoſed equally ſtrong. Our choice will depend chiefly on the facility of finding the proper points of ſupport D, E, *d*, *e*; except in the ſecond caſe, where we require no fixed points but A and B. The ſimple forms of the firſt caſe require a great extent of figure. Very rarely can we ſuſpend it from points ſituated as D and E. It is even ſeldom that we have depth enough of bank to allow the ſupport of the rafters *d*C, *e*C; but we can always find room for the ſimple truſs AFB. This therefore is the moſt uſually practiſed.

In the conſtruction, we muſt follow the maxims and directions preſcribed in the article CARPENTRY of this volume, and the article ROOF of the *Encycl.* The beams FA, FB muſt be mortiſed into AB, in the firmeſt manner, and there ſecured with ſtraps and bolts; and the middle muſt hang by a ſtrap attached to the king-poſt FC, or to the iron rod that is uſed for a king-poſt. No mortiſing in the point C muſt be employed; it is unneceſſary, and it is hurtful, becauſe it weakens the beam, and becauſe it lodges water, and ſoon decays by rot. The beſt practice is not to ſuſpend the beam immediately by this ſtrap, but to let it reſt, as in fig. 10. on a beam C, which croſſes the bridge below, and has its other end ſupported in the ſame manner by the other truſs.

It is evident that the length of the king-poſt has no effect on the ſupport of C. We may therefore contract every thing, and preſerve the ſame ſtrength of ſupport, by finding two points *a* and *b* (fig. 11.) in the banks, at a moderate diſtance below A and B, and ſetting up the rafters *a*F, *b*F, and ſuſpending C from the ſhortened king-poſt. In this conſtruction, when the beam AB reſts on a croſs bearer, as is drawn here, the

ſtruts

ſtruts *a* F, *b* F are kept clear of it. No connection between them is neceſſary, and it may be hurtful, by inducing croſs ſtrains on both. It will, however, greatly increaſe the ſtiffneſs of the whole. This conſtruction may ſafely be loaded with ten times the weight that AB can carry alone.

36 An improvement of that method.

Suppoſe this done, and that the ſcantling of AB is too weak for carrying the weight which may be brought on the parts AC, CB. We may now truſs up each half, as in fig 12. and then the whole will form a handſome bridge, of the ſimpleſt conſtruction poſſible. The interſections of the ſecondary braces with thoſe of the main truſs will form a hand-rail of agreeable figure.

We are not confined to the employment of an entire piece AB, nor to a rectilineal form. We may frame the bridge as in fig. 13. and in this form we diſſuade from allowing any connection with the middle points of the main braces. This conſtruction alſo may be followed till each beam AC and CB is loaded to ten times what it can ſafely bear without the ſecondary truſſing.

37 Another method.

There is another way by which a bridge of one beam may be ſupported beyond the power of the firſt and ſimpleſt conſtruction. This is repreſented in fig. 14. and fig. 15. The truſs beam FG ſhould occupy one-third of AB. The advantage of this conſtruction is very conſiderable. The great elevation of the braces (which is a principal element of the ſtrength) is preſerved, and the braces are greatly ſhortened.

This method may be puſhed ſtill farther, as in fig. 16.

38 Theſe methods combined.

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

In all of them there is much room for the diſplay of ſkill, in the proper adjuſtment of the ſcantling of the timber, and the obliquity of the braces to the lengths of the different bearings. A very oblique ſtrut, or a ſlender one, will ſuffice for a ſmall load, and may often give an opportunity to increaſe the general ſtrength; while the great timbers and upright ſupports are reſerved for the main preſſures. Nothing will improve the compoſition ſo much as reflecting progreſſively. and in the order of theſe examples, on the whole. This alone can preſerve the great principle in its ſimplicity and full energy.

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

Theſe conſtructions are the elements of all that can be done in the art of building wooden bridges, and are to be found more or leſs obviouſly and diſtinctly in all attempts of this kind. We may aſſert, that the more obviouſly they appear, the more perfect the bridge will be. It is aſtoniſhing to what extent the principle may be carried. We have ſeen a bridge of 42 feet ſpan formed of two oak truſſes, the biggeſt timber of which did not exceed ſix inches ſquare, bearing with perfect ſteadineſs and ſafety a waggon loaded with more than two tons, drawn by four ſtout horſes. It was framed as fig. 16. nearly, with the addition of the dotted lines, and was near thirty years old; protected, however, from the weather by a wooden roof, as many bridges in Germany are.

We recollect another in the neighbourhood of Stettin, which ſeemed conſtructed with great judgment and ſpirit. It had a carrriage road in the middle about 20 feet (we think) wide, and on each ſide a foot-way about five feet wide. The ſpan was not leſs than 60 feet, and the greateſt ſcantling did not appear to exceed 10 inches by 6.

This bridge conſiſted of four truſſes, two of which formed the outſide of the bridge, and the other two made the ſeparation between the carriage road and the two foot ways. We noticed the conſtruction of the truſſes very particularly, and found it ſimilar to the laſt, except in the middle diviſion of the upper truſs, which, being very long, was double truſſed, as in fig. 17.

The reader will find in that volume of Leupold's *Theatrum Machinarum*, which he calls *Theatrum Pontificum*, many ſpecimens of wooden bridges, which are very frequent in the champain parts of Germany. They are not, in general, models of mechanic art; but the reflecting reader, who conſiders them *carefully*, will pick up here and there ſubordinate hints, which are ingenious, and may ſometimes be uſeful.

What we have now exhibited are not to be conſidered as models of conſtruction, but as elementary examples and leſſons, for leading the reader ſyſtematically into a thorough conception of the ſubject.

40 A wonderful bridge in Switzerland.

We cannot quit the ſubject without taking notice of a very wonderful bridge at Wittengen in Switzerland, ſlightly deſcribed by Mr Coxe (*Travels*, vol. I. 132.) It is of a conſtruction more ſimple ſtill than the bridges we have been deſcribing. The ſpan is 230 feet, and it riſes only 25. The ſketch (fig. 18.) will make it ſufficiently intelligible. ABC is one of two great arches, approaching to a catenarian ſhape, built up of ſeven courſes of ſolid logs of oak, in lengths of 12 or 14 feet, and 16 inches or more in thickneſs. Theſe are all picked of a natural ſhape, ſuited to the intended curve; ſo that the wood is nowhere cut acroſs the grain to trim it into ſhape. Theſe logs are laid above each other, ſo that their abutting joints are alternate, like thoſe of a brick wall; and it is indeed a wooden wall, ſimply built up, by laying the pieces upon each other, taking care to make the abutting joints as cloſe as poſſible. They are not faſtened together by pins or bolts, or by ſcarfings of any kind. They are, however, held together by iron ſtraps, which ſurround them, at the diſtance of five feet from each other, where they are faſtened by bolts and keys.

Theſe two arches having been erected (by the help, we preſume, of pillars, or a centering of ſome kind), and well butted againſt the rock on each ſide, were freed from their ſupports, and allowed to ſettle. They are ſo placed, that the intended road *a b c* interſects them about the middle of their height. The roadway is ſupported by croſs joiſts, which reſt on a long horizontal ſummer beam. This is connected with the arches on each ſide by uprights bolted into them. The whole is covered with a roof, which projects over the arches on each ſide to defend them from the weather. Three of the ſpaces between theſe uprights have ſtruts or braces, which give the upper work a ſort of truſſing in that part.

This conſtruction is ſimple and artleſs; and appears, by the attempt to truſs the ends, to be the performance of a perſon ignorant of principle, who has taken the whole notion from a ſtone arch. It is, however, of a ſtrength much more than adequate to any load that can be laid on it. Mr Coxe ſays, but does not explain how, that it is ſo contrived that any part of it can be repaired.

ed independent of the reſt. It was the laſt work of one Ulrich Grubenhamm of Tuffen, in the canton of Appenzel, a carpenter without education, but celebrated for ſeveral works of the ſame kind; particularly the bridge over the Rhine at Schafhauſen, conſiſting of two arches, one of 172 and the other of 193 feet ſpan, both reſting on a ſmall rock near the middle of the river.

While writing this article, we got an account of a wooden bridge, erected in North America, in which this ſimple notion of Grubenhamm's is mightily improved. The ſpan of the arch was ſaid to exceed 250 feet, and its riſe exceedingly ſmall. The deſcription we got is very general, but ſufficient, we think, to make it perfectly intelligible.

41 Another in North America.

In fig. 19. DD, EE, FF, are ſuppoſed to be three beams of the arch. They conſiſt of logs of timber of ſmall lengths, ſuppoſe of 10 or 12 feet, ſuch as can be found of a curvature ſuited to its place in the arch without trimming it acroſs the grain. Each beam is double, conſiſting of two logs applied to each other, ſide to ſide, and *breaking joint*, as the workmen term it. They are kept together by wedges and keys driven through them at ſhort intervals, as at K, L, &c.

The manner of joining and ſtrongly binding the two ſide pieces of each beam is ſhewn in fig. 20. The mortiſe *aicb* and *dcio*, which is cut in each half beam, is conſiderably longer on the outſide than on the inſide, where the two mortiſes meet. Two keys, BB and CC, are formed, each with a notch *bcd*, or *aio*, on its ſide; which notch fits one end of the mortiſe. The inner ſide of the key is ſtraight, but ſo formed, that when both keys are in their places, they leave a ſpace between them wider at one end than the other. A wedge AA, having the ſame taper as the ſpace juſt mentioned, is put into it and driven hard. It is evident that this muſt hold the two logs firmly together.

This is a way of uniting timber not mentioned in the article CARPENTRY; and it has ſome peculiarities worthy of notice. In the firſt place, it may be employed ſo as to produce a very ſtrong lateral connection, and would then co-operate finely with the other artificial methods of ſcarfing and tabling that we deſcribed in the article referred to. But it requires nice attention to ſome circumſtances of conſtruction to ſecure this effect. If the joints are accurately formed to each other, as if the whole had been one piece divided by an infinitely thin ſaw, this manner of joining will *keep* them all in their places. But no driving of the wedge AA will make them firmer, or cauſe one piece to preſs hard on the other. If the abutment of two parts of the half beam is already cloſe, it will remain ſo; but if open in the ſmalleſt degree, driving of the wedge will not make it tighter. In this reſpect, therefore, it is not ſo proper as the forms deſcribed in CARPENTRY.

In order that the method now deſcribed may have the effect of *drawing* the halves of the beams together, and of keeping them hard ſqueezed on each other, the joints muſt be made ſo as not to correſpond exactly. The prominent angle *aio* (fig. 21.), formed by the ends of the two half mortiſes, muſt be made a little more obtuſe than the angle *afo* of the notch of the key which this prominence is intended to fill up. Moreover, the oppoſite ſide *et* of this key ſhould not be quite ſtraight, but a very little convex. With theſe precautions, it is eaſy to ſee that, by driving the wedge AA, we cauſe the notch *afo* to take hold, firſt at the two points *a* and *o*, and then, by continuing to drive the wedge, the ſides *af*, *of*, of the notch gradually compreſs the wood of the half beams, and preſs them on each other. By continuing to drive the wedge, the mutual compreſſion of the key and the beam ſqueezes all together, and the ſpace *afoi* is completely filled up. We may ſee, from this proceſs, that the mutual compreſſion and drawing together of the timber will be greater in proportion as we make the angle *aio* more prominent, and its correſponding angle *afo* more deep; always taking care that the key ſhall be thick enough not to break in the narrow part.

This adjuſtment of the keys to the mortiſe is neceſſary on another account. Suppoſing the joints to fit each other exactly before driving the wedge, and that the whole ſhrinks a little by drying—by this the angle *aio* will become more prominent, and the angle *afo* will become more ſhallow; the joint will open at *a* and *o*, and the mutual compreſſure will be at an end.

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

Having ſhewn how each beam is pieced together, we muſt now ſhew how a number of them are united, ſo as to compoſe an arch of any thickneſs. This is done in the very ſame way. The beams have other mortiſes worked out of their inner ſides, half out of each half of the beam. The ends of the mortiſes are formed in the ſame way with thoſe already deſcribed. Long keys BB, CC, (fig. 19.) are made to fit them properly, the notches being placed ſo as to keep the beams at a proper diſtance from each other. It is now plain that driving in a long wedge AA will bind all together.

In this manner may an arch be extended to any ſpan, and made of any thickneſs of arching. The bridge over Portſmouth river in North America was more than 250 feet in length, and conſiſted of ſeveral parallel arches of beams. The inventor (we think that his name is Bludget) ſaid that he found the ſtrength ſo great, that he could with perfect confidence make one of four times the ſpan.

We admire the ingenuity of this conſtruction, and think it very effectual for bringing the timbers into firm and uniform abutment; but we imagine that it requires equilibration, becauſe it is extremely flexible. There is nothing to keep it from bending, by an inequality of load, but the tranſverſe ſtrength of the beams. The keys and wedges can have very little power to prevent this bending. The diſtance between the beams will alſo contribute little or nothing to the ſtiffneſs; nay, we imagine that a great diſtance between them will make the frame more flexible. Could the beams be placed ſo near each other that they could be ſomehow joggled on each other, the whole would be ſtiffer; but at preſent they will bend like the plates of a coach-ſpring. But nothing hinders us from adding diagonal pieces to this conſtruction, which will give it any degree of ſtiffneſs, and will enable it to bear any inequality of loading. When completed in this manner, we imagine that it will be at leaſt equal to any conſtruction that has yet been thought of. One advantage it poſſeſſes that is very precious: Any piece that fails may

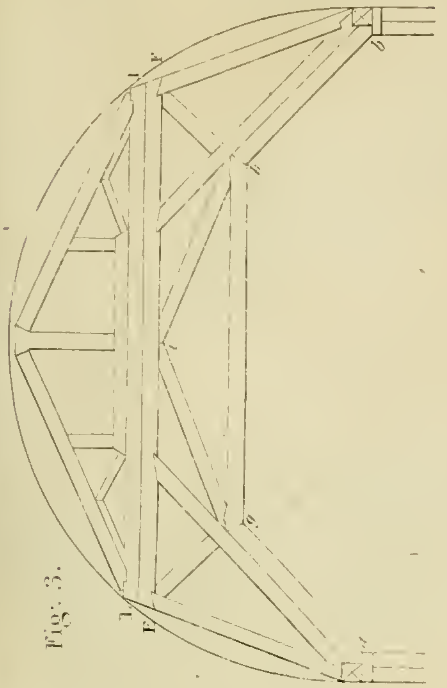


Fig. 3.

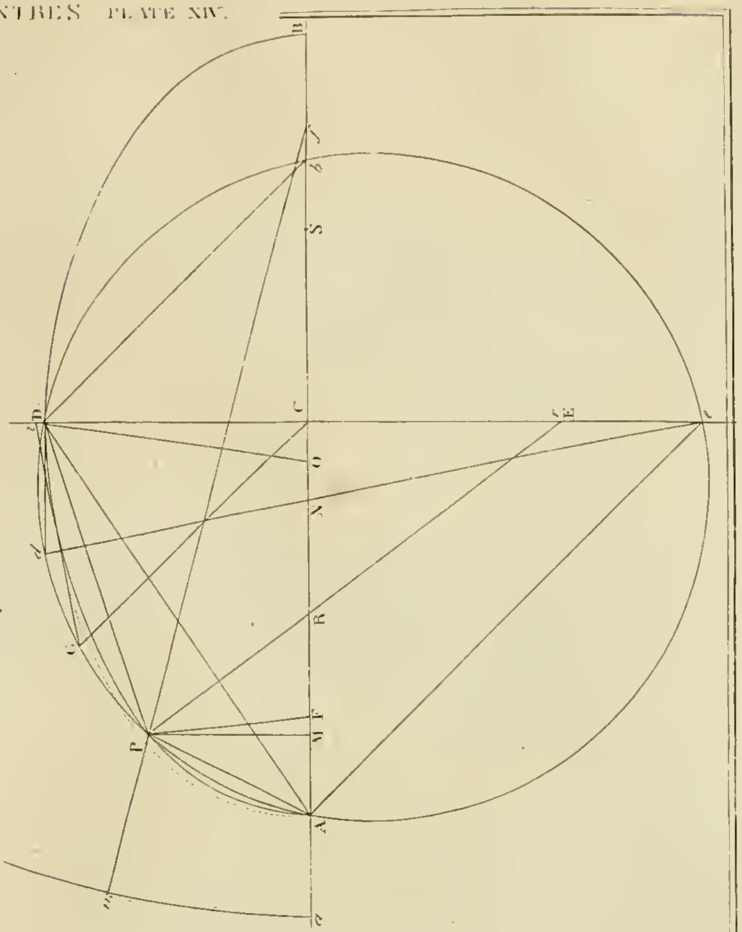


Fig. 2. N° 2.

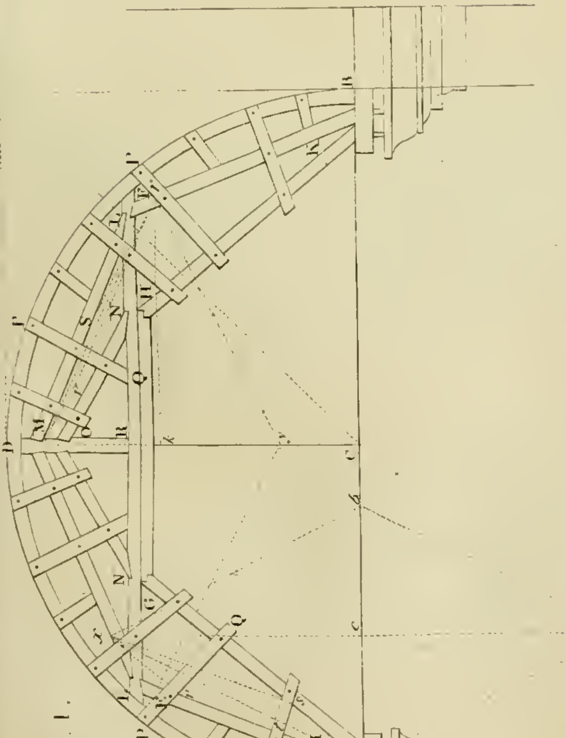


Fig. 1.

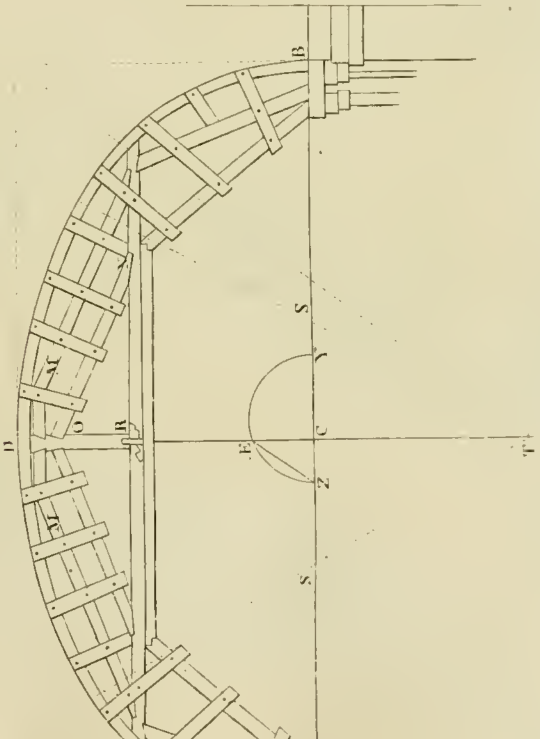


Fig. 2.

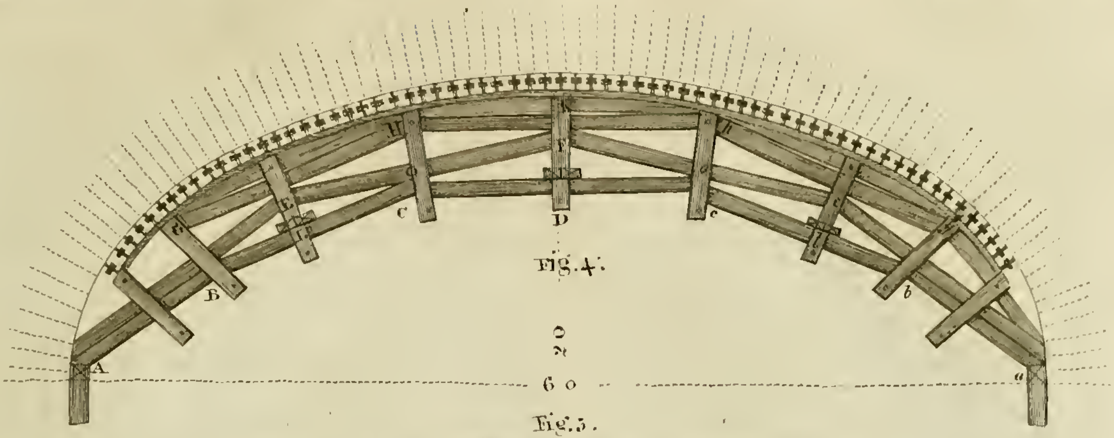


Fig. 4.

Fig. 5.

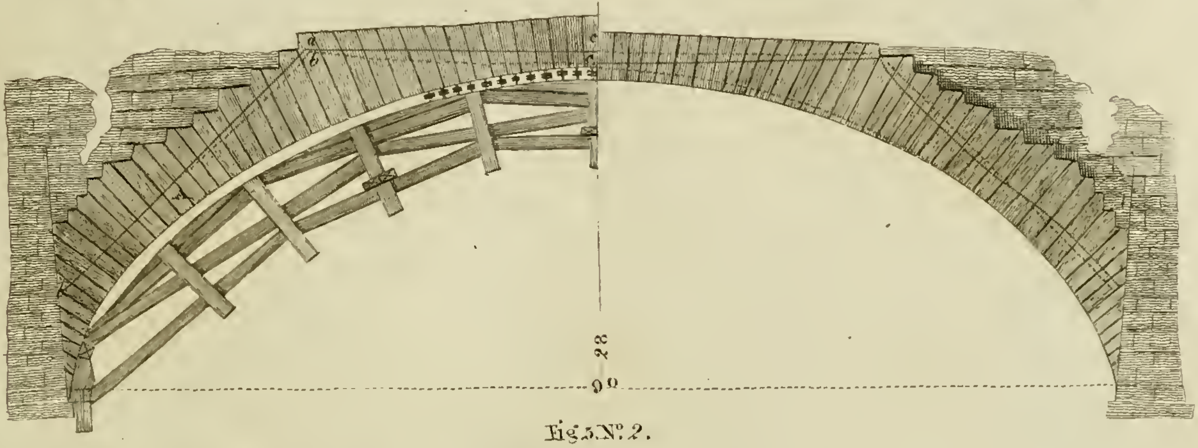


Fig. 5. No. 2.

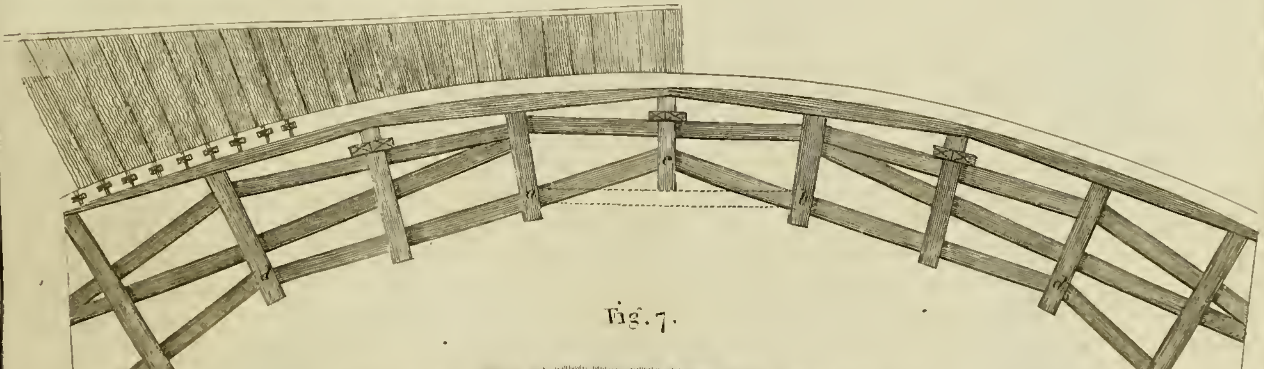
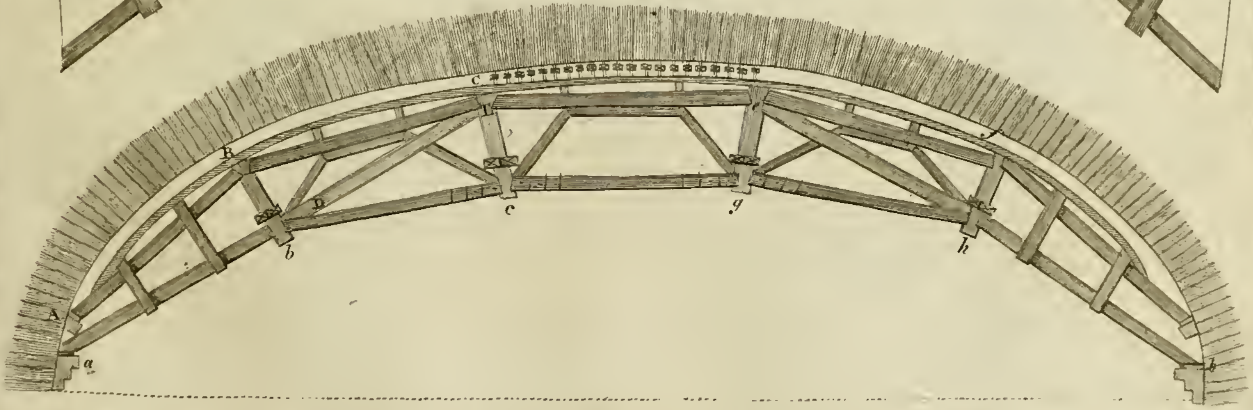
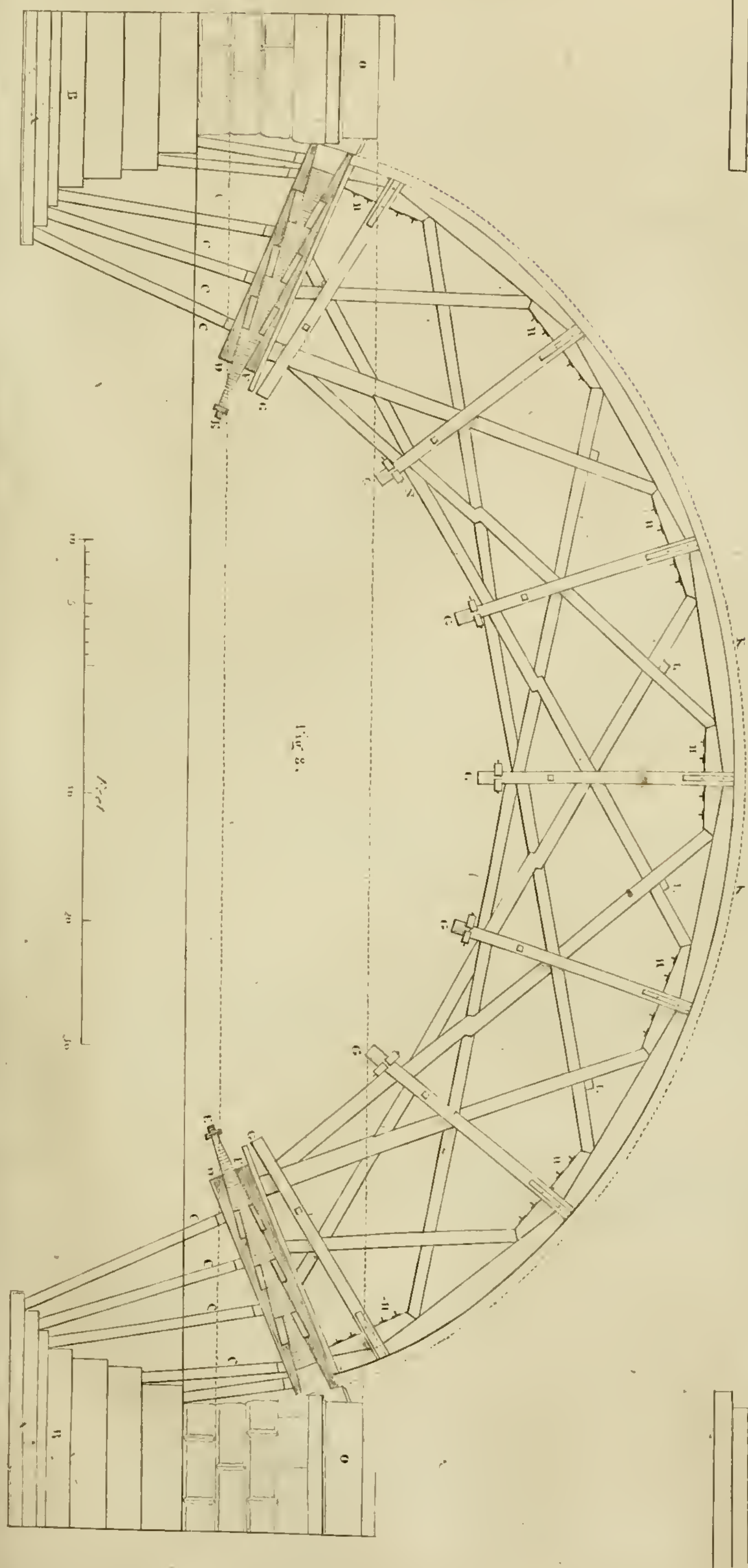


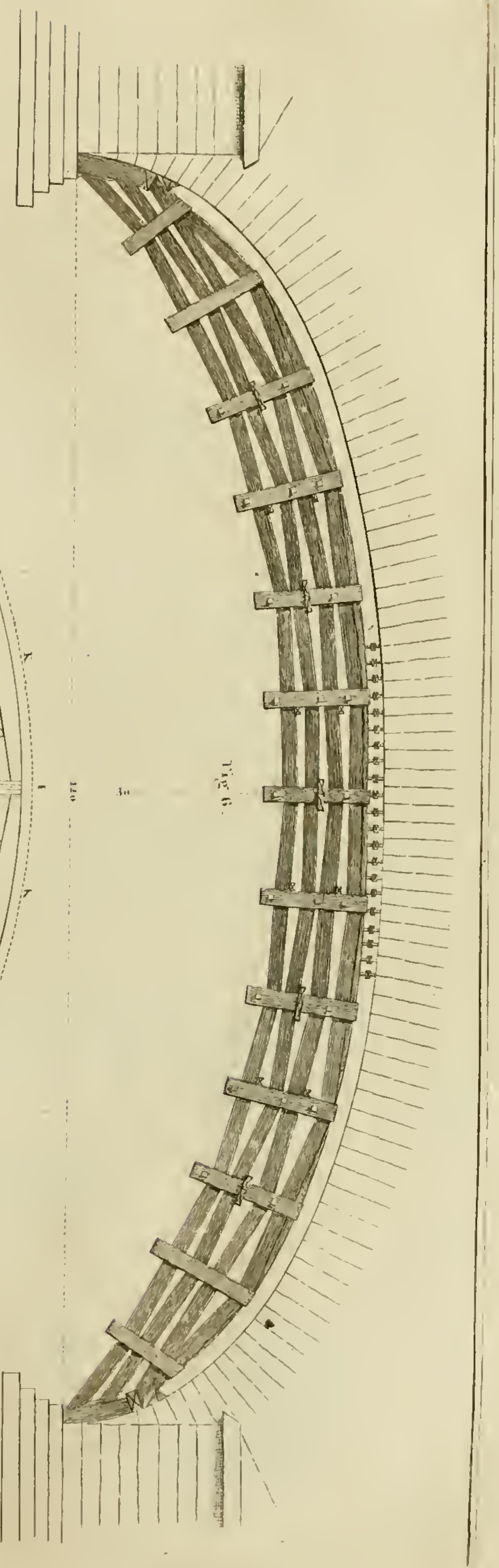
Fig. 7.



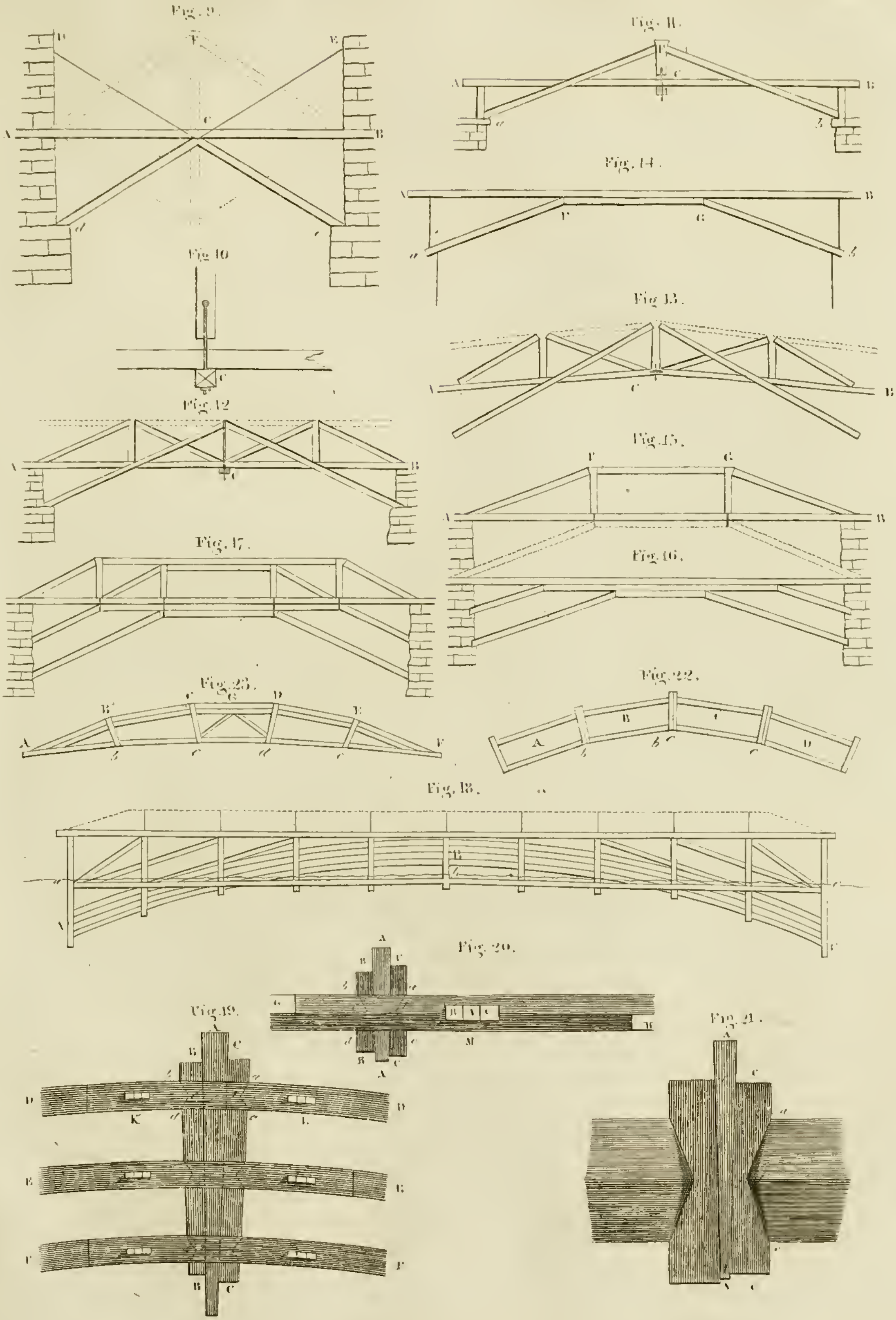
B. Evans Sculp.t

CENTRES PLATE XVI.





CENTRES PLATE XVII



[illegible] sculp.

may be taken out, and replaced by another, without diſturbing the reſt, and without the ſmalleſt riſk. On the whole, we think it a very valuable addition to Britiſh carpentry. The method here practiſed, both for joining the parts of one beam and for framing the different beams together, ſuggeſts the moſt firm and light conſtructions for dome-roofs that can be conceived; incomparably ſuperior to any that have yet been erected. The whole may be framed, without a nail or a ſpike, into one net-like ſhell that cannot even be pulled in pieces. We may perhaps conſider this in another article; at preſent we return to the conſideration of truſſed bridges.

42 Bridges combined by ſimple addition or by compoſition.

When the width of the river exceeds what is thought practicable by a ſingle truſs, we muſt then combine, either by ſimple addition, or by compoſition, different truſſes together. We compoſe a bridge by ſimple addition when we make a frame of carpentry of an unchangeable and proper ſhape, to ſerve as one of the archſtones of a bridge of maſonry. This may eaſily be comprehended by looking at fig. 22. Each of the frames A, B, C, D, muſt be conſidered as a ſeparate body, and all are ſupported by their mutual abutment. The nature of the thing is not changed, although we ſuppoſe that the rails of the frame B, inſtead of being mortiſed into an upright $b' b'$, unconnected with the frame C, is mortiſed into the upright $c c$ of that frame, the direction and intenſity of the mutual preſſures of the two frames are the ſame in both caſes; accordingly this is a very common form of ſmall wooden bridges. It is uſual, indeed, to put diagonal battens into each: but we believe that this is more frequently done to pleaſe the eye than to produce an unalterable ſhape of each frame.

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

To an unſkilful carpenter this bridge does not ſeem eſſentially different from the centering of Mr Hupeau for the bridge of Orleans; and indeed, in many caſes, it requires reflection, and ſometimes very minute reflection, to diſtinguiſh between a conſtruction which is only an addition of frame to frame till the width be covered, from a conſtruction where one frame works on the adjoining one tranſverſely, puſhing it in one part, and drawing it in another. The ready way for an unlettered artiſt to form a juſt notion of this point, is to examine whether he may ſaw through the connecting piece $b' b'$ from one end to the other, and make them two ſeparate frames. Whenever this cannot be done without that part opening, it is a conſtruction by compoſition. Some of the beams are on the ſtretch; and iron ſtraps, extending along both pieces, are neceſſary for ſecuring the joint. The bridge is no longer a piece of maſonry, but a performance of pure carpentry, depending on principles peculiar to that art. Equilibration is neceſſary in the firſt conſtruction; but, in the ſecond, any inequality of loading is made ineffectual for hurting the edifice, by means of the ſtretch that is made to operate on ſome other piece. We are of opinion, that this moſt ſimple employment of the diſtinguiſhing principle of carpentry, by which the beams are made to act as ties, will give the moſt perfect conſtruction of a wide bridge. One polygon alone ſhould contain the whole of the abutments; and one other polygon ſhould conſiſt entirely of ties; and the beams which form the radii, connecting the angles of the two polygons, complete the whole. By confining the attention to theſe two ſimple objects, the abutments of the outer polygon, and the joints of the inner one, may be formed in the moſt ſimple and efficient manner, without any collateral connections and dependencies, which divide the attention, increaſe the complication, and commonly produce unexpected and hurtful ſtrains. It was for this reaſon that we have ſo frequently recommended the centering of the bridge of Orleans. Its office will be completely performed by a truſs of the form of fig. 23.; where the polygon ABCDEF, conſiſting of two layers of beams (if one is not ſufficient), contains the whole abutments, and the other A$bcde$F is nothing but an iron rod. In this conſtruction, the obtuſeneſs of the angles of the lower polygon is rather an advantage. The braces Gc, Gd, which are wanted for truſſing the middle of the outer beams, will effectually ſecure the angles of the exterior polygon againſt all riſk of change. The reader muſt perceive that we have now terminated in the conſtruction of the Norman roof. We indeed think it the beſt general form, when ſome moderate declivity is not an inſuperable objection. When this is the caſe, we recommend the general plan of the centering of the bridge of Orleans. We would make the bridge (we ſpeak of a great bridge) conſiſt of four truſſes; two to ſerve as the outſides of the bridge, and two inner truſſes, ſeparating the carriage-way from the foot-paths. The road ſhould follow the courſe of the lower polygon, and the main truſs ſhould form the rails. It might look ſtrange; but we are here ſpeaking of ſtrength; and evident, but not unwieldy, ſtrength, once it becomes familiar, is the ſureſt ſource of beauty in all works of this kind.

44 The beſt general form of a wooden bridge.

Centre of Friction, is that point in the baſe of a body on which it revolves; into which, if the whole ſurface of the baſe, and the maſs of the body, were collected, and made to revolve about the centre of the baſe of the given body, the angular velocity deſtroyed by its friction would be equal to the angular velocity deſtroyed in the given body by its friction in the ſame time. See Friction in this Supplement.

Centre of Gyration, is that point in which, if the whole maſs be collected, the ſame angular velocity will be generated in the ſame time, by a given force acting at any place, as in the body or ſyſtem itſelf. This point differs from the centre of oſcillation, in as much as in this latter caſe the motion of the body is produced by the gravity of its own particles; but, in the caſe of the centre of gyration, the body is put in motion by ſome other force acting at one place only.

Centre of Oſcillation, is that point in the axis or line of ſuſpenſion of a vibrating body, or ſyſtem of bodies, in which, if the whole matter or weight be collected, the vibrations will ſtill be performed in the ſame time, and with the ſame angular velocity, as before. Hence, in a compound pendulum, its diſtance from the point of ſuſpenſion is equal to the length of a ſimple pendulum whoſe oſcillations are iſochronal with thoſe of the compound one.

Centre of Preſſure, of a fluid againſt a plane, is that point againſt which a force being applied equal and contrary to the whole preſſure, it will juſt ſuſtain it, ſo as that the body preſſed on will not incline to either ſide.—This is the ſame as the centre of percuſſion, ſuppoſing the axis of motion to be at the interſection of this plane with the ſurface of the fluid; and the centre of of preſſure upon a plane parallel to the horizon, or upon any plane where the preſſure is uniform, is the ſame as the centre of gravity of that plane.

CENTROBARICO, the ſame as centre of gravity.

CENTROBARIC **Method**, is a method of determining the quantity of a ſurface or ſolid, by means of the generating line or plane and its centre of gravity. The doctrine is chiefly compriſed in this theorem:

Every figure, whether ſuperficial or ſolid, generated by the motion of a line or plane, is equal to the product of the generating magnitude and the path of its centre of gravity, or the line which its centre of gravity deſcribes.

CERUSE, or **White-lead**, is a ſubſtance ſo much uſed in painting, and for other purpoſes, that numerous modes have been employed for the preparation of it. Of the moſt common of theſe, a ſufficient account has been given in the Encyclopædia (ſee **Ceruse**, and the ſame word **Chemistry**-*Index)*; but Lord Dundonald has diſcovered a more expeditious and facile method than any of them, which becomes the more uſeful, as the ſubſtance with which it is effected has been hitherto rejected by the chemical world as a *caput mortuum*.

His lordſhip directs common lead to be reduced to a calx, but not too fine, and to have a proportion of five-ſixth parts thereof, intimately mixed with muriat, or ſolution of potaſs. In this ſtate, he directs it to be frequently ſtirred, in order to have the new ſurfaces of the mixture expoſed to the carbonic acid of atmoſpheric air; as his lordſhip obſerves, that the effects of the carbonic acid on the alkali exiſting in the preſent ſtate of the mixture is eſſentially neceſſary, in order to effect the intended purpoſe. In this ſtate it is to be frequently ſprinkled with water, and, after the calx has been long enough immerſed with the muriat to be ſufficiently operated upon, the muriat is to be levigated by common water from the calx, and to be concentrated by evaporation, in order to be made uſe of at a future period with other calx. The calx is to be afterwards ground, levigated, and dried for uſe.

For this diſcovery, his lordſhip obtained a patent on the 18th of Auguſt 1797; and the ſucceſs which has attended the former patents of this ſcientific nobleman leads us to conclude, that the preſent diſcovery is entitled to the attention of the public.

CHAMBERS (Sir William), the celebrated architect, was deſcended of the ancient family of Chalmers in Scotland, barons of Tartas in France. His grandfather ſuffered conſiderably in his fortune by ſupplying Charles XII. of Sweden with money, &c. which that monarch repaid in baſe coin. Sir William's father reſided ſeveral years in Sweden to recover his claims; and there Sir William was born, and, at eighteen years of age, appointed ſupercargo to the Swediſh Eaſt India company. From a voyage which he made to China, he brought home the Aſiatic ſtyle of ornament, in tents, temples, moſques, and pagodas. Theſe ornaments (through the intereſt of Lord Bute) he was enabled to apply in the gardens at Kew. Patroniſed by the princeſs dowager and the king, Mr Chambers had much of the faſhionable buſineſs of the day. Under Burke's reform, he was appointed ſurveyor general of the board of works. Somerſet-houſe was worth to him at leaſt L. 2000 a-year. His *Chef d'œuvres* are his ſtaircaſes, particularly thoſe at Lord Beſborough's, Lord Gower's, and the Royal and Antiquarian Societies. The terrace behind Somerſet-houſe is a bold effort of conception. His deſigns for interior arrangements were excellent. His Treatiſe on Civil Architecture alone will immortalize his name. In private life, Sir William was hoſpitable, kind, and amiable. His ſon married Miſs Rodney; Mr Cotton, Mr Innis, and Mr Harward, married his beautiful daughters. Having been abſtemious in his youth, Sir William's conſtitution did not begin to break till he was ſeventy years of age. For the laſt three years, he was kept alive by wine and oxygenated air: and died on the 5th of March 1796. His celebrity will be laſting in the works which he has left; and as he was equally ſkilled in the theory and practice of the arts which he profeſſed, his precepts are as valuable as his works. At his death, he was fellow of the Royal and Antiquarian Societies, treaſurer of the Royal Academy, ſurveyor-general of the board of works, and knight of the Swediſh order of the Polar Star.

CHAMFER, or **Chamferet**, an ornament in architecture, conſiſting of half a ſcotia; being a kind of ſmall furrow or gutter on a column.

Universal CHARACTERS, could they be introduced, would contribute ſo much to the diffuſion of uſeful knowledge, that every attempt to make ſuch a ſcheme ſimple and practicable is at leaſt intitled to notice. Accordingly, in the *Encyclopædia Britannica*, under the word **Character**, a ſhort account is given of the principal plans of univerſal characters which had then fallen under our obſervation; but ſince that article was publiſhed, a new method of writing, by which the various nations of the earth may communicate their ſentiments to each other, has been propoſed by *Thomas Northmore*, Eſq; of Queen-ſtreet, Mayfair. It bears ſome reſemblance to that which we have given from the *Journal Literaire*, 1720, but it is not the ſame; and of the two, Mr Northmore's is perhaps the moſt ingenious. The ground-work of the ſuperſtructure differs not indeed from that of the journaliſt, being this in both, "That if the ſame numerical *figure* be made to repreſent the *ſame word* in the various languages upon earth, an univerſal character is immediately obtained." The only objection which the author or his friends ſaw to ſuch a plan, originates in the diverſity of idioms; but, as he truly obſerves, every ſchoolboy has this difficulty to encounter as often as he conſtrues Terence.

Such then was Mr Northmore's original plan: but he ſoon perceived that it was capable of conſiderable improvement; for, inſtead of uſing a figure for *every* word, it will be neceſſary to apply one only to every *uſeful* word; and we all know how few words are abſolutely neceſſary to the communication of our thoughts. Even theſe may be much abbreviated by the adoption of certain *uniform fixed* ſigns (not amounting to above 20), for the various caſes, numbers, genders, degrees of compariſon, of nouns, tenſes, and moods of verbs, &c. All words of negation, too, may be expreſſed by a prefixed ſign. A few inſtances will beſt explain the author's meaning.

Suppoſe the number 5 to repreſent the word *ſee*.
6 — — *a man*,
7 — — *happy*,
8 — — *never*,
9 — — *I*.

" I would then (ſays he) expreſs the tenſes, genders, caſes, &c. *in all languages*, in ſome ſuch *uniform* manner as following:

(1) 5 = *preſent tenſe,* — ſee,
(2) $.5$ = *perfect tenſe,* — ſaw,
(3) $:5$ = *perfect participle,* — ſeen,
(4) $5:$ = *preſent participle,* — ſeeing,
(5) $5\cdot$ = *future,* — — will ſee,
(6) $\underline{5}$ = *ſubſtantive,* — ſight,
(7) $\underline{\underline{5}}$ = *perſonal ſubſtantive,* — ſpectator,
(8) 6 = *nominative caſe,* — a man,
(9) $\ddot{6}$ = *genitive,* — — of a man,
(10) $\dddot{6}$ = *dative,* — — to a man,
(11) $\overset{\frown}{6}$ = *feminine,* — — a woman,
(12) $+6$ = *plural,* — — men,
(13) 7 = *poſitive,* — — happy,
(14) $\hat{7}$ = *comparative,* — happier,
(15) $\overset{\wedge\wedge}{7}$ = *ſuperlative,* — happieſt,
$\underline{7}$ = as above, No. 6. — happineſs,
(16) -7 = *negation,* — — unhappy.

" From the above ſpecimen, I ſhould find no difficulty in comprehending the following ſentence, though it were written in the language of the Hottentots:

$9,\ 8,\ .5,\ -\hat{7},\ \overset{\frown}{6}.$ *I never ſaw a more unhappy woman.*

" Thoſe languages which do not uſe the pronoun prefixed to the verb, as the Greek and Roman, &c. may apply it, in a ſmall character, ſimply to denominate the perſon; thus, inſtead of 9, 8, .5, *I never ſaw;* they may write, $8,\ {}_{9}.5$, which will ſignify that the verb is in the firſt perſon, and will ſtill have the ſame meaning."

Our author ſeems confident that, according to this ſcheme of an univerſal character, about 20 ſigns, and leſs than 10,000 *choſen* words (ſynonyms being ſet aſide), would anſwer all the ends propoſed; and that foreigners, by referring to their numerical dictionary, would eaſily comprehend each other. He proceeds next to ſhew how appropriate ſounds may be given to his ſigns, and an univerſal *living language* formed from the univerſal *characters.*

To attain this end, he propoſes to diſtinguiſh the ten numerals by ten monoſyllabic names of eaſy pronunciation, and ſuch as may run without difficulty into one another. To illuſtrate his ſcheme, however, he calls them, for the preſent, by their common Engliſh names; but would pronounce each number made uſe of by uttering ſeparately its component parts, after the manner of accountants. Thus let the number 6943 repreſent the word *horſe*, he would not, in the univerſal language, call a horſe *ſix thouſand nine hundred and forty-three*, but *ſix, nine, four, three*, and ſo on for all the words of a ſentence, making the proper ſtop at the end of each. In the ſame manner, a diſtinct appellation muſt be appropriated to each of the prefixed ſigns, to be pronounced immediately after the numeral to which it is an appendage. Thus if *plu* be the appellation or the ſign of the plural number, *ſix, nine, four, three, plu* will be *horſes*.

" Thus (ſays our author), I hope it is evident that about 30 or 40 diſtinct ſyllables are ſufficient for the above purpoſe; but I am much miſtaken if *eleven* only will not anſwer the ſame end. This is to be done by ſubſtituting the firſt 20 or 30 numerals for the ſigns, and ſaying, as in algebra, that a term is in the power of ſuch a number, which may be expreſſed by the ſimple word *under.* *Ex. gr.* Let 6943 repreſent the word *horſe;* and ſuppoſe four to be the ſign of the plural number, I would write the word thus, $\overset{4}{\overline{6943}}$; and pronounce it, ſix, nine, four, three, in the power of or *under* four. By theſe means eleven diſtinct appellations would be ſufficient, and time and uſe would much abbreviate the pronunciation."

To refuſe the praiſe of ingenuity to this contrivance for an univerſal language would be very unjuſt; but elocution in this manner would be ſo very tedious, that ſurely the author himſelf, when he thinks more coolly on the ſubject, will perceive, that in the living ſpeech its defects would more than balance its advantages. A *pangraph*, as he calls his univerſal character, would indeed be uſeful, and is certainly practicable; a *panleg* (if we may form ſuch a word) would not be very uſeful, unleſs it were much more perfect than it could be made according to the plan before us.

CHAUSETRAPPES. See *Crow's Feet*, Encycl.

CHEMIN des Ronds, in fortification, the way of the rounds, or a ſpace between the rampart and the low parapet under it, for the rounds to go about it.

CHEMISTRY,

1 Definition. IS a ſcience, the object of which is to aſcertain the ingredients that enter into the compoſition of bodies, to examine the nature of theſe ingredients, the manner in which they combine, and the properties reſulting from their combination.

As an art, it has been in ſome meaſure coeval with the human race; for many of the moſt important branches of manufactures could not have been conducted without at leaſt ſome knowledge of chemical combinations. As a ſcience, it can hardly be dated farther back than the middle of the 17th century; but ſince that time it has advanced with a rapidity altogether unprecedented in the annals of philoſophy. Newton laid its foundation; and ſince his days an almoſt incredible number of the moſt diſtinguiſhed names in Europe have enliſted under its banners. So rapid has this progreſs been, that though the article CHEMISTRY in the *Encyclopædia Britannica* was written only about ten years ago, the language and reaſoning of chemiſtry have been ſo greatly improved, and the number of facts have accumulated ſo much, that we find ourſelves under the neceſſity of tracing over again the very elements of the ſcience.

2 Importance of chemiſtry. Indeed, if we conſider the importance of chemiſtry, we ſhall not be ſo much ſurpriſed at the ardour with which it has been cultivated. As a ſcience, it is intimately connected with all the phenomena of nature; the cauſes of rain, ſnow, hail, dew, wind, earthquakes: even the changes of the ſeaſons can never be explored with any chance of ſucceſs while we are ignorant of chemiſtry; and the vegetation of plants, and ſome of the moſt important functions of animals, have received all their illuſtration from the ſame ſource. No ſtudy can give us more exalted ideas of the wiſdom and goodneſs of the Great Firſt Cauſe than this, which ſhews us everywhere the moſt aſtoniſhing effects produced by the moſt ſimple though adequate means, and diſplays to our view the great care which has everywhere been taken to ſecure the comfort and happineſs of every living creature. As an art, it is intimately connected with all our manufactures: The glaſs-blower, the potter, the ſmith, and every other worker in metals, the tanner, the ſoap-maker, the dyer, the bleacher, are really practical chemiſts; and the moſt eſſential improvements have been introduced into all theſe arts by the progreſs which chemiſtry has made as a ſcience. Agriculture can only be improved rationally and certainly by calling in the aſſiſtance of chemiſtry; and the advantages which medicine has derived from the ſame ſource are too obvious to be pointed out.

3 Arrangement. It is evident from the definition of chemiſtry that it muſt conſiſt in a hiſtory of the ſimple ſubſtances which enter into the compoſition of bodies, in an inveſtigation of the manner in which theſe ſubſtances combine, and in a deſcription of the properties of the compounds which they form. And this is the arrangement which we mean to purſue; reſerving to ourſelves, however, the liberty of deviating a little from it, whenever it may appear neceſſary for the ſake of perſpicuity. All our claſſifications are in fact artificial; nature does not know them, and will not ſubmit to them. They are uſeful, however, as they enable us to learn a ſcience ſooner, and to remember it better; but if we mean to derive theſe advantages from them, we muſt renounce a rigid adherence to arbitrary definitions, which nature diſclaims.

We ſhall begin by an account of the ſimpleſt bodies, and proceed gradually to thoſe which are more compound. By *ſimple bodies*, we do not mean what the ancient philoſophers called the *elements of bodies*, but merely ſubſtances which have not yet been decompounded. Very poſſibly the bodies which we reckon ſimple may be real compounds; but till this has actually been proved, we have no right to ſuppoſe it. Were we acquainted with all the elements of bodies, and with all the combinations of which theſe elements are capable, the ſcience of chemiſtry would be as perfect as poſſible; but at preſent this is very far from being the caſe.

We ſhall divide this article into four parts. The *firſt* part ſhall treat of thoſe bodies which are at preſent conſidered as ſimple; the *ſecond*, of thoſe bodies which are formed by the union of two ſimple bodies, and which, for want of a better word we ſhall call *compound bodies*; the *third*, of thoſe bodies which are formed by the union of two compound bodies; and the *fourth*, of bodies ſuch as they are preſented to us by nature in the mineral, vegetable, and animal kingdoms.

PART I. OF SIMPLE BODIES.

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

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

Theſe ſhall form the ſubjects of the ſix following chapters.

CHAP. I. *Of* OXYGEN.

Plate XVIII. 5 Method of procuring oxygen. TAKE a quantity of nitre, or ſaltpetre, as it is alſo called, and put it into a gun-barrel A (fig. 1.), the touch-hole of which has been previouſly cloſed up with metal. This barrel is to be bent in ſuch a manner, that while the cloſe end, in which the nitre lies, is put into the fire E, the open end may be plunged below the ſurface of the water, with which the veſſel B is filled. At the ſame time, the glaſs jar D, previouſly filled with water, is placed on the ſupport C, lying at the bottom of the veſſel of water B, ſo as to be exactly over the open end of the gun-barrel A. As ſoon as the nitre becomes hot, it emits a quantity of air, which iſſuing from the end of the gun-barrel, aſcends to the top of the glaſs jar D, and gradually diſplaces all the water. The glaſs jar D then appears to be empty, but is in fact filled with air. It may then be removed in the following manner: Slide it away a little from the gun-barrel and the ſupport, and then dipping any flat diſh into the water below it, raiſe it on it, and bear it away. The diſh muſt be allowed to retain a quantity of water in it, (ſee fig. 2.) Another jar may then be filled with air in the ſame manner; and this proceſs may be continued either till the nitre ceaſes to give out air, or till as many jarfuls have been obtained as are required. This method of obtaining and confining air was firſt invented by Dr Mayow, and afterwards much improved by Dr Hales. All the airs obtained by this or any other proceſs, or, to ſpeak more properly, all the airs differing from the air of the atmoſphere, have, in order to diſtinguiſh them from it, been called *gaſes*, and this name we ſhall afterwards employ.

6
Diſcovered by Prieſtley and Scheele.

The gas which we have obtained by the above proceſs was diſcovered by Dr Prieſtley on the 1ſt of Auguſt 1774, and called by him *dephlogiſticated air*. Mr Scheele of Sweden diſcovered it in 1775, without any previous knowledge of what Dr Prieſtley had done: he gave it the name of *empyreal air*. Condorcet, ſo conſpicuous during the French revolution, gave it firſt the name of *vital air*; and Mr Lavoiſier afterwards called it *oxygen gas*; a name which is now generally received, and which we ſhall adopt.

Oxygen gas may be obtained likewiſe by the following proceſs:

7
Another method.

D (in fig. 3.) repreſents a wooden trough, the inſide of which is lined with lead or tinned copper. AB is a ſhelf running along the inſide of it, about three inches from the top. C is the cavity of the trough, which ought to be a foot deep. It is to be filled with water at leaſt an inch above the ſhelf AB. In the body of the trough, which may be called the ciſtern, the jars deſtined to hold gas are to be filled with water, and then to be lifted, and placed inverted upon the ſhelf at B, with their edges a little over it. This trough, which was invented by Dr Prieſtley, has been called by the French chemiſts the *pneumato-chemical*, or ſimply *pneumatic* apparatus, and is extremely uſeful in all experiments in which gaſes are concerned. Into the glaſs veſſel E put a quantity of the black oxide (A) of manganeſe in powder, and pour over it as much of that liquid which in commerce is called *oil of vitriol*, and in chemiſtry *ſulphuric acid*, as will ſomewhat more than cover it. Then inſert into the mouth of the veſſel the glaſs tube F, ſo cloſely that no air can eſcape except through the tube. This may be done by covering the joining with a paſte made of wheat-flour and water, or any other *lute*, as ſubſtances uſed for ſimilar purpoſes are called. The end of the tube C is then to be plunged into the pneumatic apparatus D, and the jar G, previouſly filled with water, to be placed over it on the ſhelf. The whole apparatus being fixed in that ſituation, the glaſs veſſel E is to be heated by means of a lamp or a candle. A great quantity of oxygen gas ruſhes along the tub F, and fills the jar G. As ſoon as the jar is filled, it may be ſlid to another part of the ſhelf, and other jars ſubſtituted in its place, till as much gas has been obtained as is wanted.

8
Properties of oxygen.

1. Oxygen gas is colourleſs, and inviſible like common air. Like it too, it is elaſtic, and capable of indefinite expanſion and compreſſion.

9
Supports flame,

2. If a lighted taper be let down into a jar of oxgen gas, it burns with ſuch ſplendor that the eye can ſcarcely bear the glare of light, and at the ſame time time produces a much greater heat than when burning in common air. It is well known that a candle put into a well cloſed jar, filled with common air, is extinguiſhed in a few ſeconds. This is the caſe alſo with a candle encloſed in oxygen gas; but it burns much longer in an equal quantity of that gas than of common air.

10
And life.

3. It was proved long ago by Boyle, that animals cannot live without air, and by Mayow that they cannot breathe the ſame air for any length of time without ſuffocation. Dr Prieſtley and ſeveral other philoſophers have ſhewn us, that animals live much longer in the ſame quantity of oxygen gas than of common air. Count Morozzo placed a number of ſparrows, one after another, in a glaſs bell filled with common air, and inverted over water.

	H.	M.
The firſt ſparrow lived - -	3.	0
The ſecond - - - -	0	3
The third - - - -	0	1

He filled the ſame glaſs with oxygen gas, and repeated the experiment.

	H.	M.
The firſt ſparrow lived - -	5	23
The ſecond - - - -	2	10
The third - - - -	1	30
The fourth - - - -	1	10
The fifth - - - -	0	30
The ſixth - - - -	0	47
The ſeventh - - - -	0	27
The eighth - - - -	0	30
The ninth - - - -	0	22
The tenth - - - -	0	21

He then put in two together; the one died in 20 minutes, but the other lived an hour longer.

11
Exiſts in the atmoſphere.

4. Atmoſpherical air contains about 27 parts in the hundred of oxygen gas. This was firſt diſcovered by Scheele. It has been proved by a great number of experiments, that no ſubſtance will burn in common air previouſly deprived of all the oxygen gas which it contained; but combuſtibles burn with great ſplendor in oxygen gas, or in other gaſes to which oxygen gas has been added. Oxygen gas then is abſolutely neceſſary for combuſtion.

5. It has been proved alſo, by many experiments, that no breathing animal can live for a moment in any air or gas which does not contain oxygen mixed with it. Oxygen gas then is abſolutely neceſſary for reſpiration.

6. When ſubſtances are burnt in oxygen gas, or in any other gas containing oxygen, if the air be examined after the combuſtion, a great part of the oxygen will be found to have diſappeared. If charcoal, for inſtance, be burnt in oxygen gas, there will be found, inſtead of part of the oxygen, another very different gas, known by the name of carbonic acid gas. Exactly the ſame thing takes place when air is reſpired by animals; part of the oxygen gas diſappears, and its place is occupied by ſubſtances poſſeſſed of very different properties. Oxygen

gas

(A) This ſubſtance ſhall be afterwards deſcribed. It is now very well known in Britain, as it is in common uſe with bleachers and ſeveral other manufacturers.

gas then undergoes ſome change during combuſtion, as well as the bodies which have been burnt; and the ſame obſervation applies alſo to reſpiration (B).

12 Its ſpecific gravity.

* On *Phlogiſton*, ſect. i.

7. The ſpecific gravity of oxygen gas, as determined by Mr Kirwan *, is 0,00135, that of water being 1,0000, as is always the caſe when ſpecific gravity is mentioned abſolutely. It is therefore 740 times lighter than the ſame bulk of water. Its weight to atmoſpherical air is as 1103 to 1000: 116 cubic inches of oxygen gas weigh 39,03 grains troy, 116 cubic inches of common air, 35,38 grains.

13 *Affinity* explained.

8. Oxygen is capable of combining with a great number of bodies, and forming compounds. As the combination of bodies is of the utmoſt importance in chemiſtry, before proceeding farther we ſhall attempt to explain it. When common ſalt is thrown into a veſſel of pure water, it melts, and very ſoon ſpreads itſelf through the whole of the liquid, as any one may convince himſelf by the taſte. In this caſe the ſalt is combined with the water, and cannot afterwards be ſeparated by filtration or any other method merely mechanical. It may, however, by a very ſimple proceſs: Pour into the ſolution a quantity of ſpirit of wine, and the whole of the ſalt inſtantly falls to the bottom.

Why did the ſalt diſſolve in water, and why did it fall to the bottom on pouring in ſpirit of wine? Theſe queſtions were firſt anſwered by Sir Iſaac Newton. There is a certain attraction between the particles of common ſalt and thoſe of water, which cauſes them to unite together whenever they are preſented to one another. There is an attraction alſo between the particles of water and of ſpirit of wine, which equally diſpoſes them to unite, and this attraction is greater than that between the water and ſalt; the water therefore leaves the ſalt to unite with the ſpirit of wine, and the ſalt being now unſupported, falls to the ground by its gravity. This power, which diſpoſes the particles of different bodies to unite, was called by Newton *attraction*, by Bergman, *elective attraction*, and by many of the German and French chemiſts, *affinity*; and this laſt term we ſhall employ, becauſe the other two are rather general. All ſubſtances which are capable of combining together are ſaid to have an *affinity for* (C) each other: thoſe ſubſtances, on the contrary, which do not unite, are ſaid to have *no affinity* for each other. Thus there is no affinity between water and oil. It appears from the inſtance of the common ſalt and ſpirit of wine, that ſubſtances differ in the degree of their affinity for other ſubſtances, ſince the ſpirit of wine diſplaced the ſalt and united with the water. Spirit of wine therefore has a ſtronger affinity for water than common ſalt has.

In 1719 Geoffroi invented a method of repreſenting the different degrees of affinities in tables, which he called *tables of affinity*. His method conſiſted in placing the ſubſtances whoſe affinities were to be aſcertained at the top of a column, and the ſubſtances with which it united below it, each in the order of its affinity; the ſubſtance which had the ſtrongeſt affinity next it, and that which had the weakeſt fartheſt diſtant, and ſo of the reſt. According to this method, the affinity of water for ſpirit of wine and common ſalt would be marked as follows:

WATER,

Spirit of wine,
Common ſalt.

This method has been univerſally adopted, and has contributed very much to the rapid progreſs of chemiſtry.

14 Affinities of oxygen.

We ſhall proceed therefore to give a table of the affinities of oxygen.

OXYGEN,

Carbon,
Zinc,
Iron,
Mangeneſe,
Hydrogen,
Azot,
Sulphur,
Phoſphorus,
Cobalt,
Nickel,
Lead,
Tin,
Phoſphorous acid,
Copper,
Biſmuth,
Antimony,
Mercury,
Silver,
Arſenic,
Sulphurous acid,
Oil,
Nitrous gas,
Gold,
White oxide of arſenic,
Muriatic acid,
Oxide of tin,

White

(B) Mayow had in the laſt century made conſiderable progreſs towards the diſcovery of oxygen gas. He knew that only a part of the air ſupported combuſtion: This part he called *particulæ igneo-aereæ*. He knew that this part was contained in nitre: "Pars nitri aerea nihil aliud quam particulæ ejus igneo-aereæ eſt." He adds, "At non eſt eſtimandum pabulum igneo-aereum ipſum aerem eſſe, ſed tantum partem ejus majus activam ſubtilemque. Quippe lucerna vitro incluſa expirat cum tamen copia aeris ſatis ampla in eodem continetur." He knew alſo that it was this part of the air which was uſeful in reſpiration. After mentioning ſeveral experiments to prove this, he adds, "Ex dictis certo conſtat animalia reſpirando particulas quaſdam vitales eaſque elaſticas ab aere haurire." See his *Tractatus quinque Medico-Phyſici*, p. 12. and 106.—He knew alſo that this part of the air was neceſſary to combuſtion: "Et tamen certo conſtat, particulas nitro-aereas non minus quam ſulphureas ad ignem conflandum neceſſareas eſſe." *Ibid*, p. 26.

(C) We are not certain that the phraſe *affinity for* is warranted by claſſical authority; we have ventured, however, to uſe it, becauſe, as the word *affinity* in this article ſignifies a ſpecies of attraction, we thought it would be more perſpicuous to put after it the prepoſition *for*, which uſually follows the word *attraction*, than *to* or *with*, which come after *affinity* when uſed in its ordinary acceptation.

White oxide of lead?
Nitrous acid,
White oxide of manganeſe,
Water.

The reaſon of this order will appear when we treat of theſe various ſubſtances.

Chap. II. *Of* Simple Combustible Bodies.

15
Five ſimple combuſtibles.

By *combuſtibles*, we mean ſubſtances capable of combuſtion; and by *ſimple combuſtibles*, bodies of that nature which have not yet been decompounded. Theſe are only five in number, Sulphur, Phosphorus, Carbon, Hydrogen, and Azot. Were we to adhere ſtrictly to our definition indeed, we ſhould add all the metals; for they are alſo combuſtible, and have not yet been decompounded: But for the reaſons formerly given, we ſhall venture to deviate a little from ſtrict logic, and conſider them afterwards as a diſtinct claſs of ſubſtances.

Sect. I. *Of Sulphur.*

Sulphur, diſtinguiſhed alſo in Engliſh by the name of *brimſtone*, was known in the earlieſt ages. As it is found native in many parts of the world, it could not fail very ſoon to attract the attention of mankind. It was uſed by the ancients in medicine, and its fumes were employed in bleaching wool*.

* *Pliny.* lib. xxxv. c. 15.

16
Properties of ſulphur.

Sulphur is a hard brittle ſubſtance, commonly of a yellow colour, without any ſmell, and of a weak though perceptible taſte.

It is a non-conductor of electricity, and of courſe becomes electric by friction.

If a conſiderable piece of ſulphur be expoſed to a ſudden though gentle heat, by holding it in the hand, for inſtance, it breaks to pieces with a crackling noiſe†.

† *Fourcroy.*

Its ſpecific gravity is 1,990.

When heated to the temperature of 185° of Fahrenheit, it melts and becomes very fluid. If the temperature be ſtill farther increaſed, the fluidity diminiſhes; but when the ſulphur is then carried from the fire and allowed to cool, it becomes as fluid as ever before it congeals‡.

‡ *Dr Black.*

17
Flowers of ſulphur.

When ſulphur is heated to the temperature of 170°, it riſes up in the form of a fine powder, which may be eaſily collected in a proper veſſel. This powder is called *flowers of ſulphur*. When ſubſtances fly off in this manner on the application of a moderate heat, they are called *volatile*; and the proceſs itſelf, by which they are raiſed, is called *volatilization*.

Sulphur undergoes no change by being allowed to remain expoſed to the open air.

When thrown into water, it does not melt, as common ſalt does, but falls to the bottom, and remains there unchanged; it is therefore *inſoluble* in water. If, however, it be poured, while in a ſtate of fuſion, into water, it aſſumes a red colour, and retains ſuch a degree of ſoftneſs, that it may be kneaded between the fingers; but it loſes this property in a few days§.

Fourcroy.

18
ulphur ca-
able of
ryſtalli-
ing.

There are a great many bodies which, after being diſſolved in water or melted by heat, are capable of aſſuming certain regular figures. If a quantity of common ſalt, for inſtance, be diſſolved in water, and that fluid, by the application of a moderate heat, be made to fly off in the form of ſteam; or, in other words, if the water be ſlowly *evaporated*, the ſalt will fall to the bottom of the veſſel in cubes. Theſe regular figures are called *cryſtals*. Now ſulphur is capable of cryſtallizing. If it be melted, and as ſoon as its ſurface begins to congeal, the liquid ſulphur beneath be poured out, the internal cavity will exhibit long needle-ſhaped cryſtals of an octahedral figure. This method of cryſtallizing ſulphur was contrived by Rouelle.

19
Converted by combuſtion into an acid.

When ſulphur is heated to the temperature of 302° in the open air, it takes fire ſpontaneouſly, and burns with a pale blue flame, and at the ſame time emits a great quantity of fumes of a very ſtrong ſuffocating odour. When heated to the temperature of 570°, or a little higher, it burns with a bright white flame, and at the ſame time emits a vaſt quantity of fumes. If the heat be continued long enough, the ſulphur burns all away without leaving any aſhes or *reſiduum*. If the fumes be collected, they are found to conſiſt entirely of *ſulphuric acid*. By combuſtion, then, ſulphur is converted into an acid. This fact was known ſeveral centuries ago, but no intelligible explanation was given of it till the time of Stahl. That chemiſt undertook the taſk; and founded on his experiments a theory ſo exceedingly ingenious, and ſupported by ſuch a vaſt number of facts, that it was in a very ſhort time adopted with admiration by all the philoſophic world, and contributed not a little to raiſe chemiſtry to that rank among the ſciences from which the ridiculous pretenſions of the early chemiſts had excluded it.

20
Stahl's explanation of this.

According to Stahl, there is only one ſubſtance in nature capable of combuſtion, which therefore he called Phlogiston; and all thoſe bodies which can be ſet on fire contain leſs or more of it. Combuſtion is merely the ſeparation of this ſubſtance. Thoſe bodies which contain none of it are of courſe incombuſtible. All combuſtibles, except thoſe which conſiſt of pure phlogiſton (if there be any ſuch), are compoſed of an incombuſtbile body and phlogiſton united together. During combuſtion the phlogiſton flies off, and the incombuſtible body remains behind. Now when ſulphur is burnt, the ſubſtance which remains is ſulphuric acid, an incombuſtible body. Sulphur therefore is compoſed of ſulphuric acid and phlogiſton.

To eſtabliſh this theory completely, it was neceſſary to ſhew that ſulphur could be actually made by combining ſulphuric acid and phlogiſton; and this alſo Stahl undertook to perform. *Sulphat of potaſs* is a ſubſtance compoſed of ſulphuric acid and potaſs (d), and *charcoal* is a combuſtible body, and therefore, according to the theory of Stahl, contains phlogiſton: when burnt, it leaves a very inconſiderable reſiduum, and conſequently contains hardly any thing elſe than phlogiſton. He melted together in a crucible a mixture of *potaſs* and *ſulphat of potaſs*, ſtirred into it one-fourth part by weight of pounded charcoal, covered the crucible with another inverted over it, and applied a ſtrong heat to it. He then allowed it to cool, and examined its contents. The charcoal had diſappeared, and there only remained in the crucible a mixture of potaſs and ſulphur combined together,

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(d) The nature of *potaſs* ſhall afterwards be explained. It is the *potaſh* well known in commerce in a ſtate of purity.

together, and of a darker colour than uſual, from the reſiduum of the charcoal. Now there were only three ſubſtances in the crucible at firſt, potaſs, ſulphuric acid, and charcoal: two of theſe have diſappeared, and *ſulphur* has been found in their place. Sulphur then muſt have been formed by the combination of theſe two. But charcoal conſiſts of phlogiſton and a very ſmall reſiduum, which is ſtill found in the crucible. The ſulphur then muſt have been formed by the combination of ſulphuric acid and phlogiſton. This ſimple and luminous explanation appeared ſo ſatisfactory, that the compoſition of ſulphur was long conſidered as one of the beſt demonſtrated truths in chemiſtry.

21 Unſatiſfactory. There are two facts, however, which Stahl either did not know or did not ſufficiently attend to, neither of which were accounted for by his theory. The firſt is, that ſulphur will not burn if air be completely excluded; the ſecond, that ſulphuric acid is heavier than the ſulphur from which it was produced.

22 Real explanation by Lavoiſier.

To account for theſe, or facts ſimilar to theſe, ſucceeding chemiſts refined upon the theory of Stahl, deprived his phlogiſton of *gravity*, and even aſſigned it a principle of *levity*. Still, however, the neceſſity of the contact of air remained unexplained. At laſt Mr Lavoiſier, who had already diſtinguiſhed himſelf by the extenſiveneſs of his views, the accuracy of his experiments, and the preciſion of his reaſoning, undertook the examination of this ſubject, and his experiments were publiſhed in the Memoirs of the Academy of Sciences for 1777. He put a quantity of ſulphur into a large glaſs veſſel filled with air, which he inverted into another veſſel containing mercury, and then ſet fire to the ſulphur by means of a burning-glaſs. It emitted a blue flame, and gave out thick vapours. but was very ſoon extinguiſhed, and could not be again kindled. There was, however, a little ſulphuric acid formed, which was a good deal heavier than the ſulphur which had diſappeared; there was alſo a diminution in the air of the veſſel proportional to this increaſe of weight. The ſulphur, therefore, during its converſion into an acid, muſt have abſorbed part of the air. He then put a quantity of ſulphuret of iron, which conſiſts of ſulphur and iron combined together, into a glaſs veſſel full of air, which he inverted over water (E). The quantity of air in the veſſel continued diminiſhing for eighteen days, as was evident from the aſcent of the water to occupy the ſpace which it had left; but after that period no farther diminution took place. On examining the ſulphuret, it was found ſomewhat heavier than when firſt introduced into the veſſel, and the air of the veſſel wanted preciſely the ſame weight. Now this air had loſt all its oxygen; all the oxygen of the air in the veſſel muſt therefore have entered into the ſulphuret. Part of the ſulphur was converted into ſulphuric acid; and as all the reſt of the ſulphuret was unchanged, the whole of the increaſe of weight muſt have been owing to ſomething which had entered into that part of the ſulphur which was converted into acid. This ſomething we know was oxygen. Sulphuric acid therefore muſt be compoſed of ſulphur and oxygen; for as the original weight of the whole contents of the veſſel remained exactly the ſame, there was not the ſmalleſt reaſon to ſuppoſe that any ſubſtance had left the ſulphur.

It is impoſſible, then, that ſulphur can be compoſed of ſulphuric acid and phlogiſton, as Stahl ſuppoſed; ſince ſulphur itſelf enters as a part into the compoſition of that acid. There muſt therefore have been ſome want of accuracy in the experiment by which Stahl proved the compoſition of ſulphur, or at leaſt ſome fallacy in his reaſonings; for it is impoſſible that two contradictory facts can both be true. Upon examining the potaſs and ſulphur produced by Stahl's experiment, we find them to be conſiderably lighter than the charcoal, ſulphuric acid, and potaſs originally employed. Something therefore has made its eſcape during the application of the heat. And if the experiment be conducted in a cloſe veſſel, with a pneumatic apparatus attached to it, a quantity of gas will be obtained exactly equal to the weight which the ſubſtances operated on have loſt; and this weight conſiderably exceeds that of all the charcoal employed. This gas is *carbonic acid gas*, which is compoſed of charcoal and oxygen, as will afterwards appear. We now perceive what paſſes in this experiment: Charcoal has a ſtronger affinity for oxygen at a high temperature than ſulphur has. When charcoal therefore is preſented to ſulphuric acid in that temperature, the oxygen of the acid combines with it, they fly off in the form of carbonic acid gas, and the ſulphur is left behind.

The combuſtion of ſulphur, then, is nothing elſe than the act of its combination with oxygen; and, for any thing which we know to the contrary, it is a ſimple ſubſtance.

23 Affinities of ſulphur. The affinities of ſulphur, according to Bergman, are as follows:

Lead,
Tin,
Silver,
Mercury,
Arſenic,
Antimony,
Iron,
Fixed alkalies,
Ammonia,
Barytes,
Lime,
Magneſia,
Phoſphorus?
Oils,
Ether,
Alcohol.

SECT. II. *Of Phoſphorus.*

24 Production of phoſphorus. LET a quantity of bones be burnt, or, as it is termed in chemiſtry, *calcined*, till they ceaſe to ſmoke, or to give out any odour. and let them afterwards be reduced to a fine powder. Put this powder into a glaſs veſſel, and pour ſulphuric acid on it by little at a time, till farther additions do not cauſe any extrication of air bubbles (F). Dilute the mixture with a good deal of water, agitate it well, and keep it hot for ſome hours; then paſs it through a filter. Evaporate the liquid ſlowly

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(E) This experiment was firſt made by Scheele, but with a different view.

(F) The copious emiſſion of air bubbles is called in chemiſtry *efferveſcence*.

Phoſphorus

ſlowly till a quantity of white powder falls to the bottom. This powder muſt be ſeparated by filtration and thrown away. The evaporation is then to be reſumed; and whenever any white powder appears, the filtration muſt be repeated in order to ſeparate it. During the whole proceſs, what remains on the filter muſt be waſhed with pure water, and this water added to the liquor. The evaporation is to be continued till all the moiſture diſappears, and nothing but a dry maſs remains. Put this maſs into a crucible, and keep it melted in the fire till it ceaſes to exhale ſulphureous odours; then pour it out. When cold it aſſumes the appearance of a brittle glaſs. Pound this glaſs in a mortar, and mix it with one-third by weight of charcoal duſt. Put this mixture into an earthen ware retort, and apply a receiver containing a little water. Put the retort into a ſand bath, and increaſe the fire till it becomes red hot. A ſubſtance then paſſes into the receiver, which has the appearance of melted wax, and which congeals as it falls into the water of the receiver. This ſubſtance is *phoſphorus*.

25
Its diſcovery.

It was diſcovered by Brandt, a chemiſt of Hamburgh, about the year 1667, while he was employed in attempting to extract from human urine a liquid capable of converting ſilver into gold *.

* *Leibnitz, Melange de Berlin.*

Kunkel, another German chemiſt, hearing of the diſcovery, was anxious to find out the proceſs, and for that purpoſe aſſociated himſelf with a friend of his named Kraft. But the latter procured the ſecret from the diſcoverer; and expecting by means of it to acquire a fortune, refuſed to give any information to his aſſociate. Vexed at this treachery, Kunkel reſolved to attempt the diſcovery himſelf; and though he knew only that phoſphorus was obtained from urine, proſecuted the inquiry with ſo much zeal, that he ſucceeded, and has been deſervedly conſidered as one of the diſcoverers †.

† *Stahl's Three Hundred Experiments.*

Boyle likewiſe diſcovered phoſphorus. Leibnitz indeed affirms that Kraft taught Boyle the whole proceſs, and Kraft declared the ſame thing to Stahl. But ſurely the aſſertion of a dealer in ſecrets, and one who had deceived his own friend, on which the whole of this ſtory is founded, cannot be put in competition with the affirmation of a man like Boyle, who was one of the honeſteſt men, as well as greateſt philoſophers, of his age; and he poſitively aſſures us that he made the diſcovery without being previouſly acquainted with the proceſs ‡.

‡ *Boyle Abridged by Shaw*, iii 174.

Gahn, a Swediſh chemiſt, diſcovered, in 1769, that phoſphorus was contained in bones ‖, and Scheele (G) very ſoon after invented a proceſs for obtaining it from them. Phoſphorus is now generally procured in that manner. The proceſs deſcribed in the beginning of this ſection is that of the Dijon academicians: it differs from that of Scheele only in a ſingle particular.

‖ *Bergman's Notes on Scheffer.*

26
Its properties.

Phoſphorus, when pure, is of a clear, tranſparent, yellowiſh colour; but when kept ſome time in water, it becomes opaque, and then has a great reſemblance to white wax. Its conſiſtence is nearly that of wax: it may be cut with a knife or twiſted to pieces with the fingers. It is inſoluble in water. Its ſpecific gravity is 1,714.

It melts at the temperature of 99° *, and even at 67° it gives out a white ſmoke, and is luminous in the dark; that is to ſay, it ſuffers a ſlow combuſtion: ſo that it can only be prevented from taking fire by keeping it in a very low temperature, or by allowing it to remain always plunged in water. If air be excluded, it evaporates at 219°, and boils at 554° †. When heated to 122° (H), it burns with a very bright flame, and gives out a great quantity of white ſmoke, which is luminous in the dark; at the ſame time it emits an odour which has ſome reſemblance to that of garlic. It leaves no reſiduum; but when the white ſmoke is collected, it is found to be an *acid*. Stahl conſidered this acid as the muriatic (I). According to him, phoſphorus was compoſed of muriatic acid and phlogiſton, and the combuſtion of it was merely the ſeparation of phlogiſton. He even declared, that to make phoſphorus, nothing more was neceſſary than to combine muriatic acid and phlogiſton; and that this compoſition was as eaſily accompliſhed as that of ſulphur itſelf ‡.

* *Pelletier, Journal de Phyſique*, xxxv. 380.

† *Ibid.* 381.

27
Converted by combuſtion

‡ *Three Hundred Experiments.*

Theſe aſſertions gained implicit credit; and the compoſition and nature of phoſphorus were conſidered as completely underſtood, till Margraf of Berlin publiſhed his experiments in the year 1743. That great man, one of thoſe illuſtrious philoſophers who have contributed ſo much to the rapid increaſe of the ſcience, diſtinguiſhed equally for the ingenuity of his experiments and the clearneſs of his reaſoning, attempted to produce phoſphorus by combining together phlogiſton and muriatic acid; but though he varied his proceſs a thouſand ways, preſented the acid in many different ſtates, and employed a variety of ſubſtances to furniſh phlogiſton, all his attempts failed, and he was obliged to give up the combination as impracticable. On examining the acid produced during the combuſtion of phoſphorus, he found that its properties were very different from thoſe of muriatic acid. It was therefore a diſtinct ſubſtance. The name of *phoſphoric acid* was given to it; and it was concluded that phoſphorus was compoſed of this acid united to phlogiſton.

28
Into phoſphoric acid.

But it was obſerved in 1772 by Morveau §, that phoſphoric acid was heavier than the phoſphorus from which it was produced (K); and Boyle had long before ſhewn that phoſphorus would not burn except when in contact with air. Theſe facts were ſufficient to prove the inaccuracy of the theory concerning the compoſition of phoſphorus; but they remained themſelves unaccounted for, till Lavoiſier publiſhed thoſe celebrated experiments, which threw ſo much light on the nature and compoſition of acids.

§ *Digreſ. Academ.* p. 253.

He exhauſted a glaſs globe of air by means of an air-

(G) Crell, in his life of Scheele, informs us that Scheele was himſelf the diſcoverer of the fact. This, he ſays, clearly appears from a printed letter of Scheele to Gahn, who was before looked upon as the diſcoverer. See *Crell's Annals*, Engliſh Tranſ. I. 17.

(H) Morveau, *Encycl. Method. Chimie*, art *Affinité*.—According to Nicholſon at 160°. See his *Tranſlation of Chaptal*.

(I) This acid ſhall be afterwards deſcribed.

(K) The ſame obſervation had been made by Margraf, but no attention was paid to it.

pump; and after weighing it accurately, he filled it with oxygen gas, and introduced into it 100 grains of phoſphorus. The globe was furniſhed with a ſtop-cock, by which oxygen gas could be admitted at pleaſure. He ſet fire to the phoſphorus by means of a burning-glaſs. The combuſtion was extremely rapid, accompanied by a bright flame and much heat. Large quantities of white flakes attached themſelves to the inner ſurface of the globe, and rendered it opaque; and theſe at laſt became ſo abundant, that notwithſtanding the conſtant ſupply of oxygen gas, the phoſphorus was extinguiſhed. The globe, after being allowed to cool, was again weighed before it was opened. The quantity of oxygen employed during the experiment was aſcertained, and the phoſphorus, which ſtill remained unchanged, accurately weighed. The white flakes, which were nothing elſe than pure phoſphoric acid, were found exactly equal to the weights of the phoſphorus and oxygen, which had diſappeared during the proceſs.

29
Which is phoſphorus combined with oxygen.

Phoſphoric acid therefore muſt have been formed by the combination of theſe two bodies; for the abſolute weight of all the ſubſtances together was the ſame before and after the proceſs [*]. It is impoſſible then that phoſphorus can be compoſed of phoſphoric acid and phlogiſton, as phoſphorus itſelf enters into the compoſition of that acid (L).

Thus the combuſtion of phoſphorus, like that of ſulphur, is nothing elſe than its combination with oxygen; for during the proceſs no new ſubſtance appears except the acid, accompanied indeed with much heat and light.

30
Phoſphorus combines with ſulphur.

Phoſphorus combines readily with ſulphur, as Margraf diſcovered during his experiments on phoſphorus. This combination was afterwards examined by Mr Pelletier. The two ſubſtances are capable of being mixed in different proportions. Seventy-two grains of phoſphorus and nine of ſulphur, when heated in about four ounces of water, melt with a gentle heat. The compound remains fluid till it be cooled down to 77°, and then becomes ſolid. Theſe ſubſtances were combined in the ſame manner in the following proportions:

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

Phoſphorus and ſulphur may be combined alſo by melting them together without any water; but the combination takes place ſo rapidly, that they are apt to ruſh out of the veſſel if the heat be not exceedingly moderate [†].

Phoſphorus is capable of combining alſo with many other bodies: the compounds produced are called *phoſphurets*.

The affinities of phoſphorus have not yet been aſcertained.

Sect. III. *Of Carbon.*

If a piece of wood be put into a crucible, well covered with ſand, and kept red hot for ſome time, it is converted into a black ſhining brittle ſubſtance, without either taſte or ſmell, well known under the name of *charcoal*. This ſubſtance contains always mixed with it ſeveral earthy and ſaline particles. When freed from theſe impurities it is called *carbon*.

31
Properties of carbon.

Charcoal is inſoluble in water. It is not affected (provided that all air be excluded) by the moſt violent heat which can be applied, excepting only that it is rendered much harder.

New-made charcoal abſorbs moiſture with avidity. When heated to a certain temperature, it abſorbs air copiouſly. La Metherie plunged a piece of burning charcoal into mercury, in order to extinguiſh it, and introduced it immediately after into a glaſs veſſel filled with common air. The charcoal abſorbed four times its bulk of air. On plunging the charcoal in water, one-fifth of this air was diſengaged. This air, on being examined, was found to contain a much ſmaller quantity of oxygen than atmoſpherical air does. He extinguiſhed another piece of charcoal in the ſame manner, and then introduced it into a veſſel filled with oxygen gas. The quantity of oxygen gas abſorbed amounted to eight times the bulk of the charcoal; a fourth part of it was diſengaged on plunging the charcoal into water [*]. It appears from the experiments of Sennebier, that charcoal when expoſed to the atmoſphere abſorbs oxygen gas in preference to *azot* [†], as the other portion of common air is called.

32
Converted into an acid.

When heated to the temperature of 370° [‡], it takes fire, and, provided it has been previouſly freed from the earths and ſalts which it generally contains, it burns without leaving any reſiduum. If this combuſtion be performed in cloſe veſſels filled with oxygen gas inſtead of common air, part of the charcoal and oxygen diſappear, and in their room is found a particular gas exactly equal to them in weight. This gas has the properties of an acid, and is therefore called *carbonic acid gas*. Mr Lavoiſier, to whom we are indebted for this diſcovery, aſcertained, by a number of very accurate experiments, that this gas was compoſed of about 28 parts of carbon and 72 of oxygen [‖].

33
Suſceptible of cryſtallization.

Carbon is ſuſceptible of cryſtallization. In that ſtate it is called *diamond*. The figure of the diamond varies conſiderably; but moſt commonly it is a hexagonal priſm terminated by a ſix-ſided pyramid. When pure it is colourleſs and tranſparent. Its ſpecific gravity is from 3,44 to 3,55. It is one of the hardeſt ſubſtances in nature; and as it is not affected by a conſiderable heat, it was for many ages conſidered as incombuſtible. Sir Iſaac Newton, obſerving that combuſtibles refracted light more powerfully than other bodies, and that the diamond poſſeſſed this property in great perfection, ſuſpected,

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[*] *Lavoiſier's Chemiſtry*, Part I. chap. v.

[†] *Pelletier, Jour. de Phyſ.* xxxv. 382.

[*] *Jour. de Phyſ.* xxx. 309.

[†] *Ann. de Chim.* iv. 261.

[‡] *Morveau, Encycl. Method.* art. *Affinité.*

[‖] *Mem. Acad.* 1781, p. 448.

(L)

The quantity of phoſphorus conſumed was	45 grains
The quantity of oxygen gas - - - -	69,375
Weight of the phoſphoric acid produced	114,375

Phoſphoric acid therefore is compoſed of 100 parts phoſphorus and 154 oxygen.

pected, from that circumſtance, that it was capable of combuſtion. This ſingular conjecture was verified in 1694 by the Florentine academicians, in the preſence of Coſmo III. grand duke of Tuſcany. By means of a burning-glaſs, they deſtroyed ſeveral diamonds. Francis I. emperor of Germany, afterwards witneſſed the deſtruction of ſeveral more in the heat of a furnace. Theſe experiments were repeated by Rouelle, Macquer, and D'Arcet; who proved that the diamond was not merely evaporated, but actually burnt, and that if air was excluded it underwent no change.

No attempt, however, was made to aſcertain the product, till Lavoiſier undertook a ſeries of experiments for that purpoſe in 1772. He obtained *carbonic acid gas*. It might be concluded from theſe experiments, that the diamond contains carbon; but it was reſerved for Mr Tennant to ſhew that it conſiſted entirely of that ſubſtance.

34
When it forms *diamond*.

Into a tube of gold, having one end cloſed and a glaſs tube adapted to the other to collect the product, that gentleman put 2½ grains of diamonds and a quarter of an ounce of nitre (M). This tube was heated ſlowly; the conſequence of which was, that great part of the nitric acid paſſed off before the diamond took fire, and by that means almoſt the whole of the carbonic acid formed during the combuſtion of the diamond remained in the potaſs, for which it has a ſtrong affinity. To aſcertain the quantity of this carbonic acid, he diſſolved the potaſs in water, and added to the ſolution another ſalt compoſed of muriatic acid and lime. Muriatic acid has a ſtronger affinity for potaſs than for lime; it therefore combines with the potaſs, and at the ſame time the lime and carbonic acid unite and fall to the bottom of the veſſel, becauſe they are nearly inſoluble in water. He decanted off the liquor, and put the lime which contained the carbonic acid gas into a glaſs globe, having a tube annexed to it. This globe and tube he then filled with mercury, and inverted into a veſſel containing the ſame fluid. The lime by that means occupied the very top of the tube. It now remained to ſeparate the carbonic acid from the lime, which may be done by mixing it with any acid, as almoſt every other acid has a ſtronger affinity for lime than carbonic acid has. Accordingly on introducing muriatic acid, 10,3 ounce meaſures of carbonic acid gas, or nearly 9,166 grains, were ſeparated. But, according to the experiments of Lavoiſier, this gas is compoſed of 72 parts of oxygen and 28 of carbon; 9,166 grains, therefore contain 2,56 grains of carbon, which is almoſt preciſely the weight of the diamond conſumed. It follows, therefore, that it was compoſed of pure carbon*. The difficulty of burning the diamond is owing entirely to its hardneſs. Meſſrs Morveau and Tennant rendered common charcoal ſo hard by expoſing it for ſome time to a violent fire in cloſe veſſels, that it loſt much of its natural tendency to combuſtion, and endured even a red heat without catching fire †.

* *Phil. Tranſ.* 1797. p. 123.

† *Encycl. Method. Chimie, art.* Acier.

Charcoal poſſeſſes a number of ſingular properties, which render it of conſiderable importance. It is incapable of putrefying or rotting like wood, and is not therefore liable to decay through age. This property has been long known. It was cuſtomary among the ancients to *char* the outſide of thoſe ſtakes which were to be driven into the ground or placed in water, in order to preſerve the wood from ſpoiling. New-made charcoal, by being rolled up in cloths which have contracted a diſagreeable odour, effectually deſtroys it. It takes away the bad taint from meat beginning to putrefy, by being boiled along with it. It is perhaps the beſt teeth powder known. Mr Lowitz of Peterſburgh has ſhewn, that it may be uſed with advantage to purify a great variety of ſubſtances.

35
Carburets.

Carbon unites with a number of bodies, and forms with them compounds known by the name of *carburets*.

Its affinities have not yet been aſcertained.

Sect. IV. *Of Hydrogen.*

36
Method of procuring hydrogen.

Put into a glaſs veſſel furniſhed with two mouths a quantity of freſh iron filings, quite free from ruſt. Lute into one of theſe mouths the end of a crooked glaſs tube. Inſert the other end of this tube below a glaſs jar filled with water, and inverted into a pneumatic apparatus. Then pour upon the iron filings a quantity of ſulphuric acid, diluted with twice its own weight of water, and cloſe up the mouth of the veſſel. Immediately the iron filings and acid effervеſce with violence, a vaſt quantity of gas is produced, which ruſhes through the tube and fills the jar. This gas is called *hydrogen gas* (N).

It was obtained by Dr Mayow and by Dr Hales from various ſubſtances, and had been known long before in mines under the name of the *fire damp*. Mr Cavendiſh * was the firſt who examined its properties with attention. They were afterwards more fully inveſtigated by Prieſtley, Scheele, and Fontana.

* *Phil. Tranſ.* 1766.

37
Its properties.

Hydrogen, like *air*, is inviſible and elaſtic, and capable of indefinite compreſſion and dilatation.

Its ſpecific gravity differs according to its purity, Kirwan found it 0,00010 †; Lavoiſier 0,000094 ‡, or about twelve times lighter than common air.

All burning ſubſtances are immediately extinguiſhed by being plunged into this gas. It is incapable, therefore, of ſupporting combuſtion.

† *On Phlogiſton*, ſect. 1ſt.

‡ *Lavoiſier's Chemiſtry, Appendix.*

Animals, when they are obliged to breathe it, die almoſt inſtantaneouſly. Scheele, indeed, found that he could breathe it for ſome time without inconvenience §; but Fontana, who repeated the experiment, diſcovered that this was owing to the quantity of common air contained in the lungs when he began to breathe; for on expiring as ſtrongly as poſſible before drawing in the hydrogen gas, he could only make three reſpirations, and even theſe three produced extreme feebleneſs and oppreſſion about the breaſt ||.

§ *Scheele on Fire.*

|| *Jour de Phyſ.* xv. 99.

If a phial be filled with hydrogen gas, and a lighted candle be brought to its mouth, the gas will take fire, and burn gradually till it is all conſumed. If hydrogen

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(M) Nitre is compoſed of potaſs and nitric acid; and nitric acid contains a great quantity of oxygen, which is eaſily ſeparated by heat. Diamond, when mixed with nitre, burns at a much lower heat than by any other proceſs.

(N) It was formerly called *inflammable air*, and by ſome chemiſts *phlogiſton*.

gen and oxygen gas be mixed together and kindled, they burn inſtantaneouſly, and produce an exploſion like gunpowder. The ſame effect follows when a mixture of hydrogen gas and atmoſpherical air is kindled, but the exploſion is leſs violent. Hydrogen gas will not burn except in contact with oxygen gas, nor will it burn even in contact with oxygen gas, unleſs a red heat be applied to it. If 85 parts by weight of oxygen gas, and 15 of hydrogen gas, be mixed together, and ſet on fire in a cloſe veſſel, they diſappear, and in their place there is found a quantity of water exactly equal to them in weight. This water muſt be compoſed of theſe two gaſes; for it did not previouſly exiſt in the veſſel, and no other ſubſtance except the gaſes was introduced. Water then is compoſed of oxygen and hydrogen; and the combuſtion of hydrogen is nothing elſe but the act of its combination with oxygen (o).

38
Compoſition of water.

It had been ſuppoſed, in conſequence of the experiments of Dr Prieſtley and ſeveral other philoſophers, that when hydrogen gas was allowed to remain in contact with water, it was gradually decompoſed, and converted into another gas; but Mr de Morveau[*], Mr Haſſenfratz[†], and Mr Libes[‡], have ſhewn that it undergoes no change, provided ſufficient care be taken to exclude every other gas.

39
Compounds of hydrogen gas.

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

40
Sulphurated hydrogen gas.

1. Sulphurated hydrogen gas was firſt examined with attention by Scheele, who, together with Bergman, diſcovered many of its properties. Mr Kirwan likewiſe publiſhed a very valuable paper on the ſame ſubject. If equal parts of ſulphur and potaſs be melted together in a covered crucible, they combine together, and form a compound known by the name of *ſulphuret of potaſs*, but formerly called, from its red colour, *hepar ſulphuris*, or *liver of ſulphur*. When this ſubſtance is moiſtened with water, it gives out a quantity of ſulphurated hydrogen gas; hence this gas was at firſt called *hepatic gas*.

Mr Gengembre encloſed a bit of ſulphur in a glaſs veſſel filled with hydrogen gas, and melted the ſulphur by means of a burning-glaſs. A quantity of it diſappeared, and the hydrogen aſſumed all the properties of *hepatic gas*. Hence it follows that this gas is merely ſulphur diſſolved in hydrogen gas.

The eaſieſt method of obtaining it is to pour an acid, the muriatic for inſtance, on a quantity of the ſulphuret reduced to powder. An efferveſcence takes place, the gas is extricated, and may be collected by means of a pneumatic apparatus. The theory of this emiſſion is obvious. The ſulphur is gradually converted into ſulphuric acid, by decompoſing the water, which is always united with acids, and ſeizing its oxygen: the hydrogen of the water is thus ſet at liberty; it aſſumes the gaſeous form, and at the ſame time diſſolves part of the remaining ſulphur, for which it has a conſiderable affinity.

The ſpecific gravity of ſulphurated hydrogen gas is 0,00135[*]; it is to common air as 1106 to 1000.

It has a very fetid odour, preciſely ſimilar to that emitted by rotten eggs, which indeed is owing to the emiſſion of the very ſame gas.

It is not more reſpirable than hydrogen gas. When ſet on fire, in contact with oxygen gas, it burns with a light blue flame, without exploding, and at the ſame time a quantity of ſulphur is depoſited. The combuſtion of this gas, then, is merely the union of its hydrogen, and perhaps part of its ſulphur, with oxygen.

This gas turns ſyrup of violets to a green colour[†]. It does not ſeem capable of exiſting in atmoſpherical air without decompoſition; for the moment it comes into contact with oxygen gas, ſulphur is depoſited[‡].

41
Phoſphorated hydrogen gas.

2. Phoſphorated hydrogen gas was diſcovered by Mr Gengembre in 1783, and by Mr Kirwan ſome time after, before he became acquainted with the experiments of that gentleman. It may be procured by mixing phoſphorus with potaſs diſſolved in water, and applying a boiling heat to the ſolution. The phoſphorus is gradually converted into an acid by decompoſing the water, and uniting with its oxygen. The hydrogen aſſumes the form of a gas, and flies off after diſſolving a little of the phoſphorus. This gas may be collected by means of a pneumatic apparatus.

Phoſphorated hydrogen gas has a ſmell reſembling that of putrid fiſh. When mixed with oxygen gas or common air, it becomes luminous; and on the application of the ſmalleſt heat, it burns with aſtoniſhing rapidity[§]. The products are water and phoſphoric acid. The combuſtion of this gas therefore is nothing elſe than the union of its phoſphorus and hydrogen with oxygen, attended by an emiſſion of heat and light.

Phoſphorated hydrogen gas may alſo be formed by introducing a bit of phoſphorus into a jar containing hydrogen gas: but care muſt be taken to make this gas as dry as poſſible; for its affinity with phoſphorus is weakened in proportion to its moiſture[||].

42
Carbonated hydrogen gas.

3. Carbonated hydrogen gas ariſes ſpontaneouſly in hot weather from marſhes, but always mixed with ſeveral other gaſes. Several ſpecies of it have been lately diſcovered by the aſſociated Dutch chemiſts Bondt, Dieman, Van Trooſtwyck, and Lauwerenberg[¶]. When 75 parts of ſulphuric acid and 25 of ſpirit of wine are mixed together, a gas is extricated which ſuffers no alteration from ſtanding over water. Its ſpecific gravity is 0,00111, or it is to common air as 909 to 1000. It has a fetid odour, and burns with a ſtrong compact flame. When paſſed through ſulphur it is converted into ſulphurated hydrogen gas, and at the ſame time a quantity of carbon is depoſited in the form of a fine powder; it muſt therefore be compoſed of carbon and hydrogen gas. When burnt, the product is carbonic acid

[*] *Encycl. Method. Chim.* i 754.

[†] *Ann. de Chim.* i. 192.

[‡] *Jour. de Phyſ.* xxxvi. 412.

[*] *Kirwan on Phlogiſton*, ſect. 1ſt.

[†] *Fourcroy's Chemiſtry, art.* Sulphur

[‡] *Bergman.*

[§] *Kirwan.*

[||] *Brugnatelli, Nicholſon's Journal*, i. 445.

[¶] *Ann. de Chim.* xxi. 45.

(o) The hiſtory of this great diſcovery, and the objections which have been made to it, we reſerve for the chapter which treats of *Water*, where they will be better underſtood than they could be at preſent. This ſubſtance was called *hydrogen* by the French chemiſts, becauſe it enters into the compoſition of water, from υδωρ *water*, and γινομαι *I am born*. Objections have been made to the propriety of the name, into which we ſhall not enter. It ought never to be forgotten that Newton had long before, with a ſagacity almoſt greater than human, conjectured, from its great refracting power, that water *contained a combuſtible ſubſtance.*

acid gas and water *. By making ether (P) paſs thro' a red hot glaſs tube, another carbonated hydrogen gas was formed, the ſpecific gravity of which was 0,00086. Spirit of wine, paſſed in the ſame manner, afforded a gas, the ſpecific gravity of which was 0,00053, and which burned with a paler flame than the other two. Theſe gaſes were found to contain from 80 to 74 parts of carbon, and from 20 to 26 of hydrogen. The firſt ſpecies was found to contain moſt carbon, and the laſt to contain leaſt †.

* *Ibid.*

† *Ibid.*

43
Affinities of theſe gaſes.

The affinity of hydrogen gas for theſe three combuſtibles is as follows:

Sulphur,
Carbon,
Phoſphorus (Q).

44
Attempt to decompoſe carbon

Dr Auſtin found, that by repeatedly paſſing electric exploſions through a ſmall quantity of carbonated hydrogen gas, it was permanently dilated to more than twice its original bulk. He rightly concluded, that this remarkable expanſion could only be owing to the evolution of hydrogen gas. On burning air thus expanded, he found that it required a greater quantity of oxygen than the ſame quantity of gas not dilated by electricity: An addition therefore had been made to the combuſtible matter; for the quantity of oxygen neceſſary to complete the combuſtion of any body, is always proportional to the quantity of that body. He concluded from theſe experiments, that he had decompoſed the carbon which had been diſſolved in the hydrogen gas; and that carbon was compoſed of hydrogen and azot (R), ſome of which was always found in the veſſel after the dilated gas had been burnt by means of oxygen ‡. If this concluſion be fairly drawn, we muſt expunge *carbon* from the liſt of ſimple ſubſtances, and henceforth conſider it as a compound.

‡ *Phil. Tranſ.* lxxx. 51.

45
Examined,

There was one circumſtance which ought to have prevented Dr Auſtin from drawing this concluſion, at leaſt till warranted by more deciſive experiments. The quantity of combuſtible matter had been increaſed. Now, if the expanſion of the carbonated hydrogen gas was owing merely to the decompoſition of carbon, no ſuch increaſe ought to have taken place, but rather the contrary; for the carbon, which was itſelf a combuſtible ſubſtance, was reſolved into two ingredients, hydrogen and azot, only the firſt of which burnt on the addition of oxygen and the application of heat. Dr Auſtin's experiments have been lately repeated by Mr William Henry with a great deal of accuracy §. He found that the dilatation which Dr Auſtin deſcribes actually took place, but that it could not be carried beyond a certain degree, a little more than twice the original bulk of the gas. Upon burning ſeparately by means of oxygen, two equal portions of carbonated hydrogen gas, one of which had been expanded by electricity to double its original bulk, the other not, he found that each of them produced preciſely the ſame quantity of *carbonic acid gas*. Both therefore contained the ſame quantity of carbon; conſequently no carbon had been decompounded by the electric ſhocks.

§ *Phil. Tranſ.* 1797 part 2d.

46
And found unſucceſsful.

Mr Henry then ſuſpected that the dilatation was owing to the water which every gas contains in a larger or ſmaller quantity. To aſcertain this, he endeavoured to deprive the carbonated hydrogen gas of as much water as poſſible, by making it paſs over very dry potaſs, which attracts water with avidity. Gas treated in this manner could only be expanded one ſixth of its bulk; but on admitting a drop or two of water, the expanſion went on as uſual. The ſubſtance decompounded by the electricity, then, was not the carbon, but the water in the carbonated hydrogen gas. Nor is it difficult to ſee in what manner this decompoſition is effected. Carbon, at a high temperature, has a greater affinity for oxygen than hydrogen has; for if the ſteam of water be made to paſs over red hot charcoal, it is decompoſed, and carbonic acid and hydrogen gas are formed. The electric exploſion ſupplies the proper temperature; the carbon unites with the oxygen of the water, and forms carbonic acid; and the hydrogen, thus ſet at liberty, occaſions the dilatation. Carbonic acid gas is abſorbed with avidity by water: and when water was admitted into 709 meaſures of gas thus dilated, 100 meaſures were abſorbed; a proof that carbonic acid gas was actually preſent. As to the azot which Dr Auſtin found in his dilated gas, it evidently proceeded from the admiſſion of ſome atmoſpheric air, about 73 parts of which in the 100 conſiſt of this gas: for Dr Auſtin's gas had ſtood long over water; and Drs Prieſtley and Higgins have ſhewn that air in ſuch a ſituation always becomes impregnated with azot.

47
Affinities of hydrogen.

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

Oxygen,
Carbon,
Azot.

SECT. V. *Of Azot.*

48
Method of procuring azot.

If a quantity of iron filings and ſulphur, mixed together and moiſtened with water, be put into a glaſs veſſel full of air, it will abſorb all the oxygen in the courſe of a few days; but a conſiderable reſiduum of air ſtill remains incapable of any farther diminution. This reſiduum has obtained the appellation of *azotic gas*.

It

(P) Ether is a very volatile and fragrant liquid, obtained by mixing ſpirit of wine and acids, and diſtilling. It ſhall be afterwards deſcribed.

(Q) Sulphur decompoſes carbonated hydrogen gas; therefore its affinity is greater than that of carbon. The Dutch chemiſts melted phoſphorus in carbonated hydrogen gas, but no change was produced; therefore the affinity of phoſphorus is inferior to that of carbon.

(R) See next Section.—His theory was, that carbonated hydrogen gas was compoſed of hydrogen, and azot, and carbon of azot, and carbonated hydrogen gas, which comes nearly to the ſame thing with regard to the elements of carbon. It is ſingular enough, that though Dr Auſtin would not allow the preſence of carbon in carbonated hydrogen gas, he actually decompoſed it by melting ſulphur in it: the ſulphur combined with the hydrogen gas, and a quantity of carbon was precipitated. This experiment he relates without making any remarks upon it, and ſeems indeed not to have paid any attention to it.

49 Diſcovery of azot.

It was diſcovered in 1772 by Dr Rutherford, now profeſſor of botany in the univerſity of Edinburgh (s). Scheele procured it by the above proceſs as early as 1776, and proved that it was a diſtinct fluid. Mr Lavoiſier afterwards proved the ſame thing, without any previous knowledge of Scheele's diſcoveries.

The air of the atmoſphere contains about ,73 parts of azotic gas; almoſt all the reſt is oxygen gas. The eaſieſt method of procuring azotic gas is to put ſome ſulphuret of potaſs into a glaſs veſſel filled with air, and accurately cloſed, and then to apply heat to the ſulphuret. All the oxygen is abſorbed almoſt inſtantly. This method was firſt pointed out by Morveau*.

* *Nicholſon's Journal*, i. 208.

Mr Kirwan examined the ſpecific gravity of azotic gas obtained by Scheele's proceſs; it was 0,00120: it is therefore ſomewhat lighter than the atmoſpheric air; it is to atmoſpheric air as 985 to 1000†.

† *On Phlogiſton.* § 1ſt.

50 Its properties

It tinges delicate blue colours ſlightly with green‡. It is exceedingly noxious to animals; if they are obliged to reſpire it, they drop down dead almoſt inſtantly (t). No combuſtible will burn in it. This is the reaſon that a candle is extinguiſhed in atmoſpherical air as ſoon as the oxygen near it is conſumed. Mr Goettling, indeed, publiſhed, in 1794, that phoſphorus ſhone, and was converted into phoſphoric acid, in pure azotic gas. Were this the caſe, it would not be true that no combuſtible burns in this gas; for the converſion of phoſphorus into an acid, and even its ſhining, is an actual though ſlow combuſtion. Mr Goettling's experiments were ſoon after repeated by Drs Scherer and Jaeger, who found that phoſphorus does not ſhine in azotic gas when it is perfectly pure; and that therefore the gas on which Mr Goettling's experiments were made had contained a mixture of oxygen gas, owing principally to its having been only confined by water. Theſe reſults were afterwards confirmed by Profeſſor Lampadius and Profeſſor Hildebrandt. It is therefore proved beyond a doubt, that phoſphorus does not burn in azotic gas, and that whenever it appears to do ſo, there is always ſome oxygen gas preſent §.

‡ *Fourcroy, Ann. de Chim.* i. 45.

§ *Nicholſon's Journal*, ii. 8.

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

It diſſolves alſo a little carbon: for azotic gas obtained from animal ſubſtances, which contain a great deal of azot, when confined long in jars, depoſites on the ſides of them a black matter which has the properties of carbon*.

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

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

51 Production of nitric acid.

Azotic gas is capable of combuſtion. Take a glaſs tube, the diameter of which is about the ſixth part of an inch; ſhut one of its ends with a cork, through the middle of which paſſes a ſmall wire with a ball of metal at each end. Fill the tube with mercury, and then plunge its open end into a baſon of that fluid. Throw up into the tube as much of a mixture, compoſed of 13 parts of azotic and 87 parts of oxygen gas, as will fill 3 inches. Through this gas make, by means of the wire in the cork, a number of electric exploſions paſs. The volume of gas gradually diminiſhes, and in its place there is found a quantity of *nitrous acid.* This acid, therefore, is compoſed of azot and oxygen: and theſe two ſubſtances are capable of combining, or, which is the ſame thing, azotic gas is capable of combuſtion in the temperature produced by electricity, which we know to be pretty high. The combuſtibility of azotic gas, and the nature of the product, was firſt diſcovered by Mr Cavendiſh, and communicated to the Royal Society on the 2d of June 1785 (u).

52 Attempts to decompoſe azot

The affinities of azot are ſtill unknown. It has never yet been decompounded, and muſt therefore, in the preſent ſtate of our knowledge, be conſidered as a ſimple ſubſtance. Dr Prieſtley, who obtained azotic gas at a very early period of his experiments, conſidered it as a compound of oxygen gas and phlogiſton, and for that reaſon gave it the name of *phlogiſticated air.* According to the theory of Stahl, which was then univerſally prevalent, he conſidered combuſtion as merely the ſeparation of phlogiſton from the burning body. To this theory he made the following addition: Phlogiſton is ſeparated during combuſtion by means of chemical affinity: *Air* (that is, *oxygen gas*) has a ſtrong affinity for phlogiſton: Its preſence is neceſſary during combuſtion, becauſe it combines with the phlogiſton as it ſeparates from the combuſtible; and it even contributes by its affinity to produce that ſeparation: The moment the air has combined with as much phlogiſton as it can receive, or, to uſe a chemical term, the moment it is *ſaturated* with phlogiſton, combuſtion neceſſarily ſtops, becauſe no more phlogiſton can leave the combuſ-

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(s) See his theſis *De Aere Mephitico*, publiſhed in 1772.—" Sed aer ſalubris et purus reſpiratione animali non modo ex parte fit mephiticus ſed et *aliam indolis ſuæ mutationem inde patitur.* Poſtquam enim omnis aer mephiticus (carbonic acid gas) ex eo, ope lixivii cauſtici ſecretus et abductus fuerit, *qui tamen reſtat* nullo modo ſalubrior inde evadit; nam quamvis nullam ex aqua calcis præcipitationem faciat haud minus quam antea *et flammam et vitam extinguit.* Page 17.

" Aer qui per carbones ignitos folle adactus fuit, atque deinde ab omni aere mephitico *(carbonic acid gas)* expurgatus, malignus tamen adhuc reperitur et omnino ſimilis eſt ei qui reſpiratione inquinatur. Immo ab experimentis patet hanc ſolam eſſe aeris mutationem quæ inflammationi adſcribi poteſt. Si enim accenditur materies quælibet quæ ex phlogiſto et baſi fixa atque ſimplici conſtat, *aer inde natus ne minimam aeris mephitici quantitatem in ſe continere videtur.* Sic aer in quo ſulphur aut phoſphorus urinæ combuſtus fuit, licet maxime malignus, calcem tamen ex aqua minime præcipitat. Interdum quidem ſi ex phoſphoro natus fuerit, nubeculam aquæ calcis inducit ſed tenuiſſimam, nec aeri mephitico attribuendam, ſed potius acido illi quod in phoſphoro ineſt, et quod, ut experimenta docuerunt, hoc ſingulari dote pollet." Page 19.

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

(u) It is remarkable enough, that the acidity of nitric acid was aſcribed by Mayow, in 1674, to the preſence of oxygen. *Indoles cauſtica ſpiritus nitri* (ſays he) *a particulis ejus igneo-aereis provenit.* Tract. p. 19.

combuſtible (v): Air ſaturated with phlogiſton is azotic gas. This was a very ingenious theory, and, when Dr Prieſtley publiſhed it, exceedingly plauſible. A great number of the moſt eminent chemiſts accordingly embraced it: But it was ſoon after diſcovered, that during combuſtion the quantity of air, inſtead of increaſing, as it ought to have done, had phlogiſton been added to it, actually diminiſhed both in volume and weight. There was no proof, therefore, that during combuſtion any ſubſtance whatever combined with air, but rather the contrary. It was diſcovered alſo, that a quantity of air combined with the burning ſubſtance during combuſtion, as we have ſeen was the caſe with ſulphur, phoſphorus, carbon, and hydrogen; and that this air had the properties of oxygen gas. Theſe diſcoveries entirely overthrew the evidence on which Dr Prieſtley's theory was founded: accordingly, as no attempt to decompound azot has ſucceeded, it has been given up by almoſt every chemiſt except Dr Prieſtley himſelf. Atmoſpheric air, as Scheele firſt proved, is compoſed of about 27 parts of oxygen and 73 of azotic gas. During combuſtion, the oxygen is abſtracted and the azotic gas remains behind.

53 Unſucceſsful.

La Metherie made an attempt to prove that azot was compoſed of oxygen and carbon (w). He took a bit of burning charcoal, extinguiſhed it in mercury, and then plunged it while hot into oxygen gas. On being plunged into water, one fourth of the gas was diſengaged, and part of it was found to conſiſt of azotic gas. From this he concluded that he had formed azotic gas by combining oxygen and carbon: But it was proved by Mr Lavoiſier, beyond the poſſibility of doubt, that oxygen and carbon form carbonic acid gas. They cannot then certainly form azot; for two contradictory facts cannot both be true. There muſt then have been ſomething overlooked in the experiment. Indeed the experiment itſelf does not warrant the concluſion which De La Metherie drew from it. He did not aſcertain whether the weight of the charcoal was diminiſhed; and, beſides, there was azot mixed with the oxygen gas which he employed, as he himſelf has informed us: And how was it poſſible for him to admit the charcoal into water without, at the ſame time, admitting ſome atmoſpherical air?

We have now deſcribed all the combuſtibles which are at preſent reckoned ſimple, except the metals. We have found, that during combuſtion all of them combine with oxygen; that no part of them is diſengaged, no part of them loſt: we have therefore concluded, that the combuſtion of theſe ſubſtances is nothing elſe but the act of their uniting with oxygen. We have ſeen, however, that none of them, except phoſphorus, was capable of uniting with oxygen at the common temperature of the atmoſphere; that, in order to produce the union, heat was neceſſary, and that the degree of this heat was different for each. Hydrogen required a red heat, and azot a ſtill greater. We have ſeen, too, that during theſe combinations a quantity of heat and light eſcaped. Now, why is heat neceſſary for theſe combinations? and whence come the heat and the light which we perceive during the combuſtion of theſe bodies? Theſe queſtions are of the higheſt importance, and can only be anſwered by a particular inveſtigation of the nature and properties of heat and light. This inveſtigation we ſhall attempt, as ſoon as we have deſcribed the *metals* and *earths*, which form the ſubject of the two following chapters.

Chap. III. *Of* Metals.

54 Properties of metals.

Metals may be conſidered as the great inſtruments of all our improvements: Without them, many of the arts and ſciences could hardly have exiſted. So ſenſible were the ancients of their great importance, that they raiſed thoſe perſons who firſt diſcovered the art of working them to the rank of deities. In chemiſtry, they have always filled a conſpicuous ſtation: at one period the whole ſcience was confined to them; and it may be ſaid to have owed its very exiſtence to a rage for making and tranſmuting metals.

55 Luſtre.

1. One of the moſt conſpicuous properties of the metals is a particular brilliancy which they poſſeſs, and which has been called the *metallic luſtre.* This proceeds from their reflecting much more light than any other body; a property which ſeems to depend partly on the cloſeneſs of their texture. This renders them peculiarly proper for mirrors, of which they always form the baſis.

56 Opacity.

2. They are abſolutely opaque, or impervious to light, even after they have been reduced to very thin plates. Silver leaf, for inſtance, $\frac{1}{160000}$ of an inch thick, does not permit the ſmalleſt ray of light to paſs throught it. Gold, however, may be rendered tranſparent; for gold leaf, $\frac{1}{180000}$ of an inch thick, tranſmits light of a lively green colour*. And it is not improbable that all the other metals, as Sir Iſaac Newton ſuppoſed, would become tranſparent, if they could be reduced to a ſufficient degree of thinneſs. It is to this opacity that a part of the excellence of the metals, as mirrors, is owing; their brilliancy alone would not qualify them for that purpoſe.

* *Nicholſon's Notes on Fourcroy.*

57 Fuſibility.

3. They may be melted by the application of heat, and even then ſtill retain their opacity. This property enables us to caſt them in moulds, and then to give them any ſhape we pleaſe. In this manner many elegant iron utenſils are formed.

58 Gravity.

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

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

59 Malleability.

6. But one of their moſt important properties is *malleability;* by which is meant the capacity of being extended and flattened when ſtruck with a hammer. This property enables us to give the metallic body any form we think proper, and thus renders it eaſy for us to

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(v) This ingenious theory was firſt conceived by Dr Rutherford, as appears from the following paſſage of his theſis. "Ex iiſdem etiam deducere licet quod aer ille malignus (azotic gas) componitur ex *aere atmoſpherico cum phlogiſto unito et quaſi ſaturato.* Atque idem confirmatur eo, quod aer qui metallorum calcinationi jam inſerviit, et phlogiſton ab iis abripuit, ejuſdem plane ſit indolis." *De aere Mephitico,* p. 20.

(w) Or rather of *hydrogen,* for he conſidered carbon itſelf as a compound.

to convert them into the various inſtruments for which we have occaſion. All metals do not poſſeſs this property; but it is remarkable that almoſt all thoſe which were known to the ancients have it. Heat increaſes this property conſiderably.

60 Ductility.

7. Another property which is alſo wanting in many of the metals, is *ductility*; by which we mean the capacity of being drawn out into wire by being forced through holes of various diameters. This property has by ſome been called *tenacity*; and it doubtleſs depends upon the tenacity of the various metals.

61 Calcination

8. When expoſed to the action of heat and air, moſt of the metals loſe their luſtre, and are converted into earthy-like powders of different colours and properties, according to the metal and the degree of heat employed. Several of the metals even take fire when expoſed to a ſtrong enough heat; and after combuſtion the reſiduum is found to be the very ſame earthy-like ſubſtance. If any of theſe *calces*, as they are called, be mixed with charcoal-powder, and expoſed to a ſtrong heat in a proper veſſel, it is changed again to the metal from which it was produced. From theſe phenomena Stahl concluded, that metals were compoſed of *earth* and *phlogiſton*. He was of opinion that there was only one primitive earth, which not only formed the baſis of all thoſe ſubſtances known by the name of earths, but the baſis alſo of all the metals. He found, however, that it was impoſſible to combine any mere earth with phlogiſton; and concluded, therefore, with Becher, that there was another principle beſides earth and phlogiſton, which entered into the compoſition of the metals. To this principle Becher gave the name of *mercurial earth*, becauſe, according to him, it exiſted moſt abundantly in *mercury*. This principle was ſuppoſed to be very volatile, and therefore to fly off during calcination: and ſome chemiſts even affirmed that it might be obtained in the ſoot of thoſe chimneys under which metals have been calcined.

62 Stahl's theory of the compoſition of metals

63 Defective.

A ſtriking defect was ſoon perceived in this theory. The original metal may again be produced by heating its calx along with ſome other ſubſtance which contains phlogiſton: now, if the mercurial earth flies off during combuſtion, it cannot be neceſſary for the formation of complete metals, for they may be produced without it: if, on the contrary, it adheres always to the calx, there is no proof of its exiſtence at all. Chemiſts, in conſequence of theſe obſervations, found themſelves obliged to diſcard the mercurial principle altogether, and to conclude that metals were compoſed of earth only, united to phlogiſton. But if this be really the caſe, how comes it that theſe two ſubſtances cannot be united by art? Henkel was the firſt who attempted to ſolve this difficulty. According to him, earth and phlogiſton are ſubſtances of ſo oppoſite a nature, that it is exceedingly difficult, or rather it has been hitherto impoſſible, for us to commence their union; but after it has been once begun by nature, it is an eaſy matter to complete it. No calcination has hitherto deprived the metals of all their phlogiſton; ſome ſtill adheres to the calces. It is this remainder of phlogiſton which renders it ſo eaſy to reſtore them to their metallic ſtate. Were the calcination to be continued long enough to deprive them altogether of phlogiſton, they would be reduced to the ſtate of other earths; and then it would be equally difficult to convert them into metals, or, to uſe a chemical term, to *reduce* them. Accordingly we find that the more completely a calx has been calcined, the more difficult is its reduction. This explanation was favourably received. But after the characteriſtic properties of the various *earths* had been aſcertained, and the calces of metals were accurately examined, it was perceived that the calces differed in many particulars from all the *earths*, and from one another. To call them all the ſame ſubſtance, then, was to go much farther than either experiment or obſervation would warrant, or, rather, it was to declare open war againſt both experiment and obſervation. It was concluded, therefore, that each of the metals was compoſed of a peculiar *earthy ſubſtance* combined with phlogiſton. For this great improvement in accuracy, chemiſtry is chiefly indebted to Bergman.

64 Improved by Henkel.

65 Farther improved.

66 Still imperfect.

But there were ſeveral phenomena of calcination which had all this time been unaccountably overlooked. The calces are all conſiderably heavier than the metals from which they are obtained. Boyle had obſerved this circumſtance, and had aſcribed it to a quantity of *fire* which, according to him, became fixed in the metal during the proceſs*. But ſucceeding chemiſts paid little attention to it, or to the action of air, till Mr Lavoiſier publiſhed his celebrated experiments on calcination, in the Memoirs of the Paris Academy for 1774. He put eight ounces of *tin* into a large glaſs retort, the point of which was drawn out into a very ſlender tube to admit of eaſy fuſion. This retort was heated ſlowly till the tin began to melt, and then ſealed hermetically. This heat was applied to expel ſome of the air from the retort: without which precaution it would have expanded and burſt the veſſel. The retort, which was capable of containing 250 cubic inches, was then weighed accurately, and placed again upon the fire. The tin ſoon melted, and a pellicle formed on its top, which was gradually converted into a grey powder, that ſunk by a little agitation to the bottom of the liquid metal: in ſhort, the tin was partly converted into a *calx*. This proceſs went on for three hours; after which the calcination ſtopped, and no farther change could be produced on the metal. The retort was then taken from the fire, and found to be preciſely of the ſame weight as before the operation. It is evident, then, that no new ſubſtance had been introduced, and that therefore the increaſed weight of calces cannot, as Boyle ſuppoſed, be owing to the fixation of fire (x).

67 Refuted by Lavoiſier.

When the point of the retort was broken, the air ruſhed in with a hiſſing noiſe, and the weight of the retort was increaſed by ten grains. Ten grains of air, therefore, muſt have entered, and, conſequently, preciſely that quantity muſt have diſappeared during the calcination. The metal and its calx being weighed, were found juſt ten grains heavier than before: therefore, the air which diſappeared was abſorbed by the metal: and as that part of the tin which remained in a metallic ſtate was unchanged, it is evident that this air

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* *Fire and flame weighed.*

(x) This experiment had been performed by Boyle with the ſame ſucceſs. He had drawn a wrong concluſion from not attending to the ſtate of the air of the veſſel. *Shaw's Boyle*, II. 394.

air muſt have united with the calx. The increaſe of weight, then, which metals experience during calcination, is owing to their uniting with air (y). But all the air in the veſſel was not abſorbed, and yet the calcination would not go on. It is not the whole, then, but ſome particular part of the air which unites with the calces of metals. By the ſubſequent diſcoveries of Prieſtley, Scheele, and Lavoiſier himſelf, it was aſcertained, that the reſiduum of the air, after calcination has been performed in it, is always pure azotic gas: It follows, therefore, that it is only the *oxygen* which combines with calces; and that a metallic calx is not a ſimple ſubſtance, but a compound. Mr Lavoiſier obſerved, that the weight of the calx was always equal to that of the metal employed, together with that of the oxygen abſorbed. It became a queſtion then, Whether metals, during calcination, loſt any ſubſtance, and conſequently, whether they contained any phlogiſton? Mr Lavoiſier accordingly propoſed this queſtion; and he anſwered it himſelf by a number of accurate experiments and ingenious obſervations. Metals cannot be calcined excepting in contact with oxygen, and in proportion as they combine with it. Conſequently they not only abſorb oxygen during their calcination, but that abſorption is abſolutely neceſſary to their aſſuming the form of a calx. If the calx of mercury be heated in a retort, to which a pneumatic apparatus is attached, to the temperature of 1200°, it is converted into pure mercury; and, at the ſame time, a quantity of oxygen ſeparates from it in a gaſeous form. As this proceſs was performed in a cloſe veſſel, no new ſubſtance could enter: The calx of mercury, then, was reduced to a metallic ſtate without phlogiſton. The weights of the metal and the oxygen gas are together juſt equal to that of the calx; the calx of mercury, therefore, muſt be compoſed of mercury and oxygen; conſequently there is no reaſon whatever to ſuppoſe that mercury contains phlogiſton. Its calcination is merely the act of uniting it with oxygen (z). The calces of lead, ſilver, and gold, may be decompoſed exactly in the ſame manner; and Mr Van Marum, by means of his great electrical machine, decompoſed alſo thoſe of tin, zinc, and antimony, and reſolved them into their reſpective metals and oxygen *. The ſame concluſions, therefore, muſt be drawn with reſpect to theſe metals. All the metallic calces may be decompoſed by preſenting to them ſubſtances which have a greater affinity for oxygen than they have. This is the reaſon that charcoal-powder is ſo efficacious in reducing them: and if they are mixed with it, and heated in a proper veſſel, furniſhed with a pneumatic apparatus, it will be eaſy to diſcover what paſſes. During the reduction, a great deal of carbonic acid gas comes over, which, together with the metal, is equal to the weight of the calx and the charcoal: it muſt therefore contain all the ingredients; and we know that carbonic acid gas is compoſed of carbon and oxygen. During the proceſs, then, the oxygen of the calx combined with charcoal and the metal remained behind. It cannot be doubted, therefore, that all the metallic calces are compoſed of the entire metals combined with oxygen; and that calcination, like combuſtion, is merely the act of this combination. All metals, then, in the preſent ſtate of chemiſtry, muſt be conſidered as ſimple ſubſtances; for they have never yet been decompounded.

68 Oxide and oxidation, what.

The words *calx* and *calcination* are evidently improper, as they convey falſe ideas; we ſhall therefore afterwards employ, inſtead of them, the words *oxide* and *oxidation*, which were invented by the French chemiſts. A metallic *oxide* ſignifies a metal united with oxygen; and *oxidation* implies the act of that union.

Metals are capable of uniting with oxygen in different proportions, and, conſequently, of forming each of them different oxides. Theſe are diſtinguiſhed from one another by their colour. One of the oxides of iron, for inſtance, is of a green colour; it is therefore called the *green oxide;* the other, which is brown, is called the *brown oxide.*

69 Number of metals.

The metals at preſent amount to 21; only 11 of which were known before the year 1730. Their names are gold, ſilver, platinum, mercury, copper, iron, tin, lead, zinc, antimony, biſmuth, arſenic, cobalt, nickel, mangancſe, tungſten, molybdenum, uranium, tellurium, titanium, chromum.

The firſt eight of theſe were formerly called *metals* by way of eminence, becauſe they are poſſeſſed either of malleability or ductility, or of both properties together; the reſt were called *ſemimetals*, becauſe they are brittle. But this diſtinction is now pretty generally laid aſide; and, as Bergman obſerves, it ought to be ſo altogether, as it is founded on a falſe hypotheſis, and conveys very erroneous ideas to the mind. The firſt

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* *Jour. de Phyſ.* 1785.

(y) It is remarkable that John Rey, a phyſician of Perigord, had aſcribed it to this very cauſe as far back as the year 1630: But his writings had excited little attention, and had ſunk into oblivion, till after his opinion had been inconteſtibly proved by Lavoiſier. Mayow alſo, in the year 1674, aſcribed the increaſe of weight to the combination of metals with oxygen. *Quippe vix concipi poteſt* (ſays he), *unde augmentum illud antimonii (calcinati) niſi a particulis nitro-aereis igneiſque inter calcinandum* FIXIS *procedat.* Tract. p. 28. *Plane ut antimonii fixatio non tam a ſulphuris ejus externi aſſumptione, quam particulis nitro-aereis, quibus flamma nitri abundat* EI INFIXIS *provenire videatur.* Ibid. p. 29.

(z) This experiment was performed by Mr Bayen in 1774. This philoſopher perceived, earlier than Lavoiſier, that all metals did not contain phlogiſton. " Ces experiences (ſays he) vont nous detromper. Je ne tiendrai plus le langage des diſciples de Stahl, qui ſeront forcés de reſtreindre la doctrine ſur le phlogiſtique, ou d'avouer que les precipités mercurials, dont je parle, ne ſont pas des chaux metalliques, ou enfin qu'il y a des chaux qui peuvent ſe reduire ſans le concours du phlogiſtique. Les experiences que j'ai faites me force de conclure que dans la chaux mercuriale dont je parle, le mercure doit ſon *etat calcoire, non à la perte du phlogiſtique* qu'il n'a pas eſſuyée, *mais a ſa combinaiſon intime avec le fluide elaſtique,* dont le poids ajouté a celui du mercure eſt la ſeconde cauſe de l'augmentation de peſanteur qu'on obſerve dans les precipités que j'ai ſoumis a l'examen." *Jour. de Phyſ.* 1774, pages 288, 295. It was in conſequence of hearing Bayen's paper read that Lavoiſier was induced to turn his attention to the ſubject.

four metals were formerly called *noble* or *perfect metals*, becauſe their oxides are reducible by the mere application of heat; the next four were *imperfect metals*, becauſe their oxides were thought not reducible without the addition of ſome combuſtible ſubſtance; but this diſtinction alſo is now very properly exploded.

Sect. I. *Of Gold.*

70 Properties of gold.

Gold ſeems to have been known from the very beginning of the world. Its properties and its ſcarcity have rendered it more valuable than any other metal.

It is of an orange red, or reddiſh yellow colour, and has no perceptible taſte or ſmell.

No other ſubſtance can be compared with it in ductility and malleability. It may be beaten out into leaves ſo thin that one grain of gold will cover $56\frac{3}{4}$ ſquare inches. Theſe leaves are only $\frac{1}{282000}$ of an inch thick. But the gold leaf with which ſilver wire is covered has only $\frac{1}{12}$ of that thickneſs. An ounce of gold, upon ſilver wire, is capable of being extended more than 1300 miles in length.

Its tenacity is ſuch, that a gold wire $\frac{1}{10}$ of an inch in diameter is capable of ſupporting a weight of 500 pounds without breaking *.

* Macquer's Dict.

Its hardneſs is 6 (A); its ſpecific gravity 19,3. It melts at 32° of Wedgewood's pyrometer (B). When melted, it aſſumes a bright bluiſh green colour. It expands in the act of fuſion, and conſequently contracts while becoming ſolid more than moſt metals; a circumſtance which renders it leſs proper for caſting into moulds.

It requires a very violent heat to volatilize it; it is therefore, to uſe a chemical term, exceedingly *fixed.* Boyle and Kunkel kept it for ſome months in a glaſshouſe furnace, and yet it underwent no change: nor did it loſe any perceptible weight, after being expoſed for ſome hours to the utmoſt heat of Mr Parker's lens †. Mr Lavoiſier, however, obſerved, that a piece of ſilver, held over gold melted by a fire blown by oxygen gas, which produces a much greater heat than common air, was ſenſibly *gilt:* Part of the metal, then, muſt have been volatilized.

† Kirwan's Miner. i. 92.

After fuſion, it is capable of aſſuming a cryſtalline form. Tillet and Mongez obtained it in ſhort quadrangular pyramidal cryſtals.

71 Oxidation of gold.

It is capable of combining with oxygen, and forming an *oxide of gold.* There are two methods of producing this combination, *the application of heat*, and *ſolution in acids.* When it is expoſed to a very violent heat in contact with air, gold abſorbs oxygen. But the temperature muſt be very high; ſo high, indeed, that hardly any certain method of oxidating gold by heat is known, except by electricity. When the electric exploſion is tranſmitted through gold leaf placed between two plates of glaſs, or when a ſtrong charge is made to fall on a gilded ſurface—in both caſes the metal is oxidated, and aſſumes a purple colour. It has been ſaid alſo, that the ſame effect has been produced by a very violent fire; but few of the inſtances which have been adduced are well authenticated.

The other method of oxidating gold is much eaſier. For this purpoſe, equal parts of nitric and muriatic acids are mixed together (C) and poured upon gold; an effervеſcence takes place, the gold is gradually diſſolved, and the liquid aſſumes a yellow colour. It is eaſy to ſee in what manner this ſolution is produced. No metal is ſoluble in acids till it has been reduced to the ſtate of an oxide. There is a ſtrong affinity between the oxide of gold and muriatic acid. The nitric acid furniſhes oxygen to the gold, and the muriatic acid diſſolves the oxide as it forms. When nitric acid is deprived of the greater part of its oxygen, it aſſumes a gaſeous form, and is then called *nitrous gas.* It is the emiſſion of this gas which cauſes the effervеſcence. The oxide of gold may be precipitated from the nitro-muriatic acid by pouring in a little potaſs diſſolved in water, or, which is much better, a little lime; both of which have a ſtronger affinity for muriatic acid than the oxide has. This oxide is of a yellow colour.

It is probable that gold is capable of two different degrees of oxidation, and of forming two different oxides, *the yellow* and *the purple:* But neither the quantity of oxygen contained in theſe oxides, nor the differences between them, have been accurately aſcertained. The oxides of gold may be decompoſed in cloſe veſſels by the application of heat. The gold remains fixed, and the oxygen aſſumes the gaſeous form. They may be decompoſed, too, by all the ſubſtances which have a ſtronger affinity with oxygen than gold has. The affinities of the oxides of gold, according to Bergman *, are as follows:

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

Muriatic acid,
Nitro-muriatic,
Nitric,
Sulphuric,
Arſenic,
Fluoric,
Tartarous,

(A) We have borrowed from Mr Kirwan the method of denoting the different degrees of hardneſs by figures, which we think a great improvement. Theſe figures will be underſtood by Mr Kirwan's own explanation, which we here ſubjoin.

3, Denotes the hardneſs of chalk.
4, A ſuperior hardneſs, but yet what yields to the nail.
5, What will not yield to the nail, but eaſily, and without grittineſs, to the knife.
6, That which yields more difficultly to the knife.
7, That which ſcarcely yields to the knife.
8, That which cannot be ſcraped by a knife, but does not give fire with ſteel.
9, That which gives a few feeble ſparks with ſteel.
10, That which gives plentiful lively ſparks. *Kirwan's Mineralogy*, I. 38.

(B) According to the calculation of the Dijon academicians, it melts at 1298° Fahr.; according to Bergman, at 1301°.

(C) This mixture, from its property of diſſolving gold, was formerly called *aqua regia* (for gold, among the alchymiſts, was the king of metals); it is now called *nitro-muriatic acid.*

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

Gold is not changed either by air or water. It does not ſeem capable of combining either with ſulphur or carbon. Mr Pelletier combined it with phoſphorus, by melting together in a crucible half an ounce of gold and an ounce of phoſphoric glaſs (E), ſurrounded with charcoal. The *phoſphuret of gold* thus produced was brittle, whiter than gold, and had a cryſtallized appearance. It was compoſed of 23 parts of gold and one of phoſphorus *. He formed the ſame compound by dropping ſmall pieces of phoſphorus into gold in fuſion †.

72 Phoſphuret of gold.

* *Ann. de Chim.* i. 71.

† *Ibid.* xiii. 104.

Gold is alſo capable of combining with moſt of the metals. Its affinities are placed, by Bergman, in the following order:

Mercury,
Copper,
Silver,
Lead,
Biſmuth,
Tin,
Antimony,
Iron,
Platinum,
Zinc,
Nickel,
Arſenic,
Cobalt,
Mangneſe;
Phoſphorus?
Sulphurets of alkalies.

Sect. II. *Of Silver.*

73 Properties of ſilver.

Silver appears to have been known almoſt as early as gold. It is a metal of a ſhining white colour, without either taſte or ſmell.

It is the moſt malleable and ductile of all metals except gold, and perhaps platinum. It can be reduced to leaves about $\frac{1}{100000}$ of an inch thick, and drawn into wire much finer than a human hair.

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

Its hardneſs is 6,5 §. Its ſpecific gravity, before hammering, is 10,474; after hammering, 10,510 ||: for it is remarkable that the ſpecific gravity of almoſt all the metals is increaſed by hammering.

‡ *Macquer's Dict.*

§ *Kirwan.*

|| *Briſſon.*

It continues melted at 28° Wedgewood (F), but requires a greater heat to bring it to fuſion ¶.

¶ *Kirwan's Mineral.* ii. 107.

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

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

74 Oxides of ſilver.

Silver may be combined with oxygen, and converted into an oxide by expoſure to a very violent heat. By this method Junker partly converted it into a *glaſs*; and Macquer, by expoſing it 20 times ſucceſſively to the heat of a porcelain furnace, obtained a *glaſs* (G) of an olive green colour *. The oxide of ſilver may alſo be formed by diſſolving the metal in an acid, and precipitating it from its ſolution by potaſs, lime, &c.: for, during its ſolution, the metal becomes oxidated. Little is known at preſent concerning the oxides of ſilver, nor whether there be more than two, the *black* and the *blue*. From the experiments of Wenzel and Bergman, it follows, that one oxide of ſilver is compoſed of about 90 parts of metal and 10 of oxygen †. The affinities of the oxides, according to Bergman, are as follows:

* *Macquer's Dict.*

† *Kirwan's Miner.* ii. 493.

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

75 Sulphuret of ſilver.

When ſilver is melted with ſulphur in a low red heat, it combines with it and forms *ſulphuret of ſilver*. It is very difficult to determine the proportion of the ingredients which enter into the compoſition of this ſubſtance, becauſe there is an affinity between ſilver and its ſulphuret, which diſpoſes them to combine together. The greateſt quantity of ſulphur which a given quantity of ſilver is capable of taking up is, according to Wenzel, $\frac{13}{150}$ ‡. Sulphuret of ſilver is of a black or very deep violet colour, brittle, and much more fuſible than ſilver. If ſufficient heat be applied, the ſulphur is volatilized, and the metal remains behind in a ſtate of purity.

‡ *Ibid.* 492.

76 Phoſphuret of ſilver.

If one ounce of ſilver, one ounce of phoſphoric glaſs, and two drams of charcoal, be mixed together, and heated in a crucible, *phoſphuret of ſilver* is formed. It is

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(D) Have the alkalies any affinity for the yellow oxide? Is not their affinity confined to the purple oxide alone? And does not this oxide act as an acid?

(E) Phoſphoric acid evaporated to dryneſs, and then fuſed.

(F) According to the Dijon academicians, it melts at 1044° Fahr.; according to Bergman, at 1000°.

(G) Metallic oxides, after fuſion, are called *glaſs*, becauſe they acquire a good deal of reſemblance, in ſome particulars, to common glaſs.

is of a white colour, and appears granulated, or as it were cryſtallized. It breaks under the hammer, but may be cut with a knife. It is compoſed of four parts of ſilver and one of phoſphorus. Heat decompoſes it by ſeparating the phoſphorus *. Pelletier has obſerved, that ſilver in fuſion is capable of combining with more phoſphorus than ſolid ſilver: for when phoſphuret of ſilver is formed by projecting phoſphorus into melted ſilver, after the crucible is taken from the fire a quantity of phoſphorus is emitted the moment the metal congeals †.

* *Pelletier, Ann de Chim.* i. 73.

† *Ibid.* xiii. 110.

Silver does not ſeem capable of combining with carbon.

77
Alloys of ſilver.

Silver is capable of combining with gold, and forming an *alloy* (H) compoſed of one part of ſilver and five of gold. That this is the proportion of the ingredients, was diſcovered by Homberg. He kept equal parts of gold and ſilver in gentle fuſion for a quarter of an hour, and found, on breaking the crucible, two maſſes; the uppermoſt of which was pure ſilver, the undermoſt the whole gold combined with $\frac{1}{6}$th of ſilver. Silver, however, may be mixed with gold in almoſt any proportion. But there is a great difference between the mixture of two ſubſtances and their chemical combination. Metals which melt nearly at the ſame temperature may be mixed from that very circumſtance in any proportion; but ſubſtances can combine chemically only in one proportion. This obſervation, which is certainly of importance, was firſt made, as far as we know, by Mr Keir ‡. The alloy of ſilver and gold is of a greeniſh colour; but its properties have not yet been accurately examined.

‡ *Tranſlation of Macquer's Dict.* art. *Alloy.*

78
Becomes tarniſhed by expoſure.

Silver is not effected by water, nor by expoſure to the air; but Mr Prouſt has remarked, that when long expoſed in places frequented by men, as in churches, theatres, &c. it acquires a covering of a violet colour, which deprives it of its luſtre and malleability. This covering, which forms a thin layer, can only be detached from the ſilver by bending it, or breaking it in pieces with a hammer It was examined by Mr Prouſt, and found to be *ſulphuret of ſilver*. He accounts for this tranſition of the ſilver into a *ſulphuret*, by ſuppoſing that a quantity of ſulphur is conſtantly formed and exhaled by living bodies *.

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

79
Its affinities.

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

Lead,
Copper,
Mercury,
Biſmuth,
Tin,
Gold,
Antimony,
Iron,
Mangancſe,
Zinc,
Arſenic,
Nickel,
Platinum,
Sulphurets of alkalies,
Sulphur,
Phoſphorus.

SECT. III. *Of Platinum.*

THE metals hitherto deſcribed have been known to mankind from the earlieſt ages, and have been always in high eſtimation on account of their beauty, ſcarcity, ductility, and indeſtructibility. But platinum, though perhaps inferior to them in none of theſe qualities, and certainly far ſuperior in others, was unknown, as a diſtinct metal, before the year 1752 (I).

80
Diſcovery of platinum.

It has been found only in America, in Choco in Peru, and in the mine of Santa Fe, near Carthagena. The workmen of theſe mines muſt no doubt have been early acquainted with it; but they ſeem to have paid very little attention to it. It was unknown in Europe till Mr Wood brought ſome of it from Jamaica in 1741. Soon after it was noticed by Don Antonio de Ulloa, a Spaniſh mathematician, who had accompanied the French academicians to Peru in their voyage to meaſure a degree of the meridian. In the year 1752 it was examined by Scheffer of Sweden, and diſcovered by him to be a new metal, approaching very much to the nature of gold, and therefore called by him *aurum album*,

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

(I) Father Cortinovis, indeed, has attempted to prove that this metal was the *electrum* of the ancients. - See the *Chemical Annals of Brugnatelli*, 1790. That the electrum of the ancients was a metal, and a very valuable one, is evident from many of the ancient writers, particularly Homer. The following lines of Claudian are alone ſufficient to prove it:

Atria cinxit ebur, trabibus ſolidatur ahenis
Culmen et in celſas ſurgunt electra *columnas.* L. I. v. 164.

Pliny gives us an account of it in his Natural Hiſtory. He informs us that it was a compoſition of ſilver and gold; and that by candle-light it ſhone with more ſplendor than ſilver. The ancients made cups, ſtatues, and columns of it. Now, had it been our platinum, is it not rather extraordinary that no traces of a metal, which muſt have been pretty abundant, ſhould be perceptible in any part of the old continent?

As the paſſage of Pliny contains the fulleſt account of electrum to be found in any ancient author, we ſhall give it in his own words, that every one may have it in his power to judge whether or not the deſcription will apply to the platinum of the moderns.

"Omni auro ineſt argentum vario pondere.—Ubicunque quinta argenti portio eſt, *electrum* vocatur. Scrobes eæ reperiuntur in Canalienſi. Fit et cura electrum argento addito. Quod ſi quintam portionem exceſſit, incudibus non reſtitit. Et electro auctoritas, Homero teſte, qui Menelai regiam auro, electro, argento, ebore fulgere tradit. Minervæ templum habet Lindos inſulæ Rhodiorum in quo Helena ſacravit calicem ex electro.—Electri natura eſt ad lucernarum lumina clarius argento ſplendere. Quod eſt nativum, et venena deprehendit. Namque diſcurrunt in calicibus arcus cœleſtibus ſimiles cum igneo ſtridore, et geminaratione prædicunt."—*Lib.* xxxiii. *cap.* iv.

album, white gold. Soon after it was examined by Lewis, Margraf, Macquer and Beaumé, Morveau, Bergman, and many other illuſtrious chemiſts.

81
Its properties.

Platinum, when pure, is of a white colour like ſilver, but not ſo bright (κ). It has no taſte nor ſmell.

It is both ductile and malleable; but the preciſe degree has not yet been aſcertained. It has been drawn into a wire of $\frac{1}{1910}$ of an inch in diameter. This wire admitted of being flattened, and had more ſtrength than a wire of ſilver or gold of the ſame ſize *.

* *Withering*

It is exceedingly difficult to fuſe it. Macquer and Beaumé ſucceeded by means of a powerful burning-glaſs. It melts more eaſily when mixed with other ſubſtances. Its fixity is ſtill greater than its infuſibility. If the ſtrongeſt fires cannot melt it, much leſs can they volatilize it.

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

† *Kirwan's Miner.* ii. 103.

Some of the experiments which have been made on platinum ſeem to prove that it may be oxidated by the application of a violent heat. The oxide of this metal may be eaſily formed by diſſolving platinum in nitro-muriatic acid, and precipitating it by means of an earth or potaſs. The various oxides of platinum have never yet been examined with accuracy. The one at preſent beſt known poſſeſſes, as Mr Berthollet has proved, the properties of an acid.

The *ſulphuret of platinum* is unknown.

82
Phoſphuret of platinum.

By mixing together an ounce of platinum, an ounce of phoſphoric glaſs, and a dram of powdered charcoal, and applying a heat of about 32° Wedgewood, Mr Pelletier formed a *phoſphuret of platinum* weighing more than an ounce. It was partly in the form of a button, and partly in cubic cryſtals. It was covered above by a blackiſh glaſs. It was of a ſilver white colour, very brittle, and hard enough to ſtrike fire with ſteel. When expoſed to a fire ſtrong enough to melt it, the phoſphorus was diſengaged, and burnt on the ſurface ‡.

‡ *Ann. de Chim.* i. 71.

He found alſo, that when phoſphorus was projected on red hot platinum, the metal inſtantly fuſed and formed a phoſphuret. As heat expels the phoſphorus, Mr Pelletier has propoſed this as an eaſy method of purifying platinum §.

§ *Ibid.* xiii. 105.

Platinum does not ſeem capable of combining with carbon.

It is not in the leaſt affected by the action of water or air.

83
Alloys of platinum.

1. When gold and platinum are expoſed to a ſtrong heat, they combine, and form an alloy of a much whiter colour, but nearly as ductile as gold. The proportions of the ingredients are not known. When $\frac{1}{47}$ only of the alloy is platinum, the gold is ſcarcely altered in colour.

2. Whether ſilver and platinum combine chemically has not yet been properly aſcertained. When fuſed together (for which a very ſtrong heat is neceſſary), they form a mixture, not ſo ductile as ſilver, but harder and leſs white. The two metals are ſeparated by keeping them for ſome time in the ſtate of fuſion; the platinum ſinking to the bottom from its weight. This circumſtance would induce one to ſuppoſe that there is very little affinity between them.

Sect. IV. *Of Mercury.*

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

84
Properties of mercury.

It is of a white colour, exactly like that of poliſhed ſilver. It has no taſte, but acquires a ſlight odour when rubbed between the hands.

Its ſpecific gravity is 13,568 *.

* *Briſſon.*

It differs from all other metals in always exiſting, at the common temperature of the atmoſphere, in a ſtate of fluidity. It freezes at -39° †; or, which is the ſame thing, it ceaſes to be a ſolid, and melts whenever it is placed in a temperature above -39°. It boils at the temperature of 600°.

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

From the experiments made on frozen mercury in Ruſſia, Hudſon's Bay, and Britain, we know that this metal, when ſolid, is malleable; but the extreme difficulty of examining it in that ſtate, on account of the lowneſs of the temperature, has rendered it hitherto impoſſible to aſcertain the preciſe degree either of its malleability, ductility, or hardneſs.

85
It forms three oxides;

Mercury is capable of combining with oxygen, and of forming *oxides*, differing from each other in the quantity of oxygen which they contain. The oxides of mercury, at preſent known, are the *black*, the *yellow*, and the *red*.

86
The black oxide,

1. When mercury is agitated for ſome time in contact with oxygen gas, or atmoſpheric air, it is partly converted into a greyiſh black powder, and at the ſame time part of the oxygen diſappears. This is the *black* oxide of mercury. It is not known how much oxygen it contains, nor even whether the whole of the mercury which compoſes it be actually combined with oxygen.

87
Yellow oxide,

2. The beſt way of forming the yellow oxide is to diſſolve mercury, either in boiling ſulphuric acid or in cold nitric acid. During its ſolution, it deprives theſe acids of juſt as much oxygen as is neceſſary to convert it into a yellow oxide; and if potaſs or lime be afterwards added to the ſolution, it precipitates, and may be obtained pure by waſhing it with water. It is a bright yellow-coloured powder, which acts very powerfully as an emetic. From the obſervations of Bergman, it appears that it is compoſed of about 96,8 parts of mercury, and 3,2 of oxygen ‡.

‡ *Kirwan's Miner.* ii. 489.

88
And red oxide.

3. The *red oxide* of mercury may be prepared, either by diſtilling nitric acid off the metal repeatedly, or by keeping mercury for a long time expoſed to a heat ſufficient to evaporate it while it is in contact with air. When formed by the firſt proceſs, it was formerly called *red precipitate;* when by the laſt, *precipitate per ſe.* It is a beautiful red powder, or rather ſmall red cryſtals, which have ſome eſcharotic qualities. When prepared by the ſecond proceſs, the heat muſt not be much below 600° nor much above 800°, otherwiſe no union would take place;

(κ) To this colour it owes its name. *Plata*, in Spaniſh, is *ſilver;* and *platina*, *little ſilver*, was the name firſt given to the metal. Bergman changed that name into *platinum*, that the Latin names of all the metals might have the ſame termination and gender. It was, however, firſt called *platinum* by Linnæus.

place; and it muſt be continued for ſome weeks. From the experiments of Mr Kirwan, it appears to contain 92,6 parts of mercury and 7,4 of oxygen*.

* *Kirwan's Miner.* ii. 439.

Theſe oxides may be decompoſed by the application of a heat amounting to 1200°. The oxygen flies off in the form of gas, and running mercury remains behind.

89
Their affinities.

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

Sebacic acid,
Muriatic,
Oxalic,
Succinic,
Arſenic,
Phoſphoric,
Sulphuric,
Benzoic (L)?
Saccholactic,
Tartarous,
Citric,
Sulphurous,
Nitric,
Fluoric,
Zoonic (M)?
Acetous,
Boracic,
Pruſſic,
Carbonic.

90
Black ſulphuret of mercury.

When two parts of mercury and three parts of flowers of ſulphur are triturated for ſome time together, or when equal parts of mercury and melted ſulphur are mixed together—they combine, and form a black powder, formerly called *ethiops mineral*, and now *black ſulphuret of mercury*.

91
Red ſulphuret.

When 300 grains of mercury and 68 of ſulphur, with a few drops of ſolution of potaſs to moiſten them, are triturated for ſome time in a porcelain cup by means of a glaſs peſtle, black oxide of mercury is produced. Add to this 160 grains of potaſs, diſſolved in as much water. Heat the veſſel containing the ingredients over the flame of a candle, and continue the trituration without interruption during the heating. In proportion as the liquid evaporates, add clear water from time to time, ſo that the oxide may be conſtantly covered to the depth of near an inch. The trituration muſt be continued about two hours; at the end of which time the mixture begins to change from its original black colour to a brown, which uſually happens when a large part of the fluid is evaporated. It then paſſes very rapidly to a red. No more water is to be added; but the trituration is to be continued without interruption. When the maſs has acquired the conſiſtence of a gelly, the red colour becomes more and more bright, with an incredible degree of quickneſs. The inſtant the colour has acquired its utmoſt beauty, the heat muſt be withdrawn, otherwiſe the red paſſes to a dirty brown. This red powder is the red ſulphuret of mercury, called formerly *cinnabar*, and, when reduced to a fine powder, *vermilion* (N). The proceſs above deſcribed has been lately diſcovered by Mr Kirchoff, and is by far the ſimpleſt and cheapeſt mode of forming red ſulphuret with which we are acquainted*. Count De Mouſſin Pouſchin has diſcovered, that its paſſing to a brown colour may be prevented by taking it from the fire as ſoon as it has acquired a red colour, and placing it for two or three days in a gentle heat, taking care to add a few drops of water, and to agitate the mixture from time to time. During this expoſure, the red colour gradually improves, and at laſt becomes excellent. He diſcovered alſo, that when this ſulphuret is expoſed to a ſtrong heat, it becomes inſtantly brown, and then paſſes into a dark violet; when taken from the fire it paſſes inſtantly to a beautiful carmine red†.

* *Nicholſon's Journ.* ii. 1.
† *Ibid.* p. 7.

The difference between theſe two ſulphurets has never yet been aſcertained. One would be apt to ſuſpect at firſt that the black ſulphuret conſiſts of the real ſulphuret of mercury combined with ſulphur; the red, of the ſulphuret of mercury combined with mercury, and that the real ſulphuret of mercury was not yet accurately known. But it cannot be doubted that, during the formation of the *red ſulphuret*, according to Kirchoff's proceſs, there is an abſorption of oxygen. The phenomena above deſcribed point out *that* almoſt inconteſtibly; and we obſerved, on attempting to repeat the experiment, that the black ſulphuret, during its trituration, emitted ſulphurated hydrogen gas. Perhaps, then, the mercury may be oxidated. We ſuſpected at firſt that part of the ſulphur might be converted into an acid; but on attempting an alteration of the proceſs, in conſequence of that ſuppoſition, we could not ſucceed.

The red ſulphuret of mercury is found naturally in ſeveral parts of the world. It uſed to be prepared by forming a black ſulphuret with three parts of ſulphur and one of mercury, and then ſetting fire to it. Part of the ſulphur is burnt, and there remains behind a violet-coloured body, which is powdered and put into a glaſs veſſel, to the bottom of which a red heat is applied. A reddiſh brown ſubſtance ſublimes, which is red *ſulphuret of mercury*; but its colour is not nearly equal to that which is prepared by Kirchoff's proceſs.

92
Phoſphuret of mercury.

Mr Pelletier, after ſeveral unſucceſsful attempts to form phoſphuret of mercury, at laſt ſucceeded by diſtilling a mixture of red oxide of mercury and phoſphorus. Part of the phoſphorus combined with the oxygen of the oxide, and was converted into an acid; the reſt combined with the mercury.

Phoſphuret of mercury is of a black colour, of a pretty ſolid conſiſtence, and capable of being cut with a knife. When expoſed to the air, it exhaled vapours of phoſphorus‡.

* *Ann. de Chim.* xiii. 122.

Mercury does not ſeem capable of combining with carbon.

93
Its amalgams.

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

1. The amalgam of gold forms very readily, becauſe there is a very ſtrong affinity between the two metals. If a bit of gold be dipped into mercury, its ſurface, by combining with mercury, becomes as white as ſilver. The

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(L) Benzoat of mercury is decompoſed by ſulphuric acid. *Tromſdorf, Ann. de Chim.* xi. 316.

(M) Zoonic acid decompoſes the acetite of mercury. *Berthollet.*

(N) The word *vermilion* is derived from the French word *vermeil*, which comes from *vermiculus* or *vermiculum*; names given in the middle ages to the *kermes* or *coccus ilicis*, well known as a red dye. *Vermilion* originally ſignified the red dye of the kermes. See *Beckmann's Hiſt. of Inventions*, ii. 180.

The eaſieſt way of forming this amalgam is to throw ſmall pieces of red hot gold into mercury. The proportions of the ingredients are not eaſily determined, becauſe the amalgam has an affinity both for the gold and the mercury; in conſequence of which they appear to combine in any proportion. Moſt probably it is compoſed of two parts of gold and one of mercury. The combination is formed moſt readily in theſe proportions; and if too much mercury be added, it may be ſeparated by filtration. The amalgam is of a white colour, and of the conſiſtence of butter*. This amalgam cryſtallizes in quadrangular priſms; which cryſtals, according to the Dijon academicians, are compoſed of ſix parts of mercury and one of gold. It is much uſed in gilding.

* Keir's Notes on Macquer's Dict. art. Amalgam.

2. The amalgam of ſilver is made in the ſame manner. It forms dendritical cryſtals, which, according to the Dijon academicians, contain eight parts of mercury and one of ſilver. Gellert was the firſt who remarked that its ſpecific gravity was greater than that of mercury, though that of ſilver be leſs.

3. Dr Lewis attempted to form an amalgam of platinum, but hardly ſucceeded after a labour which laſted for ſeveral weeks. Mr Morveau ſucceeded by means of heat†. But a much more expeditious method has been lately diſcovered by Count Mouſſin Pouſchin. He took a dram of the orange-coloured ſalt, compoſed of *oxide of platinum and ammonia* (o), and triturated it with an equal weight of mercury in a mortar of chalcedony. In a few minutes the ſalt became brown, and afterwards acquired a greeniſh ſhade. The matter was reduced to a very fine powder. Another dram of mercury was added, and the trituration continued: The matter became grey. A third dram of mercury began to form an amalgam; and ſix drams made the amalgam perfect. The whole operation ſcarce laſted 20 minutes. Mercury was added till it amounted to nine times the weight of the ſalt, and yet the amalgam continued very tenacious. It was eaſily ſpread out under the peſtle; it received the impreſſion of the moſt delicate ſeals, and had a very cloſe and brilliant grain. This amalgam is decompoſed, and the mercury paſſes to the ſtate of black oxide by the ſimple contact of ſeveral of the metals and a great number of animal matters. This effect even takes place on rubbing it between the fingers‡.

† Ann. de Chim. xxiv. 205.

‡ Ibid.

94
Affinities.

The affinities of mercury, as aſcertained by the experiments of Morveau (p), are as follows:

Gold,
Silver,
Tin,
Lead,
Biſmuth,
Zinc,
Copper,
Antimony,
Arſenic (q),
Iron.

SECT. V. *Of Copper.*

EXCEPT gold and ſilver, copper ſeems to have been more early known than any other metal. In the firſt ages of the world, before the method of working iron was diſcovered, copper was a principal ingredient in all domeſtic utenſils and inſtruments of war. Even during the Trojan war, as we learn from Homer, the combatants had no other armour but what was made of bronze, which is a mixture of *copper and tin*. The word *copper* is derived from the iſland of Cyprus, where it was firſt diſcovered, or at leaſt wrought to any extent, by the Greeks.

95
Properties of copper.

Copper is of a pale red colour with a ſhade of yellow. Its taſte is ſtyptic and nauſeous; and when rubbed it emits a diſagreeable ſmell. It poſſeſſes a conſiderable degree of malleability, though leſs than ſilver. Its tenacity is ſuch, that a wire of $\frac{1}{10}$ of an inch in diameter can ſuſtain a weight of 299¼ pounds without breaking*.

Its hardneſs is 8†. Its ſpecific gravity, when not hammered, is 7,788; when wire-drawn, 8,878‡. The ſpecific gravity of Japan copper is 9,000§; that of Swediſh copper, 9,3243‖.

It melts at 27° Wedgewood; according to the calculation of the Dijon academicians, at 1449° Fahrenheit. When allowed to cool ſlowly, it aſſumes a cryſtalline form. The Abbe Mongé, to whom we owe many valuable experiments on the cryſtallization of metals, informs us, that theſe cryſtals are quadrangular pyramids, frequently inſerted into one another.

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

96
Brown oxide of copper.

When copper is heated red hot in contact with air, it is ſoon covered with a brown earthy cruſt, which may be eaſily ſeparated by hammering or by plunging the metal into water. If the heat be continued, another ſcale of the ſame kind ſoon forms; and by continuing the proceſs the whole metal may be converted into an earthy-like cruſt, which is merely a combination of copper and oxygen, and is therefore called *brown oxide of copper*. It is compoſed of about 84 parts of copper and 16 of oxygen*.

* Kirwan's Miner. ii. 487.

97
Blue and green oxides.

When copper is diſſolved in ſulphuric acid, and precipitated by means of lime, it falls in the form of a blue-coloured powder, which is the *blue oxide of copper*. If this oxide of copper be dried in the open air, it aſſumes a green colour, and is then called the *green oxide of copper*. This laſt oxide may alſo be produced by diſtilling a ſufficient quantity of nitric acid off copper. Little ſatisfactory is yet known with reſpect to theſe oxides; it has not even been aſcertained whether the blue and green be really two different oxides, or whether the difference in colour be owing to ſome other cauſe. It is probable, however, that the *green* oxide contains more oxygen than the blue; becauſe the blue oxide aſſumes a green colour when expoſed for ſome time to the open air, during which it may be ſuppoſed to abſorb oxygen. An experiment of Fourcroy proves inconteſtibly, that the *brown* oxide contains leſs oxygen than the green. He converted the green oxide into the brown by applying heat; and during the diſtillation obtained oxygen gas†.

† Fourcroy iii. 101.

98
Their affinities.

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

Pyro-mucous acid‡
Oxalic,
Tartarous,

‡ Schrickel.

(o) Ammonia is an alkali hereafter to be deſcribed. It is often called, in Engliſh, *hartſhorn*.

(p) We ſhall have occaſion to conſider theſe celebrated experiments afterwards.

(q) Theſe two are added from Bergman. Bergman places *lead* before tin, and zinc before biſmuth.

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

When copper is long expoſed to the air, its ſurface becomes covered over with a green cruſt, which is *green oxide of copper*. This oxidation never penetrates beyond the ſurface.

Copper is not attacked by water at the boiling temperature; but if cold water be allowed to remain long on its ſurface, the metal becomes partly oxidated.

99 Sulphuret of copper.

Sulphur mixes readily with copper. The combination may be formed by mixing the ingredients together and applying a pretty ſtrong heat. *Sulphuret of copper* is brittle, ſofter than copper, of a black colour externally, and within of a leaden grey. It is compoſed, according to Kirwan's experiments, of 81 parts of copper and 19 of ſulphur*.

100 Phoſphuret of copper.

Mr Pelletier formed *phoſphuret of copper* by melting together one ounce of copper, one ounce of phoſphoric glaſs, and one dram of charcoal. It was of a white colour. On expoſure to the air, it loſt its luſtre and became blackiſh†. Margraf was the firſt perſon that formed this phoſphuret. His method was to diſtil phoſphorus and brown oxide of copper together. It is formed moſt eaſily by projecting phoſphorus into red hot copper. According to Pelletier, it contains 20 parts of phoſphorus and 80 of copper‡. This phoſphuret is harder than iron: It is not ductile, and yet cannot eaſily be pulveriſed. Its ſpecific gravity is 7,1220. It cryſtallizes in tetrahedral priſms§.

* *Kirwan's Miner.* ii. 503.
† *Ann. de Chim.* i. 74.
‡ *Ibid.* xiii. 3.
§ *Sage Journ. de Phyſ.* xxxviii. 468.

101 Alloys of copper.

1. Copper combines readily with gold when the two metals are melted together. The compound is of a reddiſh colour, more fuſible than gold, but leſs ductile. The proportions of the ingredients which form this alloy are not known; nor would it be eaſy to aſcertain them, as the two metals are almoſt equally fuſible. The current gold of this country is compoſed of 11 parts of gold and one part of copper.

2. The alloy of copper and ſilver is made as eaſily as that of gold, and the properties are equally unknown. It is harder and more ſonorous than ſilver. The current ſilver coin of Britain is compoſed of 15 parts of ſilver and one of copper.

3. Platinum combines readily with copper. The alloy is much more fuſible than platinum; it is ductile, hard, takes a fine poliſh, and is not liable to tarniſh. This alloy has been employed with advantage for compoſing the mirrors of reflecting teleſcopes.

4. The amalgam of copper cannot be formed by ſimply mixing that metal with mercury, nor even by the application of heat; becauſe the heat neceſſary to melt copper ſublimes mercury. Dr Lewis has given us ſeveral proceſſes for forming this amalgam. One of the ſimpleſt is to triturate mercury with a quantity of common ſalt and verdigriſe; a ſubſtance compoſed of oxide of copper and vinegar. The theory of this proceſs is not very obvious.

102 Its affinities

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

Gold,
Silver,
Arſenic,
Iron,
Mangaueſe,
Zinc,
Antimony,
Platinum,
Tin,
Lead,
Nickel,
Biſmuth,
Cobalt,
Mercury,
Sulphuret of alkali,
Sulphur,
Phoſphorus.

SECT. VI. *Of Iron.*

103 Diſcovery of iron.

Iron, the moſt abundant and moſt uſeful of all the metals, was neither known ſo early, nor wrought ſo eaſily, as gold, ſilver, and copper. For its diſcovery we muſt have recourſe to the nations of the eaſt, among whom, indeed, almoſt all the arts and ſciences firſt ſprung up. The writings of Moſes (who was born about 1635 years before Chriſt) furniſh us with the ampleſt proof at how early a period it was known in Egypt and Phœnicia. He mentions furnaces for working iron*, ores from which it was extracted†; and tells us that ſwords‡, knives§, axes‖, and tools for cutting ſtones¶, were then made of that metal. How many ages before the birth of Moſes iron muſt have been diſcovered in theſe countries, we may perhaps conceive, if we reflect, that the knowledge of iron was brought over from Phrygia to Greece by the Dactyli*, who ſettled in Crete during the reign of Minos I. about 1431 years before Chriſt; yet during the Trojan war, which happened 200 years after that period, iron was in ſuch high eſtimation, that Achilles propoſed a ball of it as one of his prizes during the games which he celebrated in honour of Patroclus (R). At that period none of their weapons were formed of iron. Now if the Greeks in 200 years had made ſo little progreſs in an art which they learned from others, how long muſt it

* Deut. iv. 20.
† *Ibid.* viii. 9.
‡ Numb. xxxv. 16.
§ Levit. i. 17.
‖ Deut. xviii. 5.
¶ *Ibid.* xxvii. 5.
* *Heſiod*, as quoted by *Pliny*, lib. vii. c. 57.

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

it have taken the Egyptians, Phrygians, Chalybes, or whatever nation firſt diſcovered the art of working iron, to have made that progreſs in it which we find they had done in the days of Moſes?

104
Its properties.

Iron, when freſh broken, is of a bluiſh grey colour. It has a ſtyptic taſte, and emits a ſmell when rubbed.

It is malleable and ductile in every temperature; and its malleability is increaſed in proportion as the temperature augments. Its tenacity is ſuch, that an iron wire $\frac{1}{10}$ of an inch in diameter ſuſtains a weight of 450 pounds without breaking *.

Its hardneſs is ſuch, that it may be eaſily reduced to powder by the application of a file. Its ſpecific gravity is 7,788. It is infuſible in the ſtrongeſt heats hitherto produced.

It is attracted by the magnet or loadſtone, and is itſelf capable of becoming magnetic; but it retains this property only for a very ſhort time.

It is not hardened by being plunged into liquids while hot, nor ſoftened by being cooled ſlowly.

Iron combines with oxygen very readily. When kindled in oxygen gas, it burns with great rapidity and ſplendor, and is in this manner converted into an oxide. It is converted into an oxide alſo when ſurrounded by moiſt air, or when plunged in water; becauſe it has a ſtronger affinity for oxygen than hydrogen has, and is therefore capable of decompoſing water.

105
Forms two oxides.

Mr Prouſt has lately proved, that there are only two oxides of iron, the *green* and the *brown* or *red*, and that all the other ſuppoſed oxides are merely mixtures of theſe two in various proportions †.

The *green oxide* may be obtained by diſſolving iron in ſulphuric acid, and then precipitating it by potaſs. It is a light, green-coloured, earthy-like ſubſtance, compoſed, as Mr Lavoiſier has ſhewn, of 27 parts of oxygen, and 73 of iron ‡. When this oxide is expoſed to the air, it quickly abſorbs more oxygen, and is converted into a brown powder, which is the *brown oxide*. Mr Prouſt has proved that it contains 52 parts of iron and 48 of oxygen. This oxide is well known under the name of *ruſt of iron*, which is generally, however, or perhaps always, combined with carbonic acid gas.

106
Their affinities.

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

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

107
Sulphuret.

Iron unites readily with ſulphur. Sulphuret of iron, formerly called *pyrites*, is found ready formed in many parts of the world. It is not eaſy to determine the proportions of its ingredients, becauſe it is capable of combining both with iron and ſulphur, and conſequently, if there happens to be any exceſs of either during its formation, it takes it up. Perhaps the proportions are not far from equal parts of ſulphur and of iron. It is of a pale yellow or browniſh colour, and is capable of aſſuming a cryſtalline form. Its ſpecific gravity is about 4,000. When placed upon the fire it precipitates; and at a red heat loſes its yellow colour, and becomes of an iron grey, excepting its ſurface, which is of a bright red. It melts at 102° Wedgewood in a covered crucible into a bluiſh ſlag, ſomewhat porous internally *. When expoſed to air and moiſture, the ſulphur, as happens in all ſulphurets, gradually abſorbs oxygen, and is converted into an acid.

If iron filings and ſulphur be mixed together, and formed into a paſte with water, the ſulphur decompoſes the water, and abſorbs oxygen ſo rapidly, that the mixture takes fire, even though it be buried under ground. This phenomenon was firſt diſcovered by Homberg; and it is conſidered as affording an explanation of the origin of volcanoes. The native ſulphuret of iron has been obſerved more than once to take fire on being ſuddenly moiſtened with water.

108
Phoſphuret,

Iron combines readily with phoſphorus, and forms *phoſphuret of iron;* to which Bergman, who firſt diſcovered it, gave the name of *ſiderum*.

There is a particular kind of iron, known by the name of *cold ſhort iron*, becauſe it is brittle when cold, though it be malleable when hot. Bergman was employed at Upſal in examining the cauſe of this property, while Meyer was occupied at Stetin with the ſame inveſtigation; and both of them diſcovered, nearly at the ſame time, that, by means of ſulphuric acid, a white powder could be ſeparated from this kind of iron, which by the uſual proceſs they converted into a metal of a dark ſteel grey, exceedingly brittle, and not very ſoluble in acids. Its ſpecific gravity was 6,700; it was not ſo fuſible as copper; and when combined with iron rendered it *cold ſhort*. Both of them concluded that this ſubſtance was a new metal; and Bergman gave it the name of *ſiderum*. But Klaproth ſoon after recollecting that the ſalt compoſed of phoſphoric acid and iron bore a great reſemblance to the white powder obtained from cold ſhort iron, ſuſpected the preſence of

* *Macquer's Dict.*

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

‡ *Mem. Acad Par.* 1782.

§ *La Grange.*

|| *Schrickel.*

* *Kirwan's Miner.* ii. 76.

˝ Τον δ' αγετ' εν νηεσσι συν αλλοισι κτιατεσσι.
Στη δ' ορθος, και μυθον εν Αργειοισιν εειπεν·
Ορνυσθ', οἱ και τυτυ αεθλυ πειρησεσθε.
Ει οἱ και μαλλα πολλον αποπροθι πιονες αγροι,
Ἑξει μιν και περιπλομενυς ενιαυτυς
Χρεωμενος· υ μεν γαρ οἱ ατεμβομενος γε σιδηρυ
Ποιμην, υδ' αροτήρ, εισ' ες πολιν, αλλα πάρεξει. Iliad, xxiii. l. 826.

phoſphoric acid in this new metal. To decide the point, he combined phoſphoric acid and iron, and obtained, by heating it in a crucible along with charcoal powder (s), a ſubſtance exactly reſembling the new metal. Meyer, when Klaproth communicated to him this diſcovery, informed him that he had already ſatisfied himſelf, by a more accurate examination, that ſiderum contained phoſphoric acid. Soon after this Scheele actually decompoſed the white powder obtained from cold ſhort iron, and thereby demonſtrated, that it was compoſed of phoſphoric acid and iron. The ſiderum of Bergman, however, is compoſed of phoſphorus and iron, the phoſphoric acid being deprived of its oxygen during the *reduction*; or it is phoſphuret of iron. It may be formed by fuſing in a crucible an ounce of phoſphoric glaſs, an ounce of iron, and half a dram of charcoal powder. It is very brittle, and appears white when broken. When expoſed to a ſtrong heat, it melts, and the phoſphorus is diſſipated *. It may be formed alſo by melting together equal parts of phoſphoric glaſs and iron filings. Part of the iron combines with the oxygen of the phoſphoric glaſs, and is vitrified; the reſt forms the phoſphuret, which ſinks to the bottom of the crucible. It may be formed alſo by dropping ſmall bits of phoſphorus into iron filings heated red hot †. The proportions of the ingredients of this phoſpuret have not yet been determined.

* *Pelletier, Ann de Chim.* i. 104.

† *Id. Ann. de Chim.* xiii. 113.

109
And carburet of iron.

Iron likewiſe combines with carbon, and forms a *carburet*. Carburet of iron has been long known and uſed in the arts under the names of *plumbago* and *black lead*. It is of a dark iron grey or blue colour, and has ſomething of a metallic luſtre. It has a greaſy feel, and blackens the fingers, or any other ſubſtance to which it is applied. It is found in many parts of the world, eſpecially in England, where it is manufactured into pencils. It is not affected by the moſt violent heat as long as air is excluded, nor is it in the leaſt altered by ſimple expoſure to the air, or to water. Its nature was firſt inveſtigated by Scheele; who proved, by a very ingenious analyſis, that it could be converted almoſt wholly into carbonic acid gas, and that the ſmall reſiduum was iron. It follows from this analyſis, that it is compoſed of carbon and iron; for the carbon, during its combuſtion, had been converted into carbonic acid gas. By the ſubſequent experiments of Pelletier and other French chemiſts, it has been ſhewn to conſiſt nearly of nine parts of carbon to one of iron.

110
Varieties of iron.

There are a great many varieties of iron, which artiſts diſtinguiſh by particular names; but all of them may be reduced under one or other of the three following ſtates: *Wrought iron* (or ſimply *iron*), *ſteel*, and *caſt* or *raw iron*.

111
Wrought iron.

Wrought Iron is the ſubſtance which we have been hitherto deſcribing. As it has never yet been decompounded, we conſider it when pure as a ſimple body; but it has ſeldom or never been found without ſome ſmall mixture of foreign ſubſtances. Theſe ſubſtances are either ſome of the other metals, or oxygen, carbon, or phoſphorus.

112
Steel.

Steel is diſtinguiſhed from iron by the following properties.

It is ſo hard as to be unmalleable while cold, or at leaſt it acquires this property by being immerſed while ignited into a cold liquid: for this immerſion, though it has no effect upon *iron*, adds greatly to the hardneſs of *ſteel*.

It is brittle, reſiſts the file, cuts glaſs, affords ſparks with flint, and retains the magnetic virtue for any length of time.

It loſes this hardneſs by being ignited and cooled very ſlowly.

It melts at above 130° Wedgewood. It is malleable when red hot, but ſcarcely ſo when raiſed to a white heat.

It may be hammered out into much thinner plates than iron. It is more ſonorous; and its ſpecific gravity, when hammered, is greater than that of iron.

By being repeatedly ignited in an open veſſel, and hammered, it becomes *wrought iron* *.

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

113
Caſt iron.

Cast Iron is diſtinguiſhed by the following properties:

It is ſcarcely malleable at any temperature. It is generally ſo hard as to reſiſt the file. It can neither be hardened nor ſoftened as ſteel can by ignition and cooling. It is exceedingly brittle. It melts at 130° Wedgewood. It is more ſonorous than ſteel †.

† *Ibid.*

Caſt iron is converted into wrought iron by expoſing it for a conſiderable time in a furnace to a heat ſufficiently ſtrong to melt it. During the proceſs it is conſtantly ſtirred by a workman, that every part of it may be equally expoſed to the air. In about an hour the hotteſt part of the maſs begins to heave and ſwell, and to emit a lambent blue flame. This continues nearly an hour; and by that time the converſion is completed. The heaving is evidently produced by the emiſſion of an elaſtic fluid ‡.

‡ *Beddoes, Phil. Tranſ.* 1791.

Wrought iron may be converted into ſteel by being kept for ſome hours in a ſtrong red heat, ſurrounded with charcoal powder in a covered crucible. By this proceſs, which is called *cementation*, the iron gains ſome weight.

114
Cauſe of theſe varieties.

Theſe different kinds of iron have been long known, and the converting of them into each other has been practiſed in very remote ages. Many attempts have been made to explain the manner in which this converſion is accompliſhed. According to Pliny, ſteel owes its peculiar properties chiefly to the water into which it is plunged in order to be cooled §. Beccher ſuppoſed that fire was the only agent; that it entered into the iron, and converted it into ſteel. Reaumur was the firſt who attended accurately to the proceſs; and his numerous experiments have certainly contributed to elucidate the ſubject. He ſuppoſed that iron was converted into ſteel by combining with ſaline and oily or ſulphureous particles, and that theſe were introduced by the fire. But it was the analyſis of Bergman, publiſhed in 1781, that firſt paved the way to the explanation of the nature of theſe different ſpecies of iron.

§ *Pliny*, l. xxxiv. 14.

By diſſolving in diluted ſulphuric acid 100 parts of caſt iron, he obtained 40 ounce meaſures of hydrogen; from 100 parts of ſteel he obtained 48 ounce meaſures; and from 100 parts of wrought iron, 50 ounce meaſures. Now as the hydrogen is produced by the property which iron has of decompoſing water and uniting with its oxygen, it is evident that the greater the quantity of hydrogen obtained,

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

tained, with the more oxygen does the iron combine. But the quantities of iron were equal; they ought therefore to have combined with equal quantities of oxygen. But it is evident, from the quantities of hydrogen obtained, that the caſt iron received leſs oxygen than either of the other two: caſt iron therefore muſt contain already ſome oxygen, ſince it requires leſs than the other two ſpecies in order to be ſaturated. Here then is one difference between caſt iron and the other two kinds; it contains oxygen. Steel, on the contrary, does not appear to contain any oxygen. The difference between the quantity of hydrogen produced during its ſolution and that of wrought iron, which contains no oxygen, is exceedingly ſmall, and it has been found to diminiſh in proportion to the purity of the ſteel.

From 100 parts of caſt iron Bergman obtained 2,2 of plumbago, or $\frac{1}{45}$; from 100 parts of ſteel, 0,5, or $\frac{1}{200}$; and from 100 parts of wrought iron, 0,12, or $\frac{1}{900}$. Now plumbago is compoſed of $\frac{9}{10}$ths of carbon; caſt iron therefore contains a conſiderable quantity of carbon, ſteel a ſmaller quantity, and wrought iron a very minute portion, which diminiſhes according to its purity, and would vaniſh altogether if iron could be obtained perfectly pure. Mr Grignon, in his notes on this analyſis, endeavoured to prove that plumbago was not eſſentially a part of caſt iron and ſteel, but that it was merely accidentally preſent But Bergman, after conſidering his objections, wrote to Morveau on the 18th November 1783. "I will acknowledge my miſtake whenever Mr Grignon ſends me a ſingle bit of caſt iron or ſteel which does not contain plumbago; and I beg of you, my dear friend, to endeavour to diſcover ſome ſuch, and to ſend them to me; for if I am wrong, I wiſh to be undeceived as ſoon as poſſible *." This was almoſt the laſt action of the illuſtrious Bergman. He died a few months after at the age of 49, leaving behind him a moſt brilliant reputation, which no man ever more deſervedly acquired. His induſtry, his indefatigable, his aſtoniſhing induſtry, would alone have contributed much to eſtabliſh his name; his extenſive knowledge would alone have attracted the attention of philoſophers; his ingenuity, penetration, and accurate judgment, would alone have ſecured the applauſe; and his candour and love of truth procured him the confidence and the eſteem of the world.—But all theſe qualities were united in Bergman, and conſpired to form one of the greateſt men and nobleſt characters that ever adorned human nature.

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

The experiments of Bergman were fully confirmed by thoſe of Morveau, Vandermonde, Monge, and Berthollet, who have likewiſe thrown a great deal of additional light on the ſubject. From all theſe experiments the following deductions may be made.

Wrought iron is a ſimple ſubſtance, and if perfectly pure would contain nothing but *iron*.

Steel is iron combined with carbon. The proportion of this laſt ingredient has not yet been aſcertained; Dr Pearſon fixes it at $\frac{1}{300}$th part at a medium. Steel, in conſequence of its compoſition, has been called by ſome chemiſts *carburet of iron;* but before aſſigning it that name, which has been alſo given to plumbago, it ought to be determined what are the proportions of carbon and iron which ſaturate each other. Is it the proportion in which theſe two ſubſtances exiſt in ſteel, or that which forms plumbago? In the firſt caſe, plumbago is carburet of iron combined with carbon; in the ſecond, ſteel is carburet combined with iron. Or is it ſome intermediate proportion? Till theſe points be determined, perhaps it would be better to continue the old names than to riſk the impoſing of falſe ones.

Caſt iron is iron contaminated with various foreign ſubſtances, the proportions of which vary according to circumſtances. Theſe ſubſtances are chiefly oxide of iron and carbon, and ſometimes ſilica (T).

Bergman found a quantity of mangane ſe in the iron and ſteel which he examined; but it appears from the experiments of Vauquelin, that his method of determining the preſence of that metal was not accurate.

115 Vauquelin's analyſis of ſteel.

Mr Vauquelin * has lately analyſed four kinds of ſteel with great care, and contrived his proceſſes with much ingenuity. The reſult of his analyſis is as follows:

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

Firſt ſteel, compoſed of	Carbon, -	0,00789
	Silica, -	0,00315
	Phoſphorus, -	0,00345
	Iron, - -	0,98551
		1

Second ſteel, compoſed of	Carbon, -	0,00683
	Silica, -	0,00273
	Phoſphorus,	0,00827
	Iron, - -	0,98217
		1

Third ſteel, compoſed of	Carbon, -	0,00789
	Silica, -	0,00315
	Phoſphorus,	0,00791
	Iron, - -	0,98105
		1

Fourth ſteel, compoſed of	Carbon, -	0,00631
	Silica, -	0,00252
	Phoſphorus,	0,01520
	Iron, - -	0,97597
		1

It cannot be concluded from theſe experiments that all ſteel contains phoſphorus and ſilica; far leſs that theſe ſubſtances enter neceſſarily into the compoſition of ſteel. This *may* be the caſe, and former analyſes may not have been nice enough to detect it; but before it can be admitted, it muſt be ſhewn that theſe ſubſtances are always preſent in ſteel, and that it loſes its eſſential properties when deprived of them.

116 Alloys of iron.

Iron combines with moſt metals.

1. The alloy of gold and iron is very hard, and might, according to Dr Lewis, who examined it, be employed with advantage in forming cutting inſtruments.

2. That iron combines with ſilver is certain, but hardly any thing is known about the nature of the compound.

3. Platinum is uſually found alloyed with iron. Dr Lewis did not ſucceed in his attempts to unite theſe

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

metals by fuſion, but he melted together caſt iron and platinum. The alloy was exceſſively hard, and poſſeſſed ductility.

4. There is very little affinity between iron and mercury; they cannot therefore be amalgamated by ſimple mixture, even with the aſſiſtance of heat. Vogel affirms that he has produced an amalgam of iron by the following proceſs: Pound one part of iron filings and two parts of alum in a mortar to a fine powder; then pour in two or three parts of mercury, and triturate till the ſubſtances be thoroughly mixed. Pour on a little water, and continue the trituration for about an hour. If then no particles of iron can be diſtinguiſhed, pour on a little more water to waſh out the alum, and then dry the amalgam. If particles of iron be perceptible, the trituration muſt be continued till they diſappear *.

5. Iron may be united to copper by fuſion, but not without conſiderable difficulty. The alloy has been applied to no uſe.

117 Its affinities. The affinities of iron, according to Bergman, are as follows:

Nickel,
Cobalt,
Mangancſe,
Arſenic,
Copper,
Gold,
Silver,
Tin,
Antimony,
Platinum,
Biſmuth,
Lead,
Mercury,
Sulphuret of alkali,
Carbon ?
Phoſphorus ?
Sulphur ?

Sect. VII. *Of Tin.*

The Phenicians were the firſt of thoſe nations which make a figure in ancient hiſtory that were acquainted with *tin*. They procured it from Spain † and from Britain, with which nations they carried on a very lucrative commerce. At how early a period they imported this metal we may eaſily conceive, if we recollect that it was in common uſe in the time of Moſes ‡.

118 Properties of tin: Tin is of a greyiſh white colour: it has a ſtrong diſagreeable taſte, and emits a peculiar ſmell when rubbed.

It is very malleable; tin-leaf, or *tinfoil* as it is called, is about $\frac{1}{1000}$th part of an inch thick, and it might be beat out into leaves as thin again if ſuch were wanted for the purpoſes of art. Its ductility, however, is exceedingly imperfect; for a tin wire $\frac{1}{10}$th of an inch in diameter, is capable of ſupporting only 49 pounds without breaking §. It is very flexible, and produces a crackling noiſe when bended.

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

It melts at the temperature 410°, according to Dr Lewis; according to the Dijon academicians, at 419°. When heated red hot in cloſe veſſels it ſublimes. It cryſtallizes in the form of a rhomboidal priſm *.

119 Oxides, Tin unites very readily with oxygen. When heated in contact with air, its ſurface ſoon becomes covered with a grey pellicle; when this is taken off, another appears ſoon after; and in this manner the whole metal may be converted into a dirty grey powder, which is the *grey oxide of tin*. It is compoſed, according to Fourcroy, of 90 parts of tin and 10 of oxygen.

When tin is heated red hot in contact with air, it takes fire *, and burns with a very lively white flame, and is gradually ſublimed. If the ſublimate be examined, it is found to conſiſt of a white powder; it is the *white oxide of tin*. The white oxide is perhaps never obtained quite pure by this proceſs; it ſeems always to contain a mixture of *grey oxide:* but it may be obtained pure by pouring nitric acid upon tin, and then drying it. That metal having a much ſtronger attraction for oxygen than azot has, decompoſes the acid with the greateſt rapidity, and aſſumes the appearance of a white powder, which is the *white oxide*. This oxide poſſeſſes many of the properties of an acid, and is therefore often called *ſtannic acid*. It ſeems to conſiſt of about 77 parts of tin and 23 of oxygen †.

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

Pyromucous acid ‡,
Sebacic acid,
Tartaric,
Muriatic,
Sulphuric,
Oxalic,
Arſenic,
Phoſphoric,
Nitric,
Succinic,
Fluoric,
Saccholactic,
Citric,
Formic,
Lactic,
Acetous,
Boracic,
Pruſſic.

120 Sulphurets, Tin combines readily with ſulphur. This ſulphuret may be formed by fuſing the two ingredients together. It is brittle, heavier than tin, and not ſo fuſible. It is of a bluiſh colour and lamellated ſtructure, and is capable of cryſtallizing. According to Bergman, it is compoſed of 80 parts of tin and 20 of ſulphur; according to Pelletier, of 85 parts of tin and 15 of ſulphur §.

Sulphur likewiſe combines with the white oxide of tin, by mixing them together, and applying a gentle heat ‖. This compound has been called *aurum muſivum*. It is a maſs conſiſting of beautiful gold-coloured flakes, and is uſed as a paint. It is compoſed of about 40 parts of ſulphur and 60 of white oxide of tin ¶. The proceſs for making this ſubſtance was formerly very complicated. Pelletier firſt demonſtrated its real compoſition, and was hence enabled to make many important improvements in the manner of manufacturing it *.

121 Phoſphuret, Phoſphorus is eaſily combined with tin, by melting in a crucible equal parts of filings of tin and phoſphoric glaſs. Tin has a greater affinity for oxygen than phoſphorus has. Part of the metal therefore combines with the

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* *Ann. de Chim.* vi. 39.

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

‡ *Numbers*, xxxi. 22.

§ *Macquer's Dictionary.*

‖ *Kirwan's Miner.* ii. 195.

¶ *Briſſon.*

* *Pajot, Jour. de Phyſ* xxxviii. 52.

* *Geoffroy.*

† *Kirwan's Miner.* ii. 488.

‡ *Schrickel.*

§ *Ann. de Chim.* xiii. 287.

‖ *Pelletier, Ibid.* p. 297.

¶ *Ibid.* 293.

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

the oxygen of the glaſs during the fuſion, and flies off in the ſtate of an oxide, and the reſt of the tin combines with the phoſphorus. The phoſphuret of tin may be cut with a knife; it extends under the hammer, but ſeparates in laminæ. When newly cut it has the colour of ſilver; its filings reſemble thoſe of lead. When theſe filings are thrown on burning coals, the phoſphorus takes fire. This phoſphuret may likewiſe be formed by dropping phoſphorus gradually into melted tin. According to Pelletier, to whoſe experiments we are indebted for the knowledge of all the phoſphurets, it is compoſed of about 85 parts of tin and 15 of phoſphorus*. Margraf alſo formed this phoſphuret, but he was ignorant of its compoſition.

122 Alloys, Tin does not ſeem capable of combining with carbon. It is capable of combining with moſt of the metals.

1. It mixes readily with gold by fuſion; but the proportions in which theſe metals combine chemically are ſtill unknown. When one part of tin and twelve of gold are melted together, the alloy is brittle, hard, and bad coloured. Twenty-four parts of gold and one of tin produce a pale coloured alloy, harder than gold, but poſſeſſed of conſiderable ductility. Gold alloyed with no more than $\frac{1}{57}$th of tin is ſcarcely altered in its properties, according to Mr Alchorne†; but Mr Tillet, who has lately examined this alloy, found, that whenever it was heated it broke into a number of pieces.

2. The alloy of ſilver and tin is hardly known. According to Gellert and ſucceeding chemiſts, it is exceedingly brittle.

3. The alloy of platinum and tin is very fuſible and brittle, at leaſt when theſe metals are mixed in equal proportions‡.

4. Mercury diſſolves tin very readily, by being poured on it when melted. This amalgam cryſtallizes in the form of cubes, according to Daubenton; but, according to Sage, in grey brilliant ſquare plates, thin towards the edges, and attached to each other ſo that the cavities between them are polygonal. It is compoſed of three parts of mercury and one of tin. The amalgam of tin is uſed to ſilver the backs of glaſs mirrors.

5. Tin unites very readily with copper, and forms alloys known by the names of *bronze* and *bell-metal*. The proportions of the ingredients cannot eaſily be aſſigned, perhaps becauſe the alloy has an affinity both for copper and tin. The ſpecific gravity of the alloy in all proportions is greater than the mean ſpecific gravity of the two metals ſeparately. When the quantity of tin is ſmall compared to that of the copper, $\frac{1}{10}$th for inſtance, the alloy is called *bronze*: it is brittle, yellow, and much heavier than copper; much more fuſible, and leſs liable to be altered by expoſure to the air. It was this alloy which the ancients uſed for ſharp-edged inſtruments before the method of working iron was brought to perfection. The *χαλκος* of the Greeks, and perhaps the *æs* of the Romans, was nothing elſe. Even their copper coins contain a mixture of tin§.

6. Tin ſeems capable of being united to iron by fuſion. That there is an affinity between theſe metals is evident from their adheſion when iron is dipt into melted tin. This is the method of making *tinplate*.

123 And affinities of tin. The affinities of tin, according to Bergman, are as follows:

Zinc,
Mercury,
Copper,
Antimony,
Gold,
Silver,
Lead,
Iron,
Manganeſe,
Nickel,
Arſenic,
Platinum,
Biſmuth,
Cobalt,
Sulphuret of alkali,
Oxygen?
Sulphur?
Phoſphorus?

Sect. VIII. *Of Lead.*

Lead appears to have been very early known. It is mentioned ſeveral times by Moſes. The ancients ſeem to have conſidered it as nearly related to tin.

124 Properties of lead. Lead is of a bluiſh white colour, ſomewhat darker than tin. When newly melted it is very bright, but ſoon becomes tarniſhed by expoſure to the air. It has ſcarcely any taſte, but emits on friction a peculiar ſmell.

It is very malleable, and may be reduced to thin plates by the hammer; but its ductility is very imperfect: a wire of lead $\frac{1}{10}$th of an inch in diameter is only capable of ſupporting a weight of $29\frac{1}{4}$ pounds*. Its hardneſs is 5†; its ſpecific gravity is 11,3523‡. Its ſpecific gravity is not increaſed by hammering, neither does it become harder, as is the caſe with other metals: a proof that the hardneſs which metals aſſume under the hammer is in conſequence of an increaſe of denſity.

It melts, according to Dr Lewis, at 540° Fahrenheit; according to the Dijon academicians, at 549°. When expoſed to a violent heat it evaporates completely.

When cooled ſlowly, after being fuſed, it cryſtallizes. The Abbé Mongez obtained it in quadrangular pyramids, lying on one of their ſides. Each pyramid was compoſed as it were of three layers. Pajot obtained it in the form of a polyhedron with 32 ſides, formed by the concourſe of ſix quadrangular pyramids§.

Lead ſtains paper or the fingers of a bluiſh black colour.

125 Its oxides. There is a ſtrong affinity between this metal and oxygen. When nitric acid is poured upon it, an efferveſcence enſues, owing to the decompoſition of the acid; the lead ſeizes oxygen from it, and is converted into a white powder, which may be obtained pure by evaporating it to dryneſs, and then waſhing it in pure water. This is the *white oxide of lead*. It is compoſed of about 95 parts of lead and five of oxygen‖. The affinities of this oxide are, according to Bergman, as follows:

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

Benzoic,

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* *Ann. de Chim.* xiii. 116.

† *Alchorne, Phil. Tranſ.*

‡ *Dr Lewis.*

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

* *Macquer's Dictionary.*

† *Kirwan's Miner.* ii. 202.

‡ *Briſſon.*

§ *Jour. de Phyſ.* xxxviii. 53.

‖ *Kirwan's Miner.* ii. 499.

Benzoic (u)?
Sulphurous,
Suberic? } (*v*)
Zoonic? }
Nitric,
Pyromucous (v)?
Fluoric,
Citric,
Formic,
Lactic,
Acetous,
Boracic,
Pruſſic,
Carbonic,
Fixed alkali.

When lead is expoſed to heat in contact with air, its ſurface is ſoon covered with a grey pellicle; when this is taken off, another ſoon forms: and in this manner the whole lead may ſoon be converted into a dirty grey powder, which ſeems to be the white oxide mixed with a little lead. When this powder is heated red hot, it aſſumes a deep yellow colour. This is the *yellow oxide* of lead, formerly called *maſſicot*. If the heat be continued, the colour is gradually changed to a beautiful red. This is the *red oxide of lead*, formerly called *minium*. It is compoſed, as Lavoiſier has ſhewn, of 88 parts of lead and 12 of oxygen *.

* *Mem. Par.* 1781.

The manner in which theſe changes are brought about is evident; the metal gradually abſorbs oxygen from the atmoſphere. This has been actually proved by experiment. Theſe oxides (if they really differ in the proportion of oxygen) reſemble acids in ſeveral of their properties. They are very eaſily converted into glaſs by fuſion. Scheele has ſhewn that there is alſo a *brown oxide of lead*, which contains more oxygen than any of the others.

126 Sulphuret,

Sulphur unites eaſily to lead by fuſion. The ſulphuret of lead is brittle, of a deep grey colour, and much leſs fuſible than lead. Theſe two ſubſtances are often found naturally combined; the compound is then called *galena*. Sulphuret of lead is compoſed, according to the experiments of Wenzel, of 868 parts of lead and 132 of ſulphur †.

† *Kirwan's Miner.* ii. 492.

127 Phoſphuret,

Phoſphuret of lead may be formed by mixing together equal parts of filings of lead and phoſphoric glaſs, and fuſing them in a crucible. It may be cut with a knife, but ſeparates into plates when hammered. It is of a white ſilver colour with a ſhade of blue, but it ſoon tarniſhes when expoſed to the air. This phoſphuret may alſo be formed by dropping phoſphorus into melted lead. It is compoſed of about 12 parts of phoſphorus and 88 of lead ‡.

‡ *Pelletier, Ann. de Chim.* xiii. 114.

128 Alloys, and

Lead combines with moſt of the other metals.

1. Little is known concerning the alloy of lead and gold. It is ſaid to be brittle.

2. The alloy of ſilver and lead is very fuſible, and neither elaſtic nor ſonorous.

3. Platinum and lead unite in a ſtrong heat: the alloy is brittle, of a purpliſh colour, and ſoon changes on expoſure to the air *.

* *Fourcroy.*

4. Mercury, when poured upon melted lead, diſſolves it readily. The amalgam is white and brilliant, and aſſumes a ſolid form. It is capable of cryſtallizing. The cryſtals are compoſed of one part of lead and one and a half of mercury †.

† *Dijon Academicians.*

5. Copper and lead combine eaſily by fuſion; but the alloy has not been applied to any uſe.

6. Iron does not unite with lead.

7. Lead and tin may be combined by fuſion. The alloy in the proportion of two parts of lead and one of tin is more ſoluble than either of the metals ſeparately. It is accordingly uſed by plumbers as a ſolder.

129 Affinities.

Lead, when taken internally, acts as a poiſon. Its affinities, according to Bergman, are as follows:

Gold,
Silver,
Copper,
Mercury,
Biſmuth,
Tin,
Antimony,
Platinum,
Arſenic,
Zinc,
Nickel,
Iron,
Sulphuret of alkali,
Sulphur,
Phoſphorus?

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

The ancients gave to the ſeven metals laſt deſcribed (omitting *platinum*, which they did not know) the names of the planets, and denoted each of them by particular marks, which repreſented both the planet and the metal.

Gold was the Sun, and repreſented by ☉.
Silver the Moon, ☽.
Mercury Mercury, ☿.
Copper Venus, ♀.
Iron Mars, ♂.
Tin Jupiter, ♃.
Lead Saturn, ♄.

It ſeems moſt probable that theſe names were firſt given to the planets; and that the ſeven metals, the only ones then known, were ſuppoſed to have ſome relation to the planets or to the gods that inhabited them, as the number of both happened to be the ſame. It appears from a paſſage in Origen, that theſe names firſt aroſe among the Perſians (w). Why each particular metal was denominated by a particular planet it is not eaſy to ſee. Many conjectures have been made, but ſcarcely any of them are ſatisfactory.

As

(u) Benzoat of lead is decompoſed by muriatic acid. *Trommſdorf, Ann. de Chim.* xi. 317.

(*v*) Suberic acid decompoſes nitrat of lead. See *Jameſon's Mineralogy*, p. 166. Zoonic acid produces the ſame effect, as Berthollet has obſerved.

(v) Schrickel places it after the three mineral acids.

(w) *Contra Celſum*, lib vi. 22.—" Celſus de quibuſdam Perſarum myſteriis ſermonem facit. Harum rerum, inquit, aliquod reperitur in Perſarum doctrina Mithraciſque eorum myſteriis veſtigium. In illis enim duæ cæleſtes converſiones, alia ſtellarum fixarum, errantium alia, et animæ per eas tranſitus quodam ſymbolo repræſentantur, quod hujuſmodi eſt. Scala altas portas habens, in ſumma autem octava porta. Prima portarum plumbea, altera ſtannea, Lead.

131 Origin of theſe marks according to the aſtrologers;

As to the characters by which theſe metals were expreſſed, aſtrologers ſeem to have conſidered them as the attributes of the deities of the ſame name. The circle in the earlieſt periods among the Egyptians was the ſymbol of divinity and perfection; and ſeems with great propriety to have been choſen by them as the character of the ſun, eſpecially as, when ſurrounded by ſmall ſtrokes projecting from its circumference, it may form ſome repreſentation of the emiſſion of rays. The ſemicircle is, in like manner, the image of the moon; the only one of the heavenly bodies that appears under that form to the naked eye. The character ♄ is ſuppoſed to repreſent the ſcythe of Saturn; ♃ the thunderbolts of Jupiter; ♂ the lance of Mars, together with his ſhield; ♀ the looking-glaſs of Venus; and ☿ the caduceus or wand of Mercury.

132 According to the alchymiſts.

The alchymiſts, however, give a very different account of theſe ſymbols. Gold was the moſt perfect metal, and was therefore denoted by a circle. Silver approached neareſt it; but as it was inferior, it was denoted only by a ſemicircle. In the character ☿ the adepts diſcovered gold with a ſilver colour. The croſs at the bottom expreſſed the preſence of a myſterious ſomething, without which mercury would be ſilver or gold. This ſomething is combined alſo with copper; the poſſible change of which into gold is expreſſed by the character ♀. The character ♂ declares the like honourable affinity alſo; though the ſemicircle is applied in a more concealed manner: for, according to the propereſt mode of writing, the point is wanting at the top, or the upright line ought only to touch the horizontal, and not to interſect it. Philoſophical gold is concealed in ſteel; and on this account it produces ſuch valuable medicines. Of tin, one half is ſilver, and the other conſiſts of the unknown ſomething; for this reaſon the croſs with the half moon appears in ♃. In lead this ſomething is predominant, and a ſimilitude is obſerved in it to ſilver. Hence in its character ♄ the croſs ſtands at the top, and the ſilver character is only ſuſpended on the right hand behind it.

133 Their real origin.

The fact, however, according to Profeſſor Beckmann, from whom moſt of the above remarks have been taken, ſeems to be, that theſe characters are mere abbreviations of the old names of the planets. "The character of Mars (he obſerves*), according to the oldeſt mode of repreſenting it, is evidently an abbreviation of the word Θουρος, under which the Greek mathematicians underſtood that deity; or, in other words, the firſt letter Θ, with the laſt letter ς placed above it. The character of Jupiter was originally the initial letter of Ζευς; and in the oldeſt manuſcripts of the mathematical and aſtrological works of Julius Firmicus, the capital Z only is uſed, to which the laſt letter ς was afterwards added at the bottom, to render the abbreviation more diſtinct. The ſuppoſed looking-glaſs of Venus is nothing elſe than the initial letter diſtorted a little of the word Φωσφορος, which was the name of that goddeſs. The imaginary ſcythe of Saturn has been gradually formed from the two firſt letters of his name Κρονος, which tranſcribers, for the ſake of diſpatch, made always more convenient for uſe, but at the ſame time leſs perceptible. To diſcover in the pretended caduceus of Mercury the initial letter of his Greek name Στιλβων, one needs only look at the abbreviations in the oldeſt manuſcripts, where they will find that the Σ was once written as C; they will remark alſo, that tranſcribers, to diſtinguiſh this abbreviation from the reſt ſtill more, placed the C thus Ɔ, and added under it the next letter τ. If thoſe to whom this deduction appears improbable will only take the trouble to look at other Greek abbreviations, they will find many that differ ſtill farther from the original letters they expreſs than the preſent character ☿ from the C and τ united. It is poſſible alſo that later tranſcribers, to whom the origin of this abbreviation was not known, may have endeavoured to give it a greater reſemblance to the caduceus of mercury. In ſhort, it cannot be denied that many other aſtronomical characters are real ſymbols, or a kind of proper hieroglyphics, that repreſent certain attributes or circumſtances, like the characters of Aries, Leo, and others quoted by Saumaiſe."

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

SECT. IX. *Of Zinc.*

Zinc.

134 Diſcovery of zinc.

THE ancients were acquainted with a mineral to which they gave the name of *Cadmea*, from Cadmus, who firſt taught the Greeks to uſe it. They knew that when melted with copper it formed braſs; and that when burnt, a white ſpongy kind of aſhes was volatiliſed, which they uſed in medicine*. This mineral contained a good deal of zinc; and yet there is no proof remaining that the ancients were acquainted with that metal (x). It is firſt mentioned in the writings of Albertus Magnus, who died in 1280: but whether he had ſeen it is not ſo clear, as he gives it the name of *marcaſite of gold*, which implies, one would think, that it had

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

ſtannea; tertia ex ære, quarta ferrea, quinta ex ære mixto, ſexta argentea, ſeptima ex auro. Κλιμαξ ὑψιπυλος, επι δ'αιτη πυλη ογδοη. Ἡ πρωτη των πυλων μολιβδου, ἡ δευτερα κασσιτερου, ἡ τριτη χαλκου, ἡ τεταρτη σιδηρου, ἡ πεμπτη κεραστου νομισματος, ἡ ἑκτη αργυρου, χρυσου δ' ἡ ἑβδομη. Primum aſſignant Saturno tarditatem illius ſideris plumbo indicantes: alteram Veneri, quam referunt, ut ipſi quidem putant, ſtanni ſplendor et mollities; tertiam Jovi, aheneam illam quidem et ſolidam: quartam Mercurio, quia Mercurius et ferrum, uterque operum omnium tolerantes, ad mercaturam utiles, laborum patientiſſimi. Marti quintam, inæqualem illam et variam propter mixturam. Sextam, quæ argentea eſt, lunæ; ſeptimam auream ſoli tribuunt, quia ſolis et lunæ colores hæc duo metalla referunt."

Borrichius ſuſpects, with a good deal of probability, that the names of the gods in this paſſage have been tranſpoſed by tranſcribers, either through ignorance or deſign. He arranges them as follows: "Secundam portam faciunt Jovis, comparantes ei ſtanni ſplendorem et mollitiem; tertiam Veneris æratam et ſolidam; quartam Martis, eſt enim laborum patiens, æque ac ferrum, celebratus hominibus; quintam Mercurii propter miſturam inæqualem ac variam, et quia negotiator eſt; ſextam Lunæ argenteam; ſeptimam Solis auream." *Ol. Borrichius de ortu et progreſſu chemiæ.* Hafniæ, 1668, 4to, p. 29.

(x) Grignon indeed ſays, that ſomething like it was diſcovered in the ruins of an ancient Roman city in Champagne; but the ſubſtance which he took for it was not examined with any accuracy. It is impoſſible therefore to draw any inference whatever from his aſſertion. *Bulletin des fouilles d'une ville Romaine*, p. 11.

had a yellow colour (Y). The word *zinc* occurs firſt in the writings of Paracelſus, who died in 1541. He informs us very gravely, that it is a metal, and not a metal, and that it conſiſts chiefly of the aſhes of copper *. This metal has alſo been called *ſpelter*.

Zinc has never been found in Europe in a ſtate of purity, and it was long before a method was diſcovered of extracting it from its ore (Z). Henkel pointed out one in 1721, and Von Swab obtained it by diſtillation in 1742, and Margraf publiſhed a proceſs in the Berlin Memoirs in 1746 †.

135 Properties of zinc.

It is of a bluiſh white colour, ſomewhat lighter than lead. It has neither taſte nor ſmell.

It has ſome degree of malleability; for by compreſſion it may be reduced into thin plates ‡; but it cannot be drawn out into wire. It is more brittle when hot than when cold.

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

When allowed to cool ſlowly, it cryſtallizes in ſmall bundles of quadrangular priſms, diſpoſed in all directions. If they are expoſed to the air while hot, they aſſume a blue changeable colour †.

136 Its oxides,

When zinc is kept melted in contact with air, it becomes covered with a grey pellicle, which gradually aſſumes a yellowiſh tint. By removing this pellicle from time to time, the whole of the metal may be reduced into a grey powder. This is the *grey oxide of zinc*. This oxide is probably compoſed of about 85 parts of zinc and 15 of oxygen ‡. When zinc is violently heated, it burns with a bright white flame, and at the ſame time a quantity of very light white flakes are ſublimed. Theſe flakes are the *white oxide of zinc*, which contains a good deal more oxygen than the grey oxide (A).

Zinc may alſo be oxidated by ſolution in acids, particularly the nitric acid. Whether the oxide obtained by precipitating zinc from its ſolution in that acid, or by diſtilling that acid off zinc, be really different from the white oxide, has not yet been properly aſcertained; but one would be apt to ſuſpect, from the experiments mentioned by Mr Kirwan, that it contained a good deal more oxygen *.

The affinities of the oxides, or rather of the white oxide of zinc, are, according to Bergman, as follows:

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

137 Sulphuret,

There is an affinity between ſulphur and zinc, as is evident from theſe two ſubſtances being often found united; but it is very difficult to form the ſulphuret of zinc artificially, on account of the rapid oxidation and conſequent volatilization of the zinc. Morveau, however, ſucceeded in forming it.

138 Phoſphurets,

Zinc may be combined with phoſphorus, by dropping ſmall bits of phoſphorus into it while in a ſtate of fuſion. Pelletier, to whom we are indebted for the experiment, added alſo a little reſin, to prevent the oxidation of the zinc. Phoſphuret of zinc is of a white colour, a metallic ſplendor, but reſembles lead more than zinc. It is ſomewhat malleable. When hammered or filed, it emits the odour of phoſphorus. When expoſed to a ſtrong heat, it burns like zinc ‡.

Phoſphorus

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

† *Bergman*, ii. 309.

‡ *Sage.*

§ *Kirwan's Miner.* ii. 232.

‖ *Briſſon.*

¶ *Kirwan, ibid.*

* *Bergman.*

† *Mongez.*

‡ *Morveau, Kirwan's Miner.* ii. 489.

* *Mineral.* ii. 499.

† *Schrickel.*

‡ *Ann. de Chim.* xiii. 129.

(Y) The paſſages in which he mentions it are as follows:—*De Mineral.* lib. ii. cap. 11. "Marchaſita, ſive marchaſida ut quidam dicunt, eſt lapis in ſubſtantia, et habet multas ſpecies, quare colorem accipit cujuſlibet metalli, et ſic dicitur marchaſita argentea et aurea, et ſic dicitur aliis. Metallum tamen quod colorat cum non diſtillat ab ipſo, ſed evaporat in ignem, et ſic relinquitur cinis inutilis, et hic lapis notus eſt apud alchimicos, et in multis locis veniuntur.

Lib. iii. cap. 10. "Æs autem invenitur in venis lapidis, et quod eſt apud locum qui dicitur Goſelaria eſt puriſſimum et optimum, et toti ſubſtantiæ lapidis incorporatum, ita quod totus lapis eſt ſicut marchaſita aurea, et profundatum eſt melius ex eo quod purius.

Lib. v. cap. 5. "Dicimus igitur quod marchaſita duplicem habet in ſui creatione ſubſtantiam, argenti vivi ſcilicet mortificati, et ad fixionem approximantis, et ſulphuris adurentis. Ipſam habere ſulphureitatem comperimus manifeſta experientia. Nam cum ſublimatur, ex illa emanat ſubſtantia ſulphurea manifeſta comburens. Et ſine ſublimatione ſimiliter perpenditur illius ſulphureitas.

"Nam ſi ponatur ad ignitionem, non ſuſcipit illam priuſquam inflammatione ſulphuris inflammetur, et ardeat. Ipſam vero argenti vivi ſubſtantiam manifeſtatur habere ſenſibiliter. Nam albedinem præſtat Veneri meri argenti, quemadmodum et ipſum argentum vivum, et colorem in ipſius ſublimatione cæleſtium præſtare, et luciditatem manifeſtam metallicam habere vidimus, quæ certum reddunt artificem Alchimiæ, illam has ſubſtantias continere in radice ſua."

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

(A) Pott obſerved, that it was $\frac{1}{10}$th heavier than the zinc from which it was obtained; and Mr Boyle had long before aſcertained the ſame fact.—*Shaw's Boyle*, II. 391, 394.

This oxide of zinc was well known to the ancients. Dioſcorides deſcribes the method of preparing it. The ancients called it *pompholyx*, the early chemiſts gave it the name of *lana philoſophica*. Dioſcorides compares it to wool, εριων τολυπαις αφομοιονται, v. 85. p. 352.

Phoſphorus combines alſo with the oxide of zinc, a compound which Margraf had obtained during his experiments on phoſphorus. When 12 parts of oxide of zinc, 12 parts of phoſphoric glaſs, and two parts of charcoal powder, are diſtilled in an earthen ware retort, and a ſtrong heat applied, a metallic ſubſtance ſublimes of a ſilver-white colour, which, when broken, has a vitreous appearance. This, according to Pelletier, is phoſphuret of oxide of zinc. When heated by the blowpipe, the phoſphorus burns, and leaves behind a glaſs tranſparent while in fuſion, but opaque after cooling*.

* *Pelletier, ibid.* 128.

139
Carburet,

Zinc alſo combines with carbon, and forms carburet of zinc. The French chemiſts have ſhewn that zinc generally contains ſome carbon.

140
Alloys,

Zinc combines with moſt of the metals:

1. It mixes with gold in any proportion. The alloy is the whiter and the more brittle the greater quantity of zinc it contains. An alloy, conſiſting of equal parts of theſe metals, is very hard and white, receives a fine poliſh, and does not tarniſh readily. It has therefore been propoſed by Mr Malouin† as very proper for the ſpecula of teleſcopes. One part of zinc is ſaid to deſtroy the ductility of 100 parts of gold ‡.

† *Mem. Acad. Par.* 1742.
‡ *Keir's Macquer's Dictionary.*

2. The alloy of ſilver and zinc is eaſily produced by fuſion. It is brittle.

3. Platinum combines very readily with zinc. The alloy is brittle, pretty hard, very fuſible, and of a bluiſh white colour, not ſo clear as that of zinc §.

§ *Dr Lewis.*

4. Zinc may be combined with mercury by fuſion. The amalgam is ſolid. It cryſtallizes when melted and cooled ſlowly into lamellated hexagonal figures, with cavities between them. They are compoſed of one part of zinc and two and a half of mercury ‖. It is uſed to rub on electrical machines, in order to excite electricity.

‖ *Elemens de Chim. Dijon,* t. 3.

5. Zinc combines very readily with copper. This alloy, which is called *braſs*, was known to the ancients. They uſed an ore of zinc to form it, which they called *cadmia*. This alloy was very much valued by the ancients. Dr Watſon has proved that it was to braſs which they gave the name of *orichalcum* ¶. Their *æs* was copper or rather bronze (B). Braſs is compoſed of about three parts of copper and one of zinc. It is of a beautiful yellow colour, more fuſible than copper, and not ſo apt to tarniſh. It is malleable, and ſo ductile that it may be drawn out into wire. When the alloy contains three parts of zinc and four of copper, it aſſumes a colour nearly the ſame with gold, but it is not ſo malleable as braſs. It is then called *pinchbeck*, *prince's metal*, or *Prince Rupert's metal*.

¶ *Mancheſter Tranſ.* vol. ii.

6. The alloy of iron and zinc has ſcarcely been examined: but Malouin has ſhewn that zinc may be uſed inſtead of tin to cover iron plates; a proof that there is an affinity between the two metals*.

* *Mem. Par.* 1742.

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

8. Mr Gmelin has ſucceeded in forming an alloy of zinc and lead by fuſion. He put ſome ſuet into the mixture, and covered the crucible, in order to prevent the evaporation of the zinc. When the zinc exceeded the lead very much, the alloy was malleable, and much harder than lead. A mixture of two parts of zinc and one of lead formed an alloy more ductile and harder than the laſt. A mixture of equal parts of zinc and lead formed an alloy differing little in ductility and colour from lead; but it was harder, and more ſuſceptible of poliſh, and much more ſonorous. When the mixture contained a ſmaller quantity of zinc, it ſtill approached nearer the ductility and colour of lead, but it continued harder, more ſonorous, and ſuſceptible of poliſh, till the proportions approached to one of zinc and 16 of lead, when the alloy differed from the laſt metal only in being ſomewhat harder†.

† *Ann. de Chim.* ix. 95.

141
And affinities.

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

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

Sect. X. *Of Antimony.*

The ancients were acquainted with an oxide of antimony to which they gave the names of στιμμι and *ſtibium*. Pliny ‡ informs us that it was found in ſilver ore; and we know that at preſent there are ſilver ores § in which it is contained. It was uſed as an external application to ſore eyes; and Pliny gives us the method of preparing it ‖. Galen ſuppoſes that the τετραγωνον of Hippocrates was a preparation of antimony; but this wants proof. It does not appear, however, that the ancients conſidered this ſubſtance as a metal, or that they knew antimony in a ſtate of purity (C). Who firſt extracted it from its ore we do not know; but Baſil Valentine, a chemiſt of the 16th century, is the firſt who deſcribes the proceſs.

‡ *Pliny*, l. xxxiii. c. 6.
§ *Kirwan's Miner.* ii. 110.
‖ *Pliny, ibid.*

142
Diſcovery of Antimony.

(B) The ancients do not ſeem to have known accurately the difference between copper, braſs, and bronze. Hence the confuſion obſervable in their names. They conſidered braſs as only a more valuable kind of copper, and therefore often uſed the word *æs* indifferently to denote either. It was not till a late period that mineralogiſts began to make the diſtinction. They called copper *æs cyprium*, and afterwards only *cyprium*, which in proceſs of time was converted into *cuprum*. When theſe changes took place is not known accurately. Pliny uſes *cyprium*, lib. xxxvi. c. 26. The word *cuprum* occurs firſt in Spartian, who lived about the year 290. He ſays in his life of Caracalla, *cancelli ex ære vel cupro*.

(C) Mr Roux indeed, who at the requeſt of Count Caylus analyſed an ancient mirror, found it compoſed of copper, lead, and antimony. This would go far to convince us that the ancients knew this metal, provided it could be proved that the mirror was *really* an ancient one; but this point appears to be extremely doubtful.

proceſs. To him indeed we are indebted for our acquaintance with many of the properties of this metal.

Antimony is of a white colour, with a ſhade of grey. It has a ſenſible taſte, but no ſmell *.

* Fourcroy.

143 Properties of antimony.

It is neither malleable nor ductile, but exceedingly brittle. Its ſpecific gravity, according to Briſſon, is 6,702; according to Bergman, 6,860. Its hardneſs is 6,5 †. It melts at 809° Fahrenheit ‡. If after this the heat be increaſed, the metal evaporates. On cooling it aſſumes the form of oblong cryſtals, perpendicular to the internal ſurface of the veſſel in which it cools. It is to this cryſtallization that the laminated ſtructure which antimony always aſſumes is owing.

† Kirwan's Miner. ii. 244.
‡ Bergman.

Neither air nor water have much effect on this metal.

144 Its oxides.

When antimony is beat to powder, and expoſed for ſome time to a gentle heat, it abſorbs oxygen, and is converted into a grey powder. This is the *grey oxide of antimony*. When this metal is kept for ſome time melted in contact with air, it ſublimes in the form of a white powder, formerly called *ſnow* or *white flowers of antimony*. This is the *white oxide of antimony*. This oxide may be procured alſo by pouring nitric acid on antimomy, and then evaporating to dryneſs. Antimony attracts the oxygen from the acid, and thus paſſes very rapidly into the ſtate of an oxide. This oxide ſeems to conſiſt of about 77 parts of antimony and 23 of oxygen §. The nature of theſe oxides has never yet been accurately inquired into. It is not even known at preſent whether the white oxide obtained by heat and that obtained by nitric acid contain the ſame quantity of oxygen. The experiments mentioned by Mr Kirwan make the contrary probable ‖; and yet theſe oxides have too many qualities in common to render theſe experiments concluſive. The white oxide of antimony is ſoluble in water ¶; and when fuſed, is converted into a tranſparent glaſs. The white oxide obtained by nitric acid ſeems to poſſeſs many of the properties of an acid.

§ Kirwan's Miner. ii. 489.
‖ Ibid.
¶ Rouelle.

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

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

* Schrickel.

145 Sulphurets,

Sulphur combines readily with antimony. This compound is often found native: it was formerly called antimony, and the pure metal was then called *regulus of antimony*. Sulphuret of antimony is eaſily melted by a moderate heat: if the heat be continued, the ſulphur ſublimes, and at the ſame time the antimony abſorbs oxygen, and is converted into a grey oxide. This ſulphuret is compoſed of 74 parts of antimony and 26 of ſulphur *.

* Bergman, iii. 167.

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

146 Phoſphuret,

When equal parts of antimony and phoſphoric glaſs are mixed together with a little charcoal powder, and melted in a crucible, phoſphuret of antimony is produced. It is of a white colour, brittle, appears laminated when broken, and at the fracture there appear a number of ſmall cubic facettes. When melted it emits a green flame, and then ſublimes in the form of a white powder. Phoſphuret of antimony may likewiſe be prepared by fuſing equal parts of antimony and phoſphoric glaſs, or by dropping phoſphorus into melted antimony †.

† Pelletier, Ann. de Chim. xiii. 132.

Antimony is capable of combining with moſt of the metals

147 Alloys,

1. Gold may be alloyed with antimony by fuſing them together. The antimony is afterwards ſeparable by an intenſe heat. This alloy is little known, and has never been applied to any uſe.

2. The alloy of ſilver and antimony is brittle, and its ſpecific gravity, as Gellert has obſerved, is greater than intermediate between the ſpecific gravities of the two metals which enter into it.

3. Platinum eaſily combines with antimony. The alloy is brittle, and much lighter than platinum ‡. The antimony cannot afterwards be completely ſeparated by heat.

4. Mercury does not eaſily combine with antimony. Mr Gellert ſucceeded in amalgamating this metal by putting it into hot mercury, and covering the whole with water.

5. Copper combines readily with antimony by fuſion. The alloy is of a beautiful violet colour, and its ſpecific gravity is greater than intermediate §.

6. Iron combines with antimony, and forms a brittle hard alloy, the ſpecific gravity of which is leſs than intermediate. The magnetic quality of iron is much more diminiſhed by being alloyed with antimony than with any other metal ‖.

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

8. When equal quantities of lead and antimony are fuſed, the alloy is porous and brittle: three parts of lead and one of antimony form a compact alloy, malleable, and much harder than lead: 12 parts of lead and one of antimony form an alloy very malleable, and a good deal harder than lead: 16 parts of lead and one of antimony form an alloy which does not differ from lead except in hardneſs *. This alloy forms printers types.

9. Zinc and antimony form a brittle alloy, the ſpecific gravity of which is leſs than intermediate †. The alloys of antimony are little known. Gellert is almoſt the only perſon who has examined them. It would require a great number of experiments to be able to fix the proportions of their ingredients.

‡ Dr Lewis.
§ Gellert.
‖ Id.
¶ Id.
* Gmelin, Ann. de Chim. viii. 319.
† Gellert.

The

(D) Muriatic acid decompoſes benzoat of antimony. *Trommſdorf, Ann. de Chim.* xi. 317.

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

Iron,
Copper,
Tin,
Lead,
Nickel,
Silver,
Biſmuth,
Zinc,
Gold,
Platinum,
Mercury,
Arſenic,
Cobalt,
Sulphuret of arſenic,
Sulphur,
Phoſphorus?

SECT. XI. *Of Biſmuth.*

THE ancients appear to have known nothing of biſmuth, nor do we know who diſcovered it; but it is firſt mentioned by George Agricola, who was born about the end of the 15th century.

148 Properties of biſmuth.

Biſmuth is of a yellowiſh or reddiſh white colour, and almoſt deſtitute both of taſte and ſmell.

It is brittle. Its hardneſs is 6*. Its ſpecific gravity is 9,8227†. It melts at 460° Fahrenheit‡.

* *Kirwan.*
† *Briſſon.*
‡ *Lewis.*

When heated in cloſe veſſels, it ſublimes. When allowed to cool ſlowly after fuſion, it cryſtallizes.

Biſmuth is not altered by water. When expoſed to the air it ſoon tarniſhes.

149 Its oxides,

When biſmuth is kept fuſed in contact with air, it is gradually oxidated. When heated red hot, it emits a very faint blue flame, and its oxide evaporates in the form of a yellowiſh ſmoke. When this ſmoke is collected, it is found to conſiſt of a brown coloured powder. This is the *brown oxide of biſmuth*. It is compoſed of about 94 parts of biſmuth and 6 of oxygen§. Biſmuth decompoſes nitric acid with great rapidity, by attracting its oxygen. If the quantity of acid be conſiderable, it diſſolves the oxide as it forms; but the greater part of it may be precipitated by diluting the acid with water. This precipitate, which is a white powder, is *white oxide of biſmuth*. It is compoſed of about 84 parts biſmuth and 16 of oxygen‖.

§ *Kirwan's Miner.* ii. 489.
‖ *Ibid.*

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

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

150 Sulphuret,

Sulphur combines readily with biſmuth by fuſion. The ſulphuret of biſmuth is of a bluiſh grey colour, and cryſtallizes into beautiful tetrahedral needles. It is compoſed of 85 parts of biſmuth and 15 of ſulphur*.

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

151 Phoſphuret,

There appears to be little affinity between biſmuth and phoſphorus. Mr Pelletier attempted to produce the phoſphuret of biſmuth by various methods without ſucceſs. When he dropped phoſphorus, however, into biſmuth in fuſion, he obtained a ſubſtance which did not apparently differ from biſmuth, but which, when expoſed to the blow-pipe, gave evident ſigns of containing phoſphorus. Phoſphuret of biſmuth, according to Pelletier, is compoſed of about 96 parts of biſmuth and four of phoſphorus†.

† *Ann. de Chim.* xiii. 130.

152 Alloys,

Biſmuth combines readily with moſt of the metals.

1. Equal parts of biſmuth and gold form a brittle alloy, nearly of the ſame colour with biſmuth‡.

2. Equal parts of biſmuth and ſilver form alſo a brittle alloy, but leſs ſo than the laſt. The ſpecific gravity of both theſe is greater than intermediate§.

‡ *Keir, Macquer's Dict.*
§ *Ibid.*

3. The alloy of biſmuth and platinum is alſo very brittle. When expoſed to the air it aſſumes a purple, violet, or blue colour. The biſmuth may be ſeparated by heat‖.

‖ *Dr Lewis.*

4. Mercury diſſolves biſmuth very eaſily. The amalgam is more fluid than pure mercury, and has the property of diſſolving lead and rendering it alſo fluid¶. It is capable, however, of cryſtallizing. The cryſtals are either octahedrons, lamellated triangles, or hexagons. They are compoſed of one part of biſmuth and two of mercury*.

¶ *Cramer.*
* *Chim. Dijon,* i. 3.

5. The alloy of copper and biſmuth is not ſo red as copper.

6. Nothing is known concerning the alloy of iron and biſmuth.

7. Biſmuth and tin unite readily. A ſmall portion of biſmuth increaſes the brightneſs, hardneſs, and ſonorouſneſs of tin: it often therefore enters into the compoſition of the compound called *pewter*. Equal parts of tin and biſmuth form an alloy that melts at 280°: eight parts of tin and one of biſmuth, melt at 390°: two parts of tin and one of biſmuth, at 330°†.

† *Dr Lewis.*

8. The alloy of lead and biſmuth is of a dark grey colour, a cloſe grain, but very brittle.

9. Biſmuth does not combine with zinc.

10. The alloy of antimony and biſmuth is unknown.

Biſmuth likewiſe enters into triple compounds with metals: Two parts of lead, three of tin, and five of biſmuth, form an alloy which melts at the heat of boiling water, which is 212°.

153 And affinities.

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

Lead,
Silver,
Gold,

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

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

SECT XII. *Of Arſenic.*

THE word *arſenic* (αρσενικον) occurs firſt in the works of Dioſcorides, and of ſome other authors who wrote about the beginning of the Chriſtian era. It denotes in their works the ſame ſubſtance which Ariſtotle had called σανδαραχη (F), and his diſciple Theophraſtus αρσενικον, which is a reddiſh coloured mineral, compoſed of arſenic and ſulphur, uſed by the ancients in painting, and as a medicine.

The *white oxide of arſenic*, or what is known in commerce by the name of arſenic, is mentioned by Avicenna in the 11th century; but at what period the metal called *arſenic* was firſt extracted from that oxide is unknown. Paracelſus ſeems to have known it. It is mentioned by Schroeder in his Pharmacopœia publiſhed in 1649[*].

153 Properties of arſenic.

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

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

154 Its oxides.

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

When arſenic is expoſed to the open air, it very ſoon loſes its luſtre, and is gradually converted into a greyiſh black ſubſtance by combining with oxygen. This is called the *grey oxide of arſenic*.

When expoſed to a moderate heat in contact with air, it ſublimes in the form of a white powder, and at the ſame time emits a ſmell reſembling garlic. If the heat be increaſed, it burns with an obſcure bluiſh flame. This ſublimate is *white oxide of arſenic*, which is compoſed of 93 parts of arſenic and 7 of oxygen[¶].

It is of a ſharp acrid taſte, which at laſt leaves an impreſſion of ſweetneſs, and is one of the moſt virulent poiſons known. It has an alliacious ſmell. It is ſoluble in 80 parts of water at the temperature of 60°, and in 15 parts of boiling water[*]. When this ſolution is evaporated, the oxide cryſtallizes[†]. When heated to 283°, it ſublimes: if heat be applied in cloſe veſſels, it becomes pellucid like glaſs, but when expoſed to the air it ſoon recovers its former appearance. The ſpecific gravity of this glaſs is 5,000; that of the white oxide, 3,706[‡]. This oxide is capable of combining with moſt of the metals, and in general renders them brittle. Its affinities, according to Bergman, are as follows:

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

Arſenic, or rather the white oxide of arſenic, is capable of combining with an additional doſe of oxygen. The compound produced is *arſenic acid*, firſt diſcovered by Scheele, which contains 91 parts of arſenic and 9 of oxygen[*].

155 Sulphuret.

Arſenic combines readily with ſulphur. When heat is applied to a mixture of white oxide of arſenic and ſulphur, the oxide is decompoſed, part of the ſulphur combines with its oxygen, and the remainder unites with the reduced metal. The ſulphuret of arſenic produced by this proceſs is of a yellow colour, and was formerly called *orpiment*. It is compoſed, according to Weſtrum, of 20 parts of arſenic and 80 of ſulphur[†]. It is often found native. If a ſtronger heat be applied, ſo as to melt the ſulphuret, it aſſumes a ſcarlet colour, and is much leſs volatile than formerly. This new compound was formerly called *realgar*. It is compoſed, according to Weſtrum, of 80 parts of arſenic and 20 of ſulphur[‡]. The difference therefore between it and orpiment is evident. During the fuſion part of the ſulphur without doubt ſublimes. It might be called *red ſulphuret of arſenic*.

156 Phoſphuret.

Arſenic combines readily with phoſphorus. The phoſphuret of arſenic may be formed by diſtilling equal parts of its ingredients over a moderate fire. It is black and brilliant, and ought to be preſerved in water. It may be formed likewiſe by putting equal parts of phoſphorus and arſenic into a ſufficient quantity of water, and keeping the mixture moderately hot for ſome time[§].

157 Alloys.

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

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

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

3. The alloy of platinum and arſenic is brittle and very fuſible. It was firſt formed by Scheffer. The arſenic may be ſeparated by heat.

4. The amalgam of arſenic is compoſed of five parts of mercury and one of arſenic[*].

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

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

[*] Bergman, ii. 278.

[†] Kirwan's Miner. ii. 254.

[‡] Bergman, ii. 278.

[§] Ibid.

[||] Hahneman, Chim. Ann. 1788, i. 182.

[¶] Kirwan's Miner. ii. 490.

[*] Bergman, ii. 278.

[†] Brandt, Act. Upſal, 1733.

[‡] Bergman, ii. 278.

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

[†] Kirwan's Miner. ii. 492.

[‡] Ibid.

[§] Pelletier, Ann. de Chim. xiii. 139.

[||] Bergman, ibid.

[¶] Ibid.

[*] Ibid.

[†] Ibid.

Cobalt

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

[*] Gellert.

6. Iron is capable of combining with more than its own weight of arſenic [†]. This alloy is white, brittle, and capable of cryſtallizing. It is found native [‡].

[†] Bergman, Ann. de Chim xiii. 139.

[‡] Kirwan's Miner. ii. 256.

7. The alloy of tin and arſenic is harder and more ſonorous than tin, and has much reſemblance externally to zinc. Tin often contains a ſmall quantity of arſenic.

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

[§] Bergman, Ibid.

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

[||] Ibid.

158
And affinities.

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

Nickel,
Cobalt,
Copper,
Iron,
Silver,
Tin,
Gold,
Platinum,
Zinc,
Antimony,
Sulphuret of alkali,
Sulphur,
Phoſphorus.

Sect. XIII. *Of Cobalt.*

A MINERAL called *cobalt* (G), of a grey colour, and very heavy, has been uſed in different parts of Europe ſince the 15th century to tinge glaſs of a blue colour. From this mineral Brandt obtained in 1733 a new metal, to which he gave the name of *cobalt* [¶].

[¶] Act. Upſal. 1733.

159
Properties of cobalt,

Cobalt is of a white colour, inclining to a bluiſh or ſteel grey. When pure, it is ſomewhat malleable while red hot [*]. Its hardneſs is 8 [†]. Its ſpecific gravity is 8,15 (H). It requires for fuſion a heat at leaſt as great as caſt iron, which melts at 130° Wedgewood. No heat has been produced great enough to volatalize it [‡].

[*] Leonhardi.

[†] Kirwan's Miner. ii. 268.

[‡] Bergman, iv.

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

It is attracted by the magnet.

It is not oxidated by heat without very great difficulty; but it has the property of decompoſing nitric acid, and of attracting oxygen by that means with great rapidity.

160
Its oxides,

The *oxide of cobalt* is of ſo deep a blue as to appear black. The oxide procured by heat is compoſed of 88 parts of cobalt and 12 of oxygen; that by nitric acid contains about 77 parts of cobalt and 23 of oxygen [*]. Its affinities, according to Bergman, are as follows:

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

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

161
Sulphuret,

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

162
Phoſphuret,

Phoſphuret of cobalt may be formed by heating the metal red hot, and then gradually dropping in ſmall bits of phoſphorus. It contains about $\frac{1}{15}$th of phoſphorus. It is white and brittle, and when expoſed to the air ſoon loſes its metallic luſtre. The phoſphorus is ſeparated by heat, and the cobalt is at the ſame time oxidated. This phoſphuret is much more fuſible than pure cobalt [†].

[†] Pelletier, Ann. de Chim. xiii. 134.

163
Alloys,

The combinations of cobalt with other metals have been very little examined into.

1. The alloy of gold and cobalt is not known.

2. Cobalt does not combine with ſilver by fuſion [‡]; but, according to Gellert, the alloy of ſilver and cobalt *may* be formed: it is brittle and of a grey colour [§]

3. The alloy of platinum and cobalt is unknown.

4. Mer-

[‡] Bergman's Elect. Attract

[§] Metallur. Chim.

(G) The word *cobalt* ſeems to be derived from *cobalus*, which was the name of a ſpirit that, according to the ſuperſtitious notions of the times, haunted mines, deſtroyed the labours of the miners, and often gave them a great deal of unneceſſary trouble. The miners probably gave this name to the mineral out of joke, becauſe it thwarted them as much as the ſuppoſed ſpirit, by exciting falſe hopes, and rendering their labour often fruitleſs; for as it was not known at firſt to what uſe the mineral could be applied, it was thrown aſide as uſeleſs. It was once cuſtomary in Germany to introduce into the church-ſervice a prayer that God would preſerve miners and their works from *kobalts* and ſpirits. See *Beckmann's Hiſtory of Inventions*, II. 362.

Matheſius, in his tenth ſermon, where he ſpeaks of *cadmia foſſilis* (probably cobalt ore), ſays, "Ye miners call it *kobolt;* the Germans call the black devil and the old devil's whores and hags, old and black *kobel*, which, by their witchcraft do injury to people and to their cattle."

Lehmann, Paw, Delaval, and ſeveral other philoſophers, have ſuppoſed that *ſmalt* (oxide of cobalt melted with glaſs and pounded) was known to the ancients, and uſed to tinge the beautiful blue glaſs ſtill viſible in ſome of their works; but we learn from Gmelin, who analyſed ſome of theſe pieces of glaſs, that they owed their *blue* colour, not to the preſence of *cobalt* but of *iron*.

According to Lehmann, cobalt ore was firſt uſed to tinge glaſs blue by Chriſtopher Schurer, a glaſs maker at Platten, about the year 1540.

(H) *Berg*. II. 231. According to Briſſon, 7,8119.

4. Mercury does not appear to amalgamate with cobalt.

5. The alloy of copper and cobalt is ſcarcely known.

6. The alloy of iron and cobalt is very hard, and not eaſily broken. Cobalt generally contains ſome iron, from which it is with great difficulty ſeparated.

7. The alloy of tin and cobalt is of a light violet colour.

8. Cobalt does not combine with lead by fuſion.

9. The alloy of zinc and cobalt is not formed without difficulty.

10. The alloy of antimony and cobalt is unknown.

11. Cobalt does not combine with biſmuth by fuſion *.

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

164 And affinities.

The affinities of cobalt are as follows:

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

Sect. XIV. *Of Nickel.*

A heavy mineral of a red colour is met with in ſeveral parts of Germany, which bears a ſtrong reſemblance to an ore of copper; but none of that metal can be extracted from it: for this reaſon the Germans called it *kupfer nickel* (devil's copper). Hierne mentioned it in 1694. Cronſtedt was the firſt chemiſt who examined it with accuracy. He concluded from his experiments, which were publiſhed in the Stockholm Tranſactions for 1751 and 1754, that it contained a new metal, to which he gave the name of *nickel*. — 165 Diſcovery of nickel,

Some chemiſts, particularly Mr Sage, affirmed, that it contained no new metal, but merely a compound of various known metals, which could be ſeparated from each other by the uſual proceſſes. Theſe aſſertions induced Bergman to undertake a very laborious courſe of experiments, in order if poſſible to obtain *nickel* in a ſtate of purity: for Cronſtedt had not been able to ſeparate a quantity of arſenic, cobalt, and iron, which adhered to it with much obſtinacy. Theſe experiments have been very fully detailed in the article Chemistry, in the *Encycl.* to which be beg leave to refer. Bergman has ſhewn, that nickel poſſeſſes peculiar properties, and that it can neither be reduced to any other metal, nor formed artificially by any combination of metals. It muſt therefore be conſidered as a peculiar metal. It may poſſibly be a compound, and ſo may likewiſe many other metals; but we muſt admit every thing to be a peculiar body which has peculiar properties, and we muſt admit every body to be ſimple till ſome proof be actually produced that it is a compound; otherwiſe we forſake the road of ſcience, and get into the regions of fancy and romance.

166 Its properties,

Nickel is of a greyiſh white colour, and when leſs pure inclines a little to red.

It is both ductile and malleable. Its hardneſs is 8 *. Its ſpecific gravity 9,000 †. It requires for fuſion a temperature at leaſt equal to 150° Wedgewood ‡.

It is powerfully attracted by the magnet, and is even poſſeſſed of the property of attracting iron. This induced Bergman to ſuppoſe that nickel, when pureſt, was ſtill contaminated with about one-third of iron: but as this is the only proof of its containing iron, Klaproth, with reaſon, deems it an inſufficient one, and conſiders attraction by the magnet as a property of nickel §.

167 Oxides,

When expoſed to a ſtrong heat, nickel is oxidated ſlowly. Its oxide is of a *brown* colour; if impure, it is *greeniſh*. The oxide of nickel, according to Klaproth, is compoſed of 77 parts of nickel and 23 of oxygen ¶. Its affinities, according to Bergman, are as follows:

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

168 Sulphuret,

Cronſtedt found that nickel combined readily with ſulphur by fuſion. The ſulphuret which he obtained was yellow and hard, with ſmall ſparkling facets; but the nickel which he employed was impure.

169 Phoſphuret,

Nickel combines very readily with phoſphorus, either by fuſing it along with phoſphoric glaſs, or by dropping phoſphorus into it while red hot. The phoſphuret of nickel is of a white colour, and when broke exhibits the appearance of very ſlender priſms collected together. When heated, the phoſphorus burns, and the metal is oxidated. It is compoſed of 83 parts of nickel and 17 of phoſphorus *. The nickel, however, on which this experiment was made, was not pure.

170 Alloys,

Little is known concerning the alloys of nickel with other metals. Equal parts of ſilver and nickel form a white ductile alloy. Equal parts of copper and nickel form a red ductile alloy. The compounds which this metal forms with tin and zinc are brittle. It does not combine with mercury †. It has a very ſtrong affinity for iron, cobalt, and arſenic, and is ſcarcely ever found except combined with ſome of them.

171 And affinities.

Its affinities, according to Bergman, are as follows:

Iron,
Cobalt,
Arſenic,

Copper,

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* Baumé.

† Bergman, iv.

* Kirwan's Miner. ii. 281.

† Bergman, ii. 231.

‡ Ibid.

§ Ann. de Chim. i. 170.

¶ Kirwan's Miner. ii. 490.

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

† Bergman, ii. 231.

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

SECT. XV. *Of Manganeſe.*

[171] Diſcovery of manganeſe. THE dark grey mineral called *manganeſe*, in Latin *magneſia* (according to Boyle, from its reſemblance to the *magnet)*, has been long known and uſed in making glaſs. A mine of it was diſcovered in England by Mr Boyle. It was long ſuppoſed to be an ore of iron; but Port and Cronſtedt having demonſtrated that it contained very little of that metal, the latter referred it in his Mineralogy to a diſtinct order of earths, which he called *terræ magneſiæ*. Bergman, from its ſpecific gravity, and ſeveral other qualities, ſuſpected that it was a metallic oxide: he accordingly made ſeveral attempts to reduce it, but without ſucceſs; the whole maſs either aſſuming the form of ſcoriæ, or yielding only ſmall ſeparate globules attracted by the magnet. This difficulty of fuſion led him to ſuſpect that the metal he was in queſt of bore a ſtrong analogy to platinum. In the mean time, Dr Gahn, who was making experiments on the ſame mineral, actually ſucceeded in reducing it by the following proceſs: He lined a crucible with charcoal powder moiſtened with water, put into it ſome of the mineral formed into a ball by means of oil, then filled up the crucible with charcoal powder, luted another crucible over it, and expoſed the whole for about an hour to a very intenſe heat. At the bottom of the crucible was found a metallic button, or rather a number of ſmall metallic globules, equal in weight to one-third of the mineral employed *. It is eaſy to ſee by what means this reduction was accompliſhed. The charcoal attracted the oxygen from the oxide, and the metal remained behind. This metal is called *manganeſe*.

172 Its properties, Manganeſe is of a greyiſh white colour. It is not malleable, and yet not ſo brittle as to be eaſily broken. Its hardneſs is 8 †. Its ſpecific gravity is 7,000 ‡. Its fuſion requires ſo great a heat, that it has been very ſeldom accompliſhed.

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

173 Oxides, When expoſed to the air, it very ſoon tarniſhes, and aſſumes a darker colour, till at laſt it becomes black and friable. This change is produced by the abſorption of oxygen. It takes place much more rapidly if heat be applied to the metal. The ſubſtance thus obtained is the *black oxide of manganeſe*. This oxide is found in great abundance in nature, though ſcarcely ever in a ſtate of purity. It is compoſed of 75 parts of manganeſe and 25 of oxygen §.

If a quantity of muriatic acid be poured upon this oxide, and heat applied, part of the acid combines with ſome of the oxygen of the oxide, and flies off in yellow fumes. The oxide is diſſolved in the reſt. If potaſs be added to this ſolution, a white powder is precipitated. This is the *white oxide of manganeſe*. It contains, according to Bergman, about 80 parts of manganeſe and 20 of oxygen. It ſoon attracts more oxygen when expoſed to the air, and is converted into *black oxide*.

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

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

The ſulphuret of manganeſe is unknown.

174 Phoſphuret, Phoſphorus may be combined with manganeſe by melting together equal parts of the metal and of phoſphoric glaſs; or by dropping phoſphorus upon red hot manganeſe. The phoſphuret of manganeſe is of a white colour, brittle, granulated, diſpoſed to cryſtallize, not altered by expoſure to the air, and more fuſible than manganeſe. When heated, the phoſphorus burns and the metal becomes oxidated *.

175 Carburet, Manganeſe combines readily with carbon by fuſion (1).

176 Alloys, Little is known concerning the alloys of manganeſe. It combines readily with copper. The compound, according to Bergman, is very malleable, its colour is red, and it ſometimes becomes green by age. Gmelin made a number of experiments to ſee whether this alloy could be formed by fuſing the black oxide of manganeſe along with copper. He partly ſucceeded, and propoſed to ſubſtitute this alloy inſtead of the alloy of copper and arſenic, which is uſed in the arts †. We believe, however, that upon trial the new alloy has been found not to anſwer.

Manganeſe combines readily with iron; indeed it has ſcarcely ever been found quite free from ſome mixture of that metal. It combines alſo very eaſily with arſenic and tin, not eaſily with zinc, and not at all with mercury ‡.

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

Copper,
Iron,
Gold,
Silver,

* *Bergman*, ii. 211.

† *Kirwan's Miner.* ii. 288.

‡ *Hielm.*

§ *Bergman*, ii. 225.

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

† *Ann. de Chim.* i. 303.

‡ *Bergman*, ii. 211.

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(1) *Bergman*, III. 379.—Sometimes manganeſe is very ſpeedily oxidated by expoſure to the air; ſometimes ſcarcely altered by it, as Klaproth and Pelletier have obſerved. Mr Kirwan ſuppoſes that the manganeſe which is ſoon altered contains carbon, and that this is the cauſe of the difference. See *Miner.* II. 288.

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

The three metals, *cobalt*, *nickel*, and *mangancſe*, reſemble iron in ſeveral particulars: Like it, they are magnetic, very hard, and very difficult to fuſe: but they differ from it in ſpecific gravity, malleability, and in the properties of all their combinations with other ſubſtances; the oxides, for inſtance, of iron, cobalt, nickel, and mangancſe, poſſeſs very different qualities.

Sect. XVI. *Of Tungſten.*

178 Diſcovery of tungſten.

There is a mineral found in Sweden of an opaque white colour and great weight; from which laſt circumſtance it got the name of *tungſten*, or *ponderous ſtone*. Some mineralogiſts conſidered it as an ore of tin, others ſuppoſed that it contained iron. Scheele analyſed it in 1781, and found that it was compoſed of lime and a peculiar earthy-like ſubſtance, which he called from its properties *tungſtic acid*. Bergman conjectured that the baſis of this acid was a metal; and this conjecture was ſoon after fully confirmed by the experiments of Meſſrs D'Elhuyart, who obtained the ſame ſubſtance from a mineral of a browniſh black colour, called by the Germans *wolfram*, which is ſometimes found in tin mines. This mineral they found to contain $\frac{65}{100}$ of tungſtic acid; the reſt of it conſiſted of mangancſe, iron, and tin. This acid ſubſtance they mixed with charcoal powder, and heated violently in a crucible. On opening the crucible after it had cooled they found in it a button of metal, of a dark brown colour, which crumbled to powder between the fingers. On viewing it with a glaſs, they found it to conſiſt of a congeries of metallic globules, ſome of which were as large as a pin-head. The metal thus obtained is called *tungſten*. The manner in which it was produced is evident; tungſtic acid is compoſed of oxygen and tungſten: the oxygen combined with the carbon, and left the metal in a ſtate of purity.

179 Its Properties.

Tungſten is externally of a brown colour, internally of a ſteel grey *.

Its ſpecific gravity is 17,600 †. It is more infuſible than mangancſe ‡.

When heat is applied to tungſten it is converted into a yellow powder, compoſed of 80 parts of tungſten and 20 of oxygen §. This is the *yellow oxide of tungſten* or *tungſtic acid*.

The ſulphuret of tungſten is of a bluiſh black colour, hard, and capable of cryſtallizing.

Phoſphorus is capable of combining with tungſten ‖.

Of the alloys of tungſten we know nothing, except from the experiments of Elhuyarts, which have been tranſcribed into the article Chemistry in the *Encyclopædia*; to which, therefore, we beg leave to refer.

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

Sect. XVII. *Of Molybdenum.*

180 Diſcovery of molybdenum.

The Greek word *molybdena*, and its Latin tranſlation *plumbago*, ſeem to have been employed by the ancients to denote various oxides of lead; but by the moderns they were applied indiſcriminately to all ſubſtances poſſeſſed of the following properties: Light, friable, and ſoft, of a dark colour and greaſy feel, and which leave a ſtain upon the fingers. Scheele firſt examined theſe minerals with attention. He found that two very different ſubſtances had been confounded together. To one of theſe, which is compoſed of carbon and iron, and which has been already deſcribed, he appropriated the word *plumbago*; the other he called *molybdena*.

Molydbena is compoſed of ſcaly particles adhering ſlightly to each other. Its colour is bluiſh, very much reſembling that of lead. Scheele analyſed it, and obtained ſulphur and a whitiſh powder, which poſſeſſed the properties of an acid, and which, therefore, he called *acid of molybdena*. Bergman firſt ſuſpected that the baſis of this acid was a metal. It was at the requeſt of Bergman and Scheele that Mr Hielm began the laborious courſe of experiments by which he ſucceeded in obtaining a metal from this acid. His method was to form it into a paſte with linſeed oil, and then to apply a very ſtrong heat. This proceſs he repeated ſeveral times ſucceſſively. Klaproth and Pelletier alſo attempted to reduce it, and with equal ſucceſs. The metal is *molybdenum* (K).

181 Its properties.

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

Hitherto it has only been procured in ſmall grains, agglutinated together in brittle maſſes.

Its ſpecific gravity is 7,500. It is almoſt infuſible in our fires.

When expoſed to a ſtrong heat, it is gradually converted into a whitiſh-coloured oxide *. When nitric acid is poured upon it, molybdenum attracts oxygen, and is converted into a *white oxide*, which poſſeſſes the properties of an acid †. This is the *molybdic acid*.

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

Molybdenum is alſo capable of combining with phoſphorus §.

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

It ſeems capable of uniting with gold. The alloy is probably of a white colour ‖.

It combines readily with platinum while in the ſtate of an oxide. The compound is fuſible. Its ſpecific gravity is 20,00 ¶.

The alloys of molybdenum with ſilver, iron, and copper, are metallic and friable; thoſe with lead and tin are powders which cannot be fuſed *.

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

Sect. XVIII. *Of Uranium.*

182 Diſcovery of uranium.

There is a mineral found in the George Wagsfort mine at Johann-Georgenſtadt in Saxony, partly in a pure or unmixed ſtate, and partly ſtratified with other kinds of ſtones and earths. The firſt variety is of a blackiſh colour inclining to a dark iron grey, of a moderate ſplendor, a cloſe texture, and when broken preſents a ſomewhat uneven, and, in the ſmalleſt particles, a conchoidal ſurface. It is quite opaque, tolerably hard, and on being pounded yields a black powder. Its ſpecific gravity is about 7,500. The ſecond ſort is diſtinguiſhed

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(K) This name was given it by Hielm.

diſtinguiſhed by a finer black colour, with here and there a reddiſh caſt; by a ſtronger luſtre, not unlike that of pitcoal; by an inferior hardneſs; and by a ſhade of green, which tinges its black colour when it is reduced to powder *.

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

This foſſil was called *pechblende*; and mineralogiſts, miſled by the name (L), had taken it for an ore of zinc, till the celebrated Werner, convinced from its texture, hardneſs, and ſpecific gravity, that it was not a *blende*, placed it among the ores of iron. Afterwards he ſuſpected that it contained *tungsten*; and this conjecture was ſeemingly confirmed by the experiments of ſome German mineralogiſts, publiſhed in the Miners Journal †. But Klaproth, whoſe analyſes always diſplay the moſt conſummate ſkill, joined with the moſt rigid accuracy, examined this mineral about the year 1789, and found that it conſiſted chiefly of ſulphur combined with a peculiar metal, to which he gave the name of *uranium* (M).

† Ibid.

183 Its properties.

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

‡ Ibid. 233.

Its malleability is unknown. Its hardneſs is about 6. It requires a ſtronger heat for fuſion than manganeſe. Indeed Klaproth only obtained it in very ſmall conglutinated metallic grains, forming altogether a porous and ſpongy maſs.—Its ſpecific gravity is 6,440 §.

§ Ibid.

When expoſed for ſome time to a red heat, it ſuffers no change. By means of nitric acid, however, it may be converted into a yellow powder. This is the *yellow oxide of uranium*. This oxide is found native mixed with the mineral above deſcribed. Its affinities have not yet been determined.

Uranium is capable of combining with ſulphur. The mineral from which Mr Klaproth firſt obtained it is a native ſulphuret of uranium.

Nothing is known concerning the alloys or affinities of uranium.

SECT. XIX. *Of Titanium.*

184 Diſcovery of titanium.

THERE is a mineral found in Hungary which, from its external appearance, has been called *red ſhorl*; but Klaproth, who examined it about the year 1795, diſcovered that it conſiſted chiefly of a peculiar metal, to which he gave the name of *titanium*.

185 Its properties.

Titanium is of a browniſh red colour, and conſiderable luſtre. It is brittle. Its hardneſs is 9; its ſpecific gravity 4,18.

When expoſed to a ſtrong heat in a clay crucible, it ſuffered no alteration, except that its colour became browner; but in a coal crucible it loſt its luſtre and broke to pieces.

It is found naturally cryſtallized in right-angled quadrangular priſms, longitudinally furrowed, and about half an inch in length.

No acid had any effect in oxidating it; but when mixed with five times its weight of potaſs, and heated in a porcelain furnace, it melted, and formed when cold a denſe greyiſh maſs, the ſurface of which was cryſtallized. When diſſolved in boiling water, it ſoon let fall a white powder, weighing about one-third more than the titanium employed. This is the *oxide of titanium*. Fifty grains of it were reduced by ignition to 38. While hot it was yellowiſh, but, like oxide of zinc, became white as it cooled. When heated on charcoal, it aſſumes firſt a *roſy red*, and afterwards a *ſlate blue* colour, and at laſt melts into an imperfect bead with a finely ſtriated ſurface. Mr Klaproth did not ſucceed in reducing it to the metallic ſtate.

Titanium does not ſeem to have any affinity for ſulphur *.

* M'Gregor.

186 Menachanite.

There was a ſubſtance diſcovered by Mr M'Gregor in the valley of Menachan in Cornwall, and hence called *menachanite*. Upon this ſubſtance Mr M'Gregor made a very intereſting ſet of experiments, which were publiſhed in the Journal de Phyſique for 1791. He ſuſpected it to contain a new metal. From its properties, Mr Kirwan conjectured that it was the ſame with titanium †; and this conjecture has been very lately confirmed by Mr Klaproth, who analyſed menachanite, and found it to be an ore of that metal.

† Mineral. ii. 331.

SECT. XX. *Of Tellurium.*

187 Diſcovery of tellurium.

IN the mountains of Fatzbay, near Zalethna in Tranſylvania, there is a mine called *Mariahilf*; the ore of which is wrought for the gold that it contains. Mr Muller of Reichenſtein examined it in 1782, and ſuſpected that it contained a new metal; and Bergman, to whom he had ſent ſome of the ore, was of the ſame opinion: but the quantity of the mineral which theſe chemiſts had examined was too inconſiderable to enable them to decide with certainty. Klaproth analyſed a larger quantity of it about the year 1797, and found that 1000 parts of it conſiſted of 72 parts of iron, 2,5 of gold, and 925,5 of a new metal, to which he has given the name of *tellurium* (N).

188 Its properties.

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

‡ Klaproth, Philoſophical Magazine, i. 78.

It is very brittle and friable. Its fracture is laminated. Its ſpecific gravity is 6,115.

It is as eaſily melted as lead. When ſuffered to cool quietly and gradually, it readily aſſumes a cryſtallized ſurface §.

§ Muller.

When heated by the blowpipe upon charcoal, it burns with a very lively flame of a blue colour, inclining at the edges to green. It is ſo volatile as to riſe entirely in a whitiſh grey ſmoke; at the ſame time it exhales a diſagreeable odour like that of radiſhes. This ſmoke is the *white oxide* of tellurium, which may be formed alſo by diſſolving the metal in nitro-muriatic acid, and pouring into the ſaturated ſolution a quantity of water: a white powder precipitates, which is the oxide ‖.

‖ Klaproth.

When this oxide is heated for ſome time in a retort, it melts, and appears, after cooling, of a yellow ſtraw colour, having acquired a ſort of radiated texture. When formed

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

(M) From *Uranus* (Ουρανος), the name given by Mr Bode to the new planet diſcovered by Herſchel; which name the German aſtronomers have adopted. Mr Klaproth called the metal at firſt *uranite*; but he afterwards changed that name for *uranium*.

(N) Mr Kirwan, in the new edition of his Mineralogy, which was publiſhed before Mr Klaproth's experiments were known, gives this metal the name of *Sylvanite*.—Tellurium exiſts in ſeveral other mines in the ſame mountains.

Tellurium.

formed into a paſte with any fat oil, and diſtilled in a red heat, brilliant metallic drops are obſerved to cover the upper part of the retort, which at intervals fall to the bottom of the veſſel, and are immediately replaced by others. After cooling, metallic fixed drops are found adhering to the ſides and at the bottom of the veſſel; the remainder of the metal is reduced. Its ſurface is brilliant and almoſt always cryſtallized. When this oxide is expoſed to heat on charcoal, it is reduced with a rapidity that reſembles detonation *.

Tellurium combines with ſulphur. The ſulphuret of this metal is of a grey colour and radiated ſtructure. When placed on red hot charcoal, the metal burns as well as the ſulphur with a blue flame.

Tellurium amalgamates with mercury by ſimple trituration†.—The other properties of this metal are unknown.

189 Chromum.

A NEW metal has lately been diſcovered by Vauquelin in the red lead ore of Siberia. It is grey, very hard, brittle, and eaſily cryſtallizes in ſmall needles ‡. He has given it the name of *chromum* (o).

WE have now deſcribed all the metals at preſent known. The following table will exhibit in one view their principal properties.

190 General table of the properties of the metals.

Metals.	Colour.	Hardneſs.	Specific gravity	Fuſing Point.	Malleability.	Ductility	
Gold.	Yellow.	6	19,300	32 W. (P) 1298 F.	282000	500	
Silver..	White.	6½	10,510	28 W. 1044 F.	160000	270	
Platinum.	White.	7½	23,000	150 W.?		above 500	
Mercury.	White.		13,568	—39 F.			
Copper.	Red.	8	8,870	27 W. 1449 F.		299¼	
Iron.	Blue-grey.	9	7,788	150 W. 20577 F.		450	Magnetic.
Tin.	White.	6	7,299	410 F.	2000	49	
Lead.	Blue-white.	5	11,352	540 F.		29¼	
Zinc.	White.	6	7,190	700 F.		o	
Antimony.	Grey.	6½	6,860	700 F.	o	o	
Biſmuth.	Yellow-white.	6	9,822	460 F.	o	o	
Arſenic.	White.	7	8,310	400 F. ?	o	o	
Cobalt.	White.	8	8,150	130 W. 17977 F.			Magnetic.
Nickel.	White.	8	9,000	150 W. 20577 F.			Magnetic.
Mangaueſe.	White.	8	7,000	150 W. 20577 F.	o	o	Magnetic.
Tungſten.	Brown.	6	17,600		o	o	
Molybdenum	Grey.		7,500		o	o	
Uranium.	Grey.	6	6,440				
Titanium.	Red.	9	4,180		o	o	
Tellurium.	White.		6,115	540 F.	o	o	
Chromum.	Grey.				o	o	

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* *Klaproth.*

† *Muller.*

‡ *Nicholſon's Journal*, ii. 146.

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

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

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191 Remarks on metallic oxides.

We have ſeen that all the metals are capable of combining with oxygen; that almoſt every one forms various oxides, containing different quantities of oxygen, and varying in colour and other properties according to the proportion of oxygen which they contain. No part of chemiſtry has more engaged the attention of philoſophers than the metallic oxides; and yet ſuch is the difficulty of the ſubject, that ſcarcely any part of chemiſtry is more imperfectly underſtood.

We neither know how many oxides every particular metal is capable of forming, nor the manner in which they are formed: neither have the differences between oxides of the ſame metallic baſe been inquired into; though there cannot be a doubt that they differ, not only in their affinities, but in many of their other properties. The *white oxide* of manganeſe, for inſtance, combines readily with acids, but the *black* is incapable of uniting with any.

Mr Prouſt, in a very valuable paper which he lately publiſhed concerning the oxides of iron *, hints that metals are only capable of two degrees of oxidation, or, which is the ſame thing, that only two different oxides can be produced from the ſame metal. We think he has proved this completely as far as iron is concerned; and probably the obſervation holds good with reſpect to many other metals. Arſenic, copper, tin, molybdenum, and perhaps even mercury, ſeem to be capable of only two degrees of oxidation; but it would require a very numerous and accurate ſet of experiments to be able to determine the matter, or even to form a probable conjecture. Analogy is certainly againſt the ſuppoſition; for it has been demonſtrated that ſome ſubſtances at leaſt are capable of combining with three different doſes of oxygen (q), and why may not this be the caſe alſo with the metals?

There is one obſervation, however, which we owe to Mr Prouſt, the truth of which cannot be doubted, and which is certainly of the higheſt importance—that metals are not capable of indefinite degrees of oxidation, but only of a certain number; and that every particular oxide conſiſts of a determinate quantity of the metal and of oxygen chemically combined. Iron, for inſtance, is not capable, as has been ſuppoſed, of uniting with oxygen in all the intermediate degrees between $\frac{27}{100}$ and $\frac{48}{100}$, and conſequently of forming 20 or 30 different oxides; it can only combine with preciſely $\frac{27}{100}$ parts, or $\frac{48}{100}$ parts, and with no other proportions; and therefore is only capable of forming two oxides, the *green* and the *brown*. In like manner, every other metal combines with certain proportions of oxygen, and forms either two oxides or more according to its nature. To talk therefore of oxidating a metal indefinitely is not accurate, except it be intended to ſignify the combining of part of it with oxygen, while the reſt remains in its natural ſtate. If iron be oxidated at all, it muſt be combined with $\frac{27}{100}$ of oxygen; if it be oxidated more than this, it muſt be combined with $\frac{48}{100}$ of oxygen.

We beg leave to add another obſervation, which we conſider as of no leſs importance, and which will ſerve in ſome meaſure to modify and explain what has been juſt now ſaid. Oxygen is capable of uniting with metals, or with any other ſubſtance for which it has an affinity, only in *one* determinate proportion. Iron, for inſtance, and oxygen can only combine in the proportion of 73 parts of iron and 27 of oxygen. Theſe two quantities ſaturate each other, and form a compound which is incapable of receiving into it any more oxygen or iron: this compound is the *green oxide of iron*. How comes it then, it will be aſked, that there is another oxide of iron, the *brown oxide*, which contains 52 parts of iron and 48 of oxygen, proportions certainly very different from 73 and 27? We anſwer, there is an affinity between the green oxide of iron and oxygen; they are capable of combining together, and of ſaturating each other in the proportion of about 71,5 parts of green oxide and 28,5 of oxygen; and the compound which they form is the *brown oxide*, which of courſe contains 52 parts of iron and 48 of oxygen: But then it is not formed by the combination of theſe two ſubſtances directly, but by the combination of the green oxide and oxygen. In like manner, the arſenic acid is not compoſed of arſenic and oxygen combined directly, but of white oxide of arſenic combined with oxygen. The very ſame thing takes place in all the other metals. We cannot at preſent prove the truth of this obſervation in a ſatisfactory manner, becauſe it would be neceſſary to draw our proofs from combinations which are yet undeſcribed; but we will have occaſion to conſider it afterwards.

We have ſeen that all the metals hitherto tried are capable of combining with ſulphur, except gold and titanium; that all of them on which the experiments have been made can be united with phoſphorus; and that three of them, iron, zinc, and manganeſe, united with carbon; and perhaps many more of them may hereafter be found capable of aſſuming the form of carburets.

We have ſeen, too, that they are capable of uniting with one another and forming alloys. This was long reckoned peculiar to metals, and it is at preſent one of the beſt criterions for determining the metallic nature of any ſubſtance. Much is wanting to render the chemiſtry of alloys complete. Many of them have never been examined; and the proportions of almoſt all of them are unknown. Neither has any accurate method been yet diſcovered of determining the affinities of metals for each other. The order of affinities which we have given for each metal was determined by Bergman; but he acknowledged himſelf that he wanted the proper data to enſure accuracy.

CHAP. IV. *Of* EARTHS.

The word *earth*, in common language, has two meanings; it ſometimes ſignifies the *globe* which we inhabit, and ſometimes the *mould* on which vegetables grow. Chemiſts have examined this mould, and have found that it conſiſts of a variety of ſubſtances mixed together without order or regularity. The greateſt part of it, however, as well as of the ſtones, which form apparently ſo large a proportion of the globe, conſiſts of a ſmall number of bodies, which have a variety of commmon properties.

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

(q) We ſhall ſee afterwards that azot is one of theſe.

perties. Theſe bodies chemiſts have agreed to claſs together, and to denominate *earths*.

192 Properties of earths.

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

1. Inſoluble in water, or nearly ſo; or at leaſt becoming inſoluble when combined with carbonic acid.
2. Little or no taſte or ſmell; at leaſt when combined with carbonic acid.
3. Incombuſtible, and incapable while pure of being altered by the fire.
4. A ſpecific gravity not exceeding 4,9.
5. When pure, capable of aſſuming the form of a white powder.

The earths at preſent known amount to ten; the names of which are, lime, magneſia, barytes, ſtrontites, alumina, ſilica, jargonia, glucina, yttria, aguſtina.

Every one of the above characteriſtics is not perhaps rigorouſly applicable to each of theſe bodies; but all of them poſſeſs a ſufficient number of common properties to render it uſeful to arrange them under one claſs.

SECT. I. *Of Lime.*

LIME has been known from the earlieſt ages. The ancients employed it in medicine; it was the chief ingredient in their mortar; and they uſed it as a manure to fertilize their fields.

193 Method of procuring lime.

It abounds in many parts of the world, or perhaps we ſhould rather ſay, that there is no part of the world where it does not exiſt. It is found pureſt in limeſtones, and marbles and chalk. None of theſe ſubſtances, however, is, ſtrictly ſpeaking, lime; but they are all capable of becoming lime by a well-known proceſs, by keeping them for ſome time in a white heat: this proceſs is called *the burning of lime;* the product is denominated *quicklime*. This laſt ſubſtance is what we call *lime*.

194 Properties of lime.

Pure lime is of a white colour, moderately hard, but eaſily reduced to a powder.

It has a hot burning taſte, and in ſome meaſure corrodes and deſtroys the texture of thoſe animal bodies to which it is applied. It has no ſmell. Its ſpecific gravity is 2,3 *.

If water be poured on newly burnt lime, it ſwells and falls to pieces, and is ſoon reduced to a very fine powder. In the mean time, ſo much heat is produced, that part of the water flies of in vapour. If the quantity of lime ſlacked (as this proceſs is termed) be great, the heat produced is ſufficient to ſet fire to combuſtibles. In this manner veſſels loaded with lime have ſometimes been burnt. When great quantities of lime are ſlacked in a dark place, not only heat, but light alſo is emitted, as Mr Pelletier has obſerved †. When ſlacked lime is weighed, it is found to be heavier than it was before. This additional weight is owing to the combination of part of the water with the lime; which water may be ſeparated again by the application of a red heat; and by this proceſs the lime becomes juſt what it was before being ſlacked ‡.

195 Lime-water.

Six hundred parts of water, at the temperature of 60°, diſſolve about one part of lime; boiling hot water diſſolves about double that quantity §. This ſolution is called *lime-water*. It is limpid, has an acrid taſte, and changes vegetable blue colours to green. One ounce troy of lime-water contains about one grain of lime.

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

Lime has never yet been obtained in the ſtate of cryſtals.

It is incapable of being fuſed by the moſt violent heat that can be produced in furnaces, or even by the moſt powerful burning-glaſſes.

196 Sulphuret, and

Lime unites readily with ſulphur, and forms *ſulphuret of lime*. This compound may be obtained by mixing unſlacked lime and flowers of ſulphur together, and adding a little water. The heat produced by the ſlacking of the lime is ſufficient to make the ſulphur and the lime unite. This ſulphuret is of a red colour. When water is poured on it, ſulphurated hydrogen gas is emitted. The ſulphur is gradually converted into ſulphuric acid by uniting with the oxygen of the water, the hydrogen of which flies off in the form of gas, diſſolving at the ſame time a part of the ſulphur.

197 Phoſphuret of lime.

It is capable alſo of combining with phoſphorus.— The phoſphuret of lime decompoſes water by the aſſiſtance of a moderate heat, and gives out phoſphurated hydrogen gas.

198 Cauſe of the difference between limeſtone and lime.

Limeſtone and chalk, though they are capable of being converted into lime by *burning*, poſſeſs hardly any of the properties of that active ſubſtance. They are taſteleſs, ſcarcely ſoluble in water, and do not perceptibly act on animal bodies. Now, to what are the new properties of lime owing? What alteration does it undergo in the fire?

It had been long known that limeſtone loſes a good deal of weight by being burned or *calcined*. It was natural to ſuppoſe, therefore, that ſomething was ſeparated from it during calcination. Accordingly, Van Helmont, Ludovicus, and Macquer, made experiments in ſucceſſion, in order to diſcover what that *ſomething* was; and they concluded from them that it was *pure water*, which the lime recovered again when expoſed to the atmoſphere. As the new properties of lime could hardly be aſcribed to this loſs, but to ſome other cauſe, Stahl's opinion, like all the other chemical theories of that wonderful man, was generally acceded to. He ſuppoſed that the new properties which lime acquired by calcination, were owing entirely to the more minute diviſion of its particles by the action of the fire. Boyle indeed had endeavoured to prove, that theſe properties were owing to the *fixation of fire* in the lime: a theory which was embraced by Newton and illuſtrated by Hales, and which Meyer new modelled, and explained with ſo much ingenuity and acuteneſs as to draw the attention of the moſt diſtinguiſhed chemiſts. But while Meyer was thus employed in Germany, Dr Black, of Edinburgh, publiſhed thoſe celebrated experiments which form ſo brilliant an era in the hiſtory of chemiſtry.

199 According to Stahl;

200 Explained by Dr Black.

He firſt aſcertained that the quantity of water ſeparated from limeſtone during its calcination was not nearly equal to the weight which it loſt. He concluded in conſequence that it muſt have loſt ſomething elſe than mere water. What this could be, he was at firſt at a loſs to conceive; but recollecting that Dr Hales had proved, that limeſtone, during its ſolution in acids, emitted a great quantity of *air*, he conjectured that *this* might probably be what it loſt during calcination. He calcined it accordingly, and applied a pneumatic apparatus to receive the product. He found his conjecture verified;

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* Kirwan's Miner. i. 5.

† Jour. de Phyſ. t. 22.

‡ Dr Black.

§ Kirwan's Miner. i. 5.

* Lavoiſier.

verified ; and that the *air* and *the water* which ſeparated from the lime, were together preciſely equal to the loſs of weight which it had ſuſtained. Lime therefore owes its new properties to the loſs of *air ;* and limeſtone differs from lime merely in being combined with a certain quantity of *air :* for he found that, by reſtoring again the ſame quantity of *air* to lime, it was converted into limeſtone. This air, becauſe it exiſted in lime in a fixed ſtate, he called *fixed air.* It was afterwards examined by Dr Prieſtley and other philoſophers, found to poſſeſs peculiar properties, and to be that ſpecies of gas now known by the name of *carbonic acid gas.* Lime then is a ſimple ſubſtance, that is to ſay, it has never yet been decompounded ; and limeſtone is compoſed of carbonic acid and lime. Heat ſeparates the carbonic acid, and leaves the lime in a ſtate of purity.

201 Affinities of lime.

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

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

Sect. II. *Of Magneſia.*

202 Diſcovery of magneſia.

About the beginning of the eighteenth century, a Roman canon expoſed a white powder to ſale at Rome as a cure for all diſeaſes. This powder he called *magneſia alba.* He kept the manner of preparing it a profound ſecret ; but in 1707 Valentini informed the public that it might be obtained by calcining the lixivium which remains after the preparation of nitre ; and two years after, Slevogt diſcovered that it might be precipitated by potaſs from the mother ley (s) of common ſalt. This powder was generally ſuppoſed to be *lime,* till Frederic Hoffman obſerved that it formed very different combinations with other bodies *. But little was known concerning its nature till Dr Black publiſhed his celebrated experiments in 1755. Margraf publiſhed a diſſertation on it in 1759, and Bergman another in 1775, in which he collected the obſervations of theſe two philoſophers, and which he enriched alſo with many additions of his own.

* Bergman, i. 365.

203 Method of procuring it.

As magneſia has never yet been found native in a ſtate of purity, it may be prepared in the following manner : *Sulphat of magneſia,* a ſalt compoſed of this earth and ſulphuric acid, exiſts in ſea-water, and in many ſprings, particularly ſome about Epſom, from which circumſtance it was formerly called *Epſom ſalt.* This ſalt is to be diſſolved in water, and half its weight of potaſs added. The magneſia is immediately precipitated, becauſe potaſs has a ſtronger affinity for ſulphuric acid. It is then to be waſhed with a ſufficient quantity of water, and dried.

204 Its properties.

Magneſia thus obtained is a very ſoft white powder, which has very little taſte, and is totally deſtitute of ſmell. Its ſpecific gravity is about 2,3 †.

It is ſoluble in about 7900 times its own weight of water at the temperature of 60° ‡.

† Kirwan's Miner. i. 8.

‡ Ibid.

Even when combined with carbonic acid (for which it has a ſtrong affinity) it is capable of abſorbing and retaining 1½ times its own weight of water, without letting go a drop ; but on expoſure to the air, this water evaporates, though more ſlowly than it would from lime.

Magneſia has never yet been obtained in a cryſtallized form.

It tinges vegetable blues of an exceedingly ſlight green.

It is not melted by the ſtrongeſt heat which it has been poſſible to apply ; but Mr D'Arcet obſerved that, in a very high temperature, it became ſomewhat agglutinated.

When magneſia and ſulphur are put into a veſſel of water, and kept for ſome time expoſed to a moderate heat, they combine, and form ſulphuret of magneſia ; which, according to Fourcroy, is capable of cryſtallizing.

The phoſphuret of magneſia has never been examined.

Effect of heat on mixtures of lime and magneſia.

Equal parts of lime and magneſia mixed together, and expoſed by Lavoiſier to a very violent heat, did not melt ; neither did they melt when Mr Kirwan placed them in the temperature of 150° Wedgewood. The following Table, drawn up by Mr Kirwan from his own experiments, ſhews the effect of heat on theſe two earths mixed together in different proportions.

Proportions.

(R) The affinity of this acid for lime is inferior to the oxalic, which decompoſes the ſuberat of lime. *Jameſon's Mineral. of Shetland and Arran,* p. 168.

(S) *The mother ley* is the liquid that remains after as much as poſſible of any ſalt has been obtained from it. Common ſalt, for inſtance, is obtained by evaporating ſea-water. After as much ſalt has been extracted from a quantity of ſea-water as will cryſtallize, there is ſtill a portion of liquid remaining. This portion is the mother ley.

Proportions.	Heat.	Effect.
80 Lime 20 Mag.	150° Wedg.	Went through the crucible.
75 Lime 25 Mag.	160	Went through the crucible.
66 Lime 33 Mag.		Went through the crucible.
20 Lime 80 Mag.	165	Did not melt.
33 Lime 66 Mag.	138	Did not melt.
30 Lime 10 Mag.	156	Melted into a fine greeniſh yellow glaſs; but the crucible was corroded throughout.

206 Affinities of magneſia. The affinities of magneſia, according to Bergman, are as follows:

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

Sect. III. *Of Barytes.*

207 Diſcovery of barytes. A very heavy mineral is found in Sweden, Germany, and Britain, which Margraf conſidered as a compound of ſulphuric acid and lime. But Scheele and Gahn analyſed it in 1774, and found that it conſiſted of ſulphuric acid combined with a peculiar ſpecies of earth. This analyſis was ſoon after confirmed and extended by Bergman. The earth was at firſt called *terra ponderoſa, heavy earth,* on account of the great ſpecific gravity of the ſubſtance from which it was obtained. Morveau called it *barote* (from ϐαρυς, *heavy),* which Bergman changed into *barytes;* and this laſt term is now univerſally adopted.

Barytes is generally found combined either with ſulphuric or carbonic acid. From the firſt of theſe compounds, which is by far the moſt common, it may be obtained by the following proceſs:

208 Method of obtaining it. Reduce the mineral to a powder and mix it with $2\frac{1}{2}$ its weight of carbonat of ſoda (T), previouſly deprived of all its water. Expoſe the mixture to a red heat for an hour and a half, avoiding fuſion, and a double decompoſition takes place; the ſulphuric acid unites with the ſoda, while the carbonic acid combines with the barytes. Waſh it in a ſufficient quantity of water to diſſolve the compound of ſulphuric acid and ſoda, the carbonat of barytes, which is almoſt inſoluble, remains behind. Leſt it ſhould be mixed with ſome other earths, which is generally the caſe, boil it for three hours in ten times its weight of diſtilled vinegar, the ſpecific gravity of which is 1,033; by which the barytes will be diſſolved, and likewiſe the lime and magneſia, if there happen to be any; but every other earth (U) remains untouched. Pour off the ſolution, and add to it ſulphuric acid as long as any precipitate is formed. This precipitate conſiſts of the whole barytes and the lime (if there be any) combined with ſulphuric acid. Waſh it in 50 times its weight of water, and all the lime will be diſſolved. There will now remain nothing but barytes combined with ſulphuric acid, which may be decompoſed as before by carbonat of ſoda *. The carbonic acid may then be ſeparated by applying a very violent heat †; or, what is better, nitric acid may be poured upon it, which will ſeparate the carbonic acid and combine with the barytes; and then the nitric acid may be driven off by a moderate heat ‡.

209 Its properties. Barytes thus obtained is a light, ſpongy, porous body, which may be very eaſily reduced to powder. It has a harſh and more cauſtic taſte than lime; and when taken into the ſtomach, proves a moſt violent poiſon. It has no perceptible ſmell.

Its ſpecific gravity has not yet been aſcertained.

It imbibes water with a hiſſing noiſe, but, according to Dr Hope, without ſwelling or ſplitting as lime does §. However, when expoſed to the air, as Fourcroy and Vauquelin inform us, it effloreſces, cracks, burſts, ſwells up, heats, and becomes white, by abſorbing moiſture ||.

Cold water diſſolves about $\frac{1}{17}$th part of its weight of barytes, and boiling water more than half its weight. As the water cools, the barytes is depoſited in cryſtals, the ſhape of which varies according to the rapidity with which they have been formed. When moſt regular, they are flat hexagonal priſms, having two broad ſides, with two intervening narrow ones, and terminated at each end by a four-ſided pyramid, which in ſome inſtances conſtitutes the larger part of the cryſtal. When formed ſlowly, they are diſtinct and large; but when the water is ſaturated with barytes, they are depoſited rapidly, and are generally more ſlender and delicate. Then, too, they are attached to one another in ſuch a manner as to aſſume a beautiful foliacious appearance, not unlike the leaf of a fern ¶.

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

* *Afſvelius, Ann. de Chim.* iii.

† *Hope, Edin. Tranſ.* iv. 36.

‡ *Fourcroy* and *Vauquelin. Ann. de Chim.* xxi. 276.

§ *Edin. Tranſ. ibid.*

|| *Ann. de Chim. ibid.* and *Nicholſon's Journal*, i. 535.

¶ *Hope, ibid.*

(T) Soda is an alkali, which ſhall be afterwards deſcribed. Carbonat of ſoda is ſoda combined with carbonic acid, the common ſtate in which it is obtained; potaſs might alſo be uſed.

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

of barytes. When expoſed to the heat of boiling water, they undergo the *watery fuſion*, or, which is the ſame thing, they melt without loſing any of the water which they contain. A ſtronger heat makes the water fly off. When expoſed to the air, they attract carbonic acid, and crumble into duſt. They are ſoluble in 17½ parts of water at the temperature of 60°; but boiling water diſſolves any quantity whatever: the reaſon of which is evident; at that temperature their own water of cryſtallization is ſufficient to keep them in ſolution *.

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

When barytes is expoſed to the blowpipe on a piece of charcoal, it fuſes, bubbles up, and runs into globules, which quickly penetrate the charcoal †. This is probably in conſequence of containing water; for Lavoiſier found barytes not affected by the ſtrongeſt heat which he could produce.

210 Sulphuret of barytes.

Barytes combines readily with ſulphur. The eaſieſt way of forming ſulphuret of barytes is to mix eight parts of ſulphat of barytes with one part of pounded charcoal, and to apply a ſtrong heat. The charcoal combines with the oxygen of the ſulphuric acid, and the compound flies off in the form of carbonic acid gas. There remains behind ſulphur combined with barytes. Sulphuret of barytes is ſoluble in water: It is of a yellow colour. It is capable of cryſtallizing; and then aſſumes a yellowiſh white colour ‡.

The phoſphuret of barytes has not been examined.

No mixture of barytes and lime, nor of barytes and magneſia, is fuſible in the ſtrongeſt heat which it has been poſſible to apply §.

211 Its affinities.

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

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

* Id.

† Fourcroy and Vauquelin, ibid.

‡ Fourcroy.

§ Lavoiſier, Acad. Par. 1782.

Sect. IV. *Of Strontites.*

212 Diſcovery of ſtrontites.

About the year 1787, a mineral was brought to Edinburgh, by a dealer in foſſils, from the lead mine of Strontian in Argyleſhire, where it is found imbedded in the ore, mixed with ſeveral other ſubſtances. It is ſometimes tranſparent and colourleſs, but generally has a tinge of yellow or green. Its hardneſs is 5. Its ſpecific gravity varies from 3,4 to 3,726. Its texture is generally fibrous; and ſometimes it is found cryſtallized in ſlender priſmatic columns of various lengths *.

This mineral was generally conſidered as a carbonat of barytes; but Dr Crawford having obſerved ſome differences between its ſolution in muriatic acid and that of barytes, mentioned in his treatiſe on *Muriat of Barytes*, publiſhed in 1790, that it probably contains a new earth, and ſent a ſpecimen to Mr Kirwan that he might examine its properties. Dr Hope had alſo ſuſpected that its baſis differed from barytes; and accordingly he made a ſet of experiments on it in 1791, which were read to the Royal Society of Edinburgh in 1792. Theſe experiments fully proved that it contained a peculiar earth. Mr Kirwan likewiſe analyſed the ſtrontian mineral, and drew preciſely the ſame concluſions. It has been analyſed alſo by Mr Klaproth of Berlin, and Mr Pelletier of Paris. It conſiſts of carbonic acid combined with a peculiar earth, to which Dr Hope gave the name of *ſtrontites*. This appellation we ſhall adopt.

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

213 Its properties.

Strontites has been found in Argyleſhire in Scotland, near Briſtol in England, and in Pennſylvania ‡. It has been found alſo in France and in Sicily. It is of a white colour. It has a pungent acrid taſte. When pounded in a mortar, the powder that riſes is offenſive to the noſtrils and lungs §. It is not poiſonous ||.

One hundred and ſixty-two parts of water, at the temperature of 60°, diſſolve nearly one part of it. The ſolution is clear and tranſparent, and converts vegetable blues to a green. Hot water diſſolves it in much larger quantities; and as it cools the ſtrontites is depoſited in colourleſs tranſparent cryſtals. Theſe are in the form of thin quadrangular plates, generally parallelograms, the largeſt of which ſeldom exceeds one-fourth of an inch in length. Sometimes their edges are plain, but they oftener conſiſt of two facets, meeting together and forming an angle like the roof of a houſe. Theſe cryſtals generally adhere to each other in ſuch a manner as to form a thin plate of an inch or more in length and half an inch in breadth. Sometimes they aſſume a cubic form. They contain about 68 parts in 100 of water. They are ſoluble in 51,4 parts of water, at the temperature of 60°. Boiling water diſſolves nearly half its weight of them. When expoſed to the air, they loſe their water, attract carbonic acid, and fall into powder ¶.

When ſtrontites is thrown into water, it attracts it with a hiſſing noiſe, much heat is produced, and it falls into powder much more rapidly than lime *.

It combines with ſulphur either by fuſion in a crucible, or by being boiled with it in water. The ſulphuret

* Hope, Edin. Tranſ. iv. 44.

† Kirwan's Miner. i. 332.

‡ Klaproth, ii. ſect. 39.

§ Hope, ibid.

|| Pelletier.

¶ Hope, ibid.

* Id.

(v) Suberic acid decompoſes muriat and nitrat of barytes. *Jameſon's Mineral. of Shetland and Arran.*

phuret is of a dark yellowiſh brown colour. It is ſoluble in water*.

214
Its affinities.

The affinities of ſtrontites, as aſcertained by Dr Hope, are as follows :

Sulphuric acid,
Oxalic,
Tartarous,
Fluoric,
Nitric,
Muriatic,
Succinic,
Phoſphoric,
Acetous,
Arſenic,
Boracic,
Carbonic.

Sect. V. *Of Silica.*

215
Method of obtaining ſilica.

If one part of powdered flints or ſand, mixed with three parts of potaſs, be put into a crucible, and kept in a ſtate of fuſion for half an hour, a brittle maſs will be formed almoſt as tranſparent as glaſs, which quickly attracts moiſture from the atmoſphere, and is entirely ſoluble in water. This ſolution is called *liquor ſilicum*, or *liquor of flints*. It was firſt accurately deſcribed by Glauber, a chemiſt who lived about the middle of the 17th century.

If an acid be poured into this liquor, a white ſpongy ſubſtance is precipitated, which may be purified from every accidental mixture by waſhing it in acids, muriatic acid for inſtance. This ſubſtance is called *ſiliceous earth* or *ſilica*. It was firſt diſtinguiſhed as a peculiar earth by Pott in 1746, though it had been known long before ; and Cartheuſer, Scheele, and Bergman, proved in ſucceſſion that it could not, as ſome chemiſts had ſuppoſed, be reduced to any other earth.

216
Its properties.

Silica, when dried, is a ſoft white powder, without either taſte or ſmell.

Its ſpecific gravity is 2,66 †.

It is inſoluble in water except when newly precipitated from the liquor ſilicum, and then one part of it is ſoluble in 1000 parts of water ‡. It has no effect on vegetable colours.

It is capable of abſorbing about one-fourth of its weight of water, without letting any drop from it ; but on expoſure to the air, the water evaporates very readily §.

Silica may be formed into a paſte with a ſmall quantity of water : this paſte has not the ſmalleſt ductility, and when dried forms a looſe, friable, and incoherent maſs ||.

Silica is capable of aſſuming a cryſtalline form. Cryſtals of it are found in many parts of the world. They are known by the name of *rock cryſtal*. When pure they are tranſparent and colourleſs like glaſs : they aſſume various forms ; the moſt uſual is a hexagonal priſm, ſurmounted with hexagonal pyramids on one or both ends, the angles of the priſm correſponding with thoſe of the pyramids. Their hardneſs is very great, amounting to eleven. Their ſpecific gravity is 2,653 ¶.

There are two methods of imitating theſe cryſtals by art. The firſt method was diſcovered by Bergman. He diſſolved ſilica in fluoric acid, the only acid in which it is ſoluble, and allowed the ſolution to remain undiſturbed for two years. A number of cryſtals were then found at the bottom of the veſſel, moſtly of irregular figures, but ſome of them cubes with their angles truncated. They were hard, but not to be compared in this reſpect with rock cryſtal *.

The other method was diſcovered by accident. Profeſſor Seigling of Erfurt had prepared a liquor ſilicum, which was more than uſually diluted with water, and contained a ſuperabundance of alkali. It lay undiſturbed for eight years in a glaſs veſſel, the mouth of which was only covered with paper. Happening to look to it by accident, he obſerved it to contain a number of cryſtals ; on which he ſent it to Mr Trommſdorff, profeſſor of chemiſtry at Erfurt, who examined it. The liquor remaining amounted to about two ounces. Its ſurface was covered by a tranſparent cruſt, ſo ſtrong that the veſſel might be inverted without ſpilling any of the liquid. At the bottom of the veſſel were a number of cryſtals, which proved on examination to be ſulphat of potaſs and carbonat of potaſs (w). The cruſt on the top conſiſted partly of carbonat of potaſs, partly of cryſtallized ſilica. Theſe laſt cryſtals had aſſumed the form of tetrahedral pyramids in groups ; they were perfectly tranſparent, and ſo hard that they ſtruck fire with ſteel †.

Silica endures the moſt violent heat without alteration.

It ſeems incapable of combining with ſulphur or phoſphorus.

217
Effect of heat on mixtures of lime and ſilica ;

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

Proportions.	Heat.	Effect.
50 Lime 50 Silica	150° Wedg.	Melted into a maſs of a white colour, ſemitranſparent at the edges, and ſtriking fire, tho' feebly, with ſteel: it was ſomewhat between porcelain and enamel.
80 Lime 20 Silica	156	A yellowiſh white looſe powder.
20 Lime 80 Silica	156	Not melted, formed a brittle maſs.

218
Magneſia and ſilica :

2. Equal part of magneſia and ſilica melt with great difficulty into a white enamel when expoſed to the moſt violent heat which can be produced §. They are infuſible in inferior heats in whatever proportion they are mixed ||.

219
Barytes and ſilica ; proportions.

3. The effect of heat on various mixtures of barytes and ſilica will appear from the following experiments of Mr Kirwan ¶.

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

* Id.

† Kirwan's Miner. i. 10.

‡ Ibid.

§ Ibid.

|| Scheele.

¶ Kirwan's Min. i. 242.

* Bergman, ii. 32.

† Nicholſon's Jour. i. 217.

‡ Mineral. i. 56.

§ Lavoiſier, Mem. Par. 1787, p. 598.

|| Achard, Mem. Berl. 1780, p. 33.

¶ Mineral. i. 57.

Proportions.	Heat.	Effect.
80 Silica 20 Barytes	155° Wedg.	A white brittle maſs.
75 Silica 20 Barytes	150	A brittle hard maſs, ſemitranſparent at the edges.
66 Silica 33 Barytes	150	Melted into a hard ſomewhat porous porcelain maſs.
50 Silica 50 Barytes	148	A hard maſs not melted.
20 Silica 80 Barytes	148	The edges were melted into a pale greeniſh matter between a porcelain and enamel.
25 Silica 75 Barytes	150	Melted into a ſomewhat porous porcelain maſs.
33 Silica 66 Barytes	150	Melted into a yellowiſh and partly greeniſh white porous porcelain.

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

220 And lime, magneſia, and ſilica. 5. It follows from the experiments of Achard, that equal parts of lime, magneſia, and ſilica, may be melted into a greeniſh-coloured glaſs, hard enough to ſtrike fire with ſteel; that when the magneſia exceeds either of the other two, the mixture will not melt; that when the ſilica exceeds, the mixture ſeldom melts, only indeed with him in the following proportions; three ſilica, two lime, one magneſia, which formed a porcelain; and that when the lime exceeds, the mixture is generally fuſible *.

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

221 Affinities of ſilica. The affinities of ſilica are as follows:

Fluoric acid,
Fixed alkali.

Sect. VI. *Of Alumina.*

222 Method of obtaining alumina. Dissolve alum in hot water, and add to the ſolution potaſs as long as any precipitate is formed. Decant off the fluid part, and waſh the precipitate in a ſufficient quantity of water, and then allow it to dry. The ſubſtance thus obtained is called *alumina*. Its properties were firſt aſcertained with accuracy by Margraf.

223 Its properties. Alumina thus obtained is a very white ſpongy powder, without any ſmell or taſte.

Its ſpecific gravity is 2,00 †. It is ſcarcely ſoluble in water, but may be diffuſed through it with great facility. With a ſmall quantity of water it forms a very tough ductile paſte, and does not readily mix with more.

† *Kirwan's Miner.* i. 9.

In its uſual ſtate of dryneſs it is capable of abſorbing 2½ times its weight of water, without ſuffering any to drop out. It retains this water more obſtinately than any of the earths hitherto deſcribed. In a freezing cold it contracts more, and parts with more of its water than any other earth; a circumſtance which is of ſome importance in agriculture *.

* *Ibid.*

Alumina has never yet been obtained in a cryſtallized form. It has no effect whatever on vegetable colours.

The moſt intenſe heat does not fuſe it, but it has the ſingular property of diminiſhing in bulk in proportion to the intenſity of the fire to which it is expoſed. It becomes at the ſame time exceedingly hard: Mr Lavoiſier rendered it capable of cutting glaſs; and Mr Boyle had long before done the ſame thing †.

† *Shaw's Boyle*, iii. 422.

224 Wedgewood's thermometer. Wedgewood took advantage of this property of alumina, and by means of it conſtructed an inſtrument for meaſuring high degrees of heat. It conſiſts of pieces of clay of a determinate ſize, and an apparatus for meaſuring their bulk with accuracy: One of theſe pieces is put into the fire, and the temperature is eſtimated by the contraction of the piece. For a more complete deſcription of this important inſtrument, we refer to the article Thermometer in the *Encycl.*

Alumina is hardly ſuſceptible of combining with ſulphur or phoſphorus; but from the experiments of La Grange, it appears to have an affinity for carbon ‡.

‡ *Nicholſon's Jour.* ii. 101.

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

§ *Kirwan*, i. 56.

Proportions.	Heat.	Effect.
75 Lime 25 Alumina	150° Wedg.	Not melted.
66 Lime 33 Alumina	150	Remained a powder.
33 Lime 66 Alumina	(x)	Melted.
25 Lime 75 Alumina	(x)	Melted.
20 Lime 80 Alumina	(x)	Melted.

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

|| *Ibid.* i. 57.

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

¶ *Ibid.*

(x) Theſe three experiments were made by Ehrman: The heat was produced by directing a ſtream of oxygen gas on burning charcoal, and is the moſt intenſe which it has been hitherto poſſible to produce.

Proportions.	Heat.	Effect.
80 Alumina 20 Barytes	150° Wedg.	Scarcely hardened.
75 Alumina 25 Barytes	156	No ſign of fuſion, a looſe powder.
66 Alumina 33 Barytes	152	As the former.
50 Alumina 50 Barytes	150	As the former.
20 Alumina 80 Barytes	148	Somewhat harder, but no ſign of fuſion.
25 Alumina 75 Barytes	150	Harder, but no ſign of fuſion.

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

228 Alumina and ſilica; 5. Equal parts of alumina and ſilica harden in the temperature of 160° Wedgewood, but do not fuſe *. Achard found them infuſible in all proportions in a heat probably little inferior to 150° Wedgewood. Mixtures of theſe two earths in various proportions form *clays*, but theſe are ſeldom uncontaminated with ſome other ingredients.

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

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

230 Lime, ſilica, and alumina; 7. From the ſame experiments, and thoſe of Kirwan, we learn, that in mixtures of lime, ſilica, and alumina, when the lime exceeds, the mixture is generally fuſible either into a glaſs or a porcelain, according to the proportions. The only infuſible proportions were,

2	3	Lime
1	1	Silica
2	2	Alumina.

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

231 Magneſia, ſilica, and alumina; 8. As to the mixtures of magneſia, ſilica, and alumina, when the magneſia exceeds, no fuſion takes place at 150°. When the ſilica exceeds, a porcelain may often be attained; and three parts ſilica, two magneſia, and one alumina, formed a glaſs. When the alumina exceeds, nothing more than a porcelain can be produced †.

232 And lime, magneſia, ſilica, and alumina. 9. Achard found that equal parts of lime, magneſia, ſilica, and alumina, melted into a glaſs. They fuſed alſo in various other proportions, eſpecially when the ſilica predominated.

233 Affinities of alumina. The affinities of alumina as as follows:

Sulphuric acid,
Nitric,
Muriatic,
Oxalic,
Arſenic,
Fluoric,
Sebacic,
Tartarous,
Succinic,
Saccholactic,
Citric,
Phoſphoric,
Formic,
Lactic,
Benzoic,
Acetous,
Boracic,
Sulphurous,
Nitrous,
Carbonic,
Pruſſic.

SECT. VII. *Of Jargonia.*

234 Diſcovery of jargonia. AMONG the precious ſtones which come from the iſland of Ceylon, there is one called *jargon*, which is poſſeſſed of the following properties.

Its colour is various, grey, greeniſh white, yellowiſh, reddiſh brown, and violet. It is often cryſtallized, either in right angular quadrangular priſms ſurmounted with pyramids, or octahedrals conſiſting of double quadrangular pyramids. It has generally a good deal of luſtre, at leaſt internally. It is moſtly ſemitranſparent. Its hardneſs is from 10 to 16: Its ſpecific gravity from 4,416 to 4,7 ‡.

It loſes ſcarcely any of its weight in a melting heat; for Klaproth found that 300 grains, after remaining in it for an hour and a half, were only one-fourth of a grain lighter than at firſt §. Neither was it attacked either by muriatic or ſulphuric acid, even when aſſiſted by heat. At laſt, by calcining it with a large quantity of ſoda, he diſſolved it in muriatic acid, and found that 100 parts of it contained 31,5 of ſilica, five of a mixture of nickel,

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* *Kirwan's Min.* i. 58.

† *Ibid.* i. 72.

* *Ibid.* i. 73.

† *Ibid.* i. 72.

‡ *Ibid.* i. 333.

§ *Jour. de Phyſ.* 36. 180.

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

235 Its properties. Jargonia has a ſtrong reſemblance to alumina. It is of a white colour. Its ſpecific gravity probably exceeds 4,000.

It differs from alumina in the compounds which it forms with other bodies, in being inſoluble in a boiling ſolution of pure potaſs or ſoda, and in being infuſible by heat when mixed with theſe ſubſtances in a ſtate of dryneſs *.

* *Kirwan's Mineral.* i. p. 14.

No more of its properties are yet known.

Sect. VIII. *Of Glucina.*

236 Diſcovery of glucina. In the beryl was diſcovered, ſome time ago by Vauquelin, a new earth, to which he gave the name of *glucina*. To obtain it pure, the beryl, reduced to powder, is to be fuſed with thrice its weight of potaſs. The maſs is to be diluted with water, diſſolved in muriatic acid, and the ſolution evaporated to dryneſs. The reſiduum is to be mixed with a large quantity of water, and the whole thrown on a filter. The ſilica, which conſtitutes more than half the weight of the ſtone, remains behind; while the glucina and the other earths, combined with muriatic acid, remain in ſolution. They are to be precipitated by means of carbonat of potaſs; the precipitate is to be waſhed, and then diſſolved in ſulphuric acid. When the ſolution, after potaſs has been added to it, has been evaporated to the proper conſiſtency, alum cryſtals are gradually formed. When as many of theſe have been obtained as poſſible, carbonat of ammonia in exceſs is to be poured into the liquid, which is firſt to be filtered and then boiled for ſome time, when a white powder gradually appears. This powder is *glucina*.

237 Its properties. It is a ſoft light powder, without either taſte or ſmell, but has the property of adhering ſtrongly to the tongue. It has no action on vegetable colours, is altogether infuſible by heat, and neither hardens nor contracts in its dimenſions. It is inſoluble in water, but forms with a ſmall quantity of that liquid a paſte to a certain degree ductile. It does not combine with oxygen, nor with any of the ſimple combuſtibles; but ſulphurated hydrogen diſſolves it, and forms with it a hydroſulphuret, ſimilar in its properties to other hydroſulphurets. Glucina is ſoluble in the liquid fixed alkalies; inſoluble in ammonia, but ſoluble in carbonat of ammonia. It combines with all the acids, and forms with them ſweet taſted ſalts; and hence its name, from γλυκος, *ſweet*. Its other properties have not been examined.

Sect. IX. *Of Yttria and Aguſtina.*

238 Diſcovery and properties of yttria. Some time before 1788 was diſcovered, in the quarry of Ytterby in Sweden, a peculiar mineral, called from Profeſſor Gadolin, who firſt analyſed it, *gadolinite*. Its colour is black, and its fracture like that of glaſs. It is magnetic, and ſoft enough to be ſcratched by a knife, and ſometimes even by the nail. In this mineral a new earth has been diſcovered by various chemiſts, who have agreed to give it the name of *yttria*. When ſeparated from the other ſubſtances with which it is combined, viz. the oxides of iron and manganeſe, a little lime, and a conſiderable quantity of ſilica, it has the appearance of a fine white powder, and has neither taſte nor ſmell. It is not melted by the application of heat, has no action on vegetable blues, and is not ſoluble in water. It is likewiſe inſoluble in pure alkalies; but it diſſolves readily in carbonat of ammonia. It combines with acids, and forms with them ſalts, which have a ſweet taſte, and at the ſame time a certain degree of auſterity.

239 Diſcovery of aguſtina. Trommſdorf has lately diſcovered in the *Saxon beryl* a new earth, to which he has given the name of *Aguſtina*, becauſe the ſalts which it forms have little or no taſte. As Trommſdorf's experiments have not hitherto been repeated, the exiſtence of this earth muſt continue doubtful till the concluſions of the diſcoverer be confirmed by other philoſophers.

240 Remarks on the earths. These are all the ſimple earths that have yet been diſcovered; and the firſt four of them have a great many common properties. They tinge vegetable blues green, they have a ſtrong affinity for carbonic acid, and combine readily with all acids. They have ſometimes been called *alkaline earths*.

None of the earths have been hitherto decompounded, nor has the ſmalleſt proof ever been brought that they are compounds. We muſt therefore, in the preſent ſtate of chemiſtry, conſider them as ſimple bodies. Many attempts, indeed, have been made to ſhew that there was but one earth in nature, and that all others were derived from it. The earth generally made choice of as the ſimpleſt was ſilica (y). But none of theſe attempts, notwithſtanding the ingenuity of ſeveral of the authors, has been attended with the ſmalleſt ſhadow of ſucceſs.

We have mentioned formerly, that it was almoſt the univerſal opinion of chemiſts that metals were compoſed of ſome of the earths united to phlogiſton; but of late an attempt has been made to prove that all the earths are metallic oxides, and that they can actually be reduced to the ſtate of metals.

Baron had long ago ſuſpected that alumina had ſomewhat of a metallic nature; and Bergman had been induced, by its great weight and ſeveral other appearances, to conjecture that barytes was a metallic oxide: But the firſt chemiſt who ventured to hint that all earths might be metallic oxides was Mr Lavoiſier *. About the year 1790, ſoon after the publication of Mr Lavoiſier's book, Mr Tondi and Profeſſor Ruprecht, both of Schemnitz, announced, that they had obtained from barytes, by the application of a ſtrong heat, a metal of the colour of iron, and attracted by the magnet, which they called *borbonium*; from magneſia another, which they called *auſtrum*; a third from lime, alſo called *auſtrum*; and a fourth from alumina, which they denominated *apulum*. Their method of proceeding was to apply a violent heat to the earths, which were ſurrounded with charcoal in a Heſſian crucible, and covered with calcined bones in powder.

* *Chemiſtry*, p. 217. Eng. Tranſl.

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

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

chemiſts ſoon proved, that the pretended metals were all of them *phoſphurets of iron*. The iron, by the violence of the heat, had been extracted from the crucible, and the phoſphorus from the bones. The earths therefore muſt ſtill continue a diſtinct claſs of bodies: and, as Klaproth has obſerved, their properties are ſo exceedingly different from thoſe of metallic oxides, that the ſuppoſition of their being compoſed of the ſame ingredients is contrary to every fact, and to every analogy with which we are acquainted.

CHAP. V. *Of* CALORIC.

NOTHING is more familiar to us than *heat;* to attempt to define it therefore would be unneceſſary. When we ſay that *a perſon feels heat*, that *a ſtone is hot*, the expreſſions cauſe no difficulty; every one underſtands them perfectly: yet in each of theſe propoſitions the word *heat* has a diſtinct meaning. In the one, it ſignifies the *ſenſation* of heat; in the other, the *cauſe* of that ſenſation. This ambiguity, though of little conſequence in common life, leads unavoidably in philoſophical diſcuſſions to confuſion and perplexity. It was to prevent this that the French chemiſts made choice of the word *caloric* to ſignify the *cauſe of heat*. When I put my hand on a hot ſtone, I experience a certain ſenſation, which I call the *ſenſation of heat;* the cauſe of this ſenſation is *caloric*.

241
Whether caloric be a ſubſtance.

Concerning the nature of caloric, there are two opinions which have divided philoſophers ever ſince they turned their attention to the ſubject. Some ſuppoſe that caloric, like gravity, is merely a property of matter, and that it conſiſts, ſome how or other, in a peculiar vibration of its particles; others, on the contrary, think that it is a diſtinct ſubſtance. Each of theſe opinions has been ſupported by the greateſt philoſophers; and the obſcurity of the ſubject is ſuch, that both ſides have been able to produce exceedingly plauſible and forcible arguments. The recent diſcoveries, however, in this branch of chemiſtry, have rendered the latter opinion much more probable than the former. Indeed we do not ſee how it is poſſible to account for many of the phenomena of nature, unleſs caloric be conſidered as a ſubſtance, as we truſt ſhall appear from the inveſtigation into which we are about to enter. We mean, then, with the generality of modern chemiſts, to take it for granted that caloric is a ſubſtance, without pretending to be able to demonſtrate the truth of our opinion, but merely becauſe we conſider it as infinitely more plauſible than the other. If the receiver of an air-pump, while it contains a thermometer, be ſuddenly exhauſted of air, the thermometer ſinks ſeveral degrees, and then gradually riſes again to its former height. Now if heat be owing to vibration, how comes it that the ſmall quantity of matter remaining in the receiver is firſt inſufficient, and afterwards ſufficient to maintain the temperature? Is it not more probable that part of the caloric was carried off with the air, and that it gradually returned through the glaſs, which it is capable of pervading, though with difficulty *. When air is let into an exhauſted receiver, the thermometer, as Lambert firſt obſerved, riſes ſeveral degrees. Is not this owing to an additional quantity of caloric introduced by the air? The thermometer then ſinks ſlowly. Is not this becauſe the ſuperabundant caloric gradually pervades the glaſs and flies off? Taking it for granted then that caloric is a ſubſtance, we proceed to examine its propertis.

242
Caloric expands bodies.

1. When bodies become hot, or, which is the ſame thing, when caloric enters into them, they expand in every direction; and this expanſion is proportional to the accumulation of caloric. The firſt and moſt obvious property of caloric then is the power of expanding bodies. It does not, however, expand all ſubſtances equally, and we are ſtill ignorant of the law which it follows. All that can be done therefore is to collect facts till this law be diſcovered. A number of theſe may be ſeen in the following Table:

TABLE of the Expanſion of various Bodies at different Temperatures..

* *Blagden.*
† *Newton.*

Temperature.	Water *.	Mercury.	Linſeed oil†.	Alcohol *.	Temperature.	Water *.	Mercury.	Linſeed oil†.	Alcohol *.
30°	—	—	—	100000	100°	100908	100711,8	—	104162
32	—	100000,0	100000	—	105	—	100762,7		
35	100000	100030,0	—	100267	110	—	100813,6		
40	99997	100081,0	—	100539	120	101404	100915,4		
45	100005	100131,9	—	101818	130	—	101017,2		
50	100023	100182,8	—	101105	140	—	101119,0		
55	100053	100253,7	—	101401	150	102017	101220,8		
60	100091	100304,6	—	101688	160	—	101322,6		
65	100141	100355,5	—	101984	167	102753	—		
70	100197	100406,4	—	102281	170	—	101424,4		
75	100261	100457,3	—	102583	180	—	101526,2		
80	100332	100508,2	—	102890	190	103617	101628,0		
85	100411	100559,1	—	103202	200	—	101729,8		
90	100694	100610,0	—	103517	212	104577	101835,0	107250	
95	100790	100660,9	102560	103840	408	—	—	115160	

* *Blagden.*
† *Newton.*

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* See *Pictet ſur le Feu*, ch. 1.

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

* *Kirwan.*
† *De Luc.*

Temperature	Sulph. acid *.	Nitric acid *.	Glaſs †.	Air.	Oxygen gas §.	Azotic gas §.	Hydrogen gas §.	Nitrous gas §.	Carb. acid gas §.	Ammoniacal gas §.
32°	—	—	100000	100000	100000	100000	100000	100000	100000	100000
40	—	—	—	101790						
45	—	100005	—	—						
50	100149	100149	—	104140						
55	100263	101074	100006	—						
60	100382	101389	—	106560						
65	100615	101767	—	—						
70	100751	102096	—	108950						
75	—	—	100014	—						
77	—	—	—	—	104520	103400	108390	106520	111050	127910
80	—	—	—	111300						
90	—	—	—	113590						
100	—	—	100023	—						
110	—	—	—	117580						
122	—	—	100033	—	124830	121860	122830	117630	130660	184870
130	—	—	—	121870						
150	—	—	100044	126030						
167	—	—	100056	—	190180	176640	137420‡	144370	173850	358780
170	—	—	—	130090						
190	—	—	100069	133970						
212	—	—	100083	134890	547670‡	694120	139120‡	160290‡	200940‡	680090‡ (A)

§ *Du Vernois, Encyc. Method.* art. *Air.*

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

† *Smeaton, Phil. Tranſ* xlviii. 612.

Temperature.	Antimony.	Steel.	Iron.	Caſt Iron.	Biſmuth.	Copper.	Caſt Braſs.	Braſs Wire.
32°	120000	120000	120000	120000	120000	120000	120000	120000
212	120130	120147	120151		120167	120204	120225	120232
White heat		123428*	121500*	122571*				

* *Rinman.*

	Tin.	Lead.	Zinc.	Hammered Zinc.	Zinc 8 Tin 1	Lead 2 Tin 1	Braſs 2 Zinc 1	Pewter.	Copper 3 Tin (B) 1
32°	120000	120000	120000	120000	120000	120000	120000	120000	120000
212	120298	120344	120355	120373	120323	120301	120247	120274	120218

From

(A) This mark ‡ implies that, owing to ſome inaccuracy in making the experiments, the numbers to which it is attached are not to be depended on.

(B) The metal whoſe expanſion is here given was an alloy compoſed of three parts of copper and one of tin. The figures in ſome of the preceding columns are to be underſtood in the ſame manner. Thus in the laſt column but two, the metal conſiſted of two parts of braſs alloyed with one of zinc.

From this table, it appears that the gaſes are more expanded by caloric than fluids, and fluids more than ſolids; and that the expanſion of all bodies hitherto examined, mercury alone excepted, goes on in an increaſing ſeries.

243 Exception.

To the expanding power of caloric there is one ſingular exception: From 30° to 40° Fahrenheit, *water*, inſtead of being expanded, ſuffers a remarkable contraction, as is evident from the following table of its bulk for every degree between 30° and 40°.

	Bulk.
30° - - -	100074
31 - - -	100070
32 - - -	100066
33 - - -	100063
34 - - -	100060
35 - - -	100058
36 - - -	100056
37 - - -	100055
38 - - -	100054
39 - - -	100054
40 - - -	100054 *.

* *Blagden.*

From 40° it expands like other ſubſtances on being heated (B).

244 Thermometer.

The expanſion of bodies by caloric has furniſhed us with an inſtrument for meaſuring the various degrees of it in different ſubſtances, we mean the thermometer; and as mercury is the only fluid which expands equably, it is obviouſly the only proper one for thermometers. The thermometer uniformly uſed in this article is that of Fahrenheit, except when ſome other is particularly mentioned.

245 No body without caloric.

2. By means of the thermometer, we learn that there is no body which does not contain caloric, becauſe there is none ſo cold that it cannot be made colder: and cooling a body is nothing elſe but abſtracting a part of the caloric which it contains.

246 Equilibrium of caloric.

3. Caloric cannot be confined in any body while thoſe in its neighbourhood are colder, but continues to ruſh out till every thing is reduced to the ſame temperature. This does not proceed from the attraction of the colder bodies, but from the tendency of caloric to exiſt everywhere in an equal degree of tenſion: For when hot bodies are placed in the exhauſted receiver of an air-pump, as we learn from Mr Pictet †, or in the Torricellian vacuum, as Count Rumford has ſhewn us ‡, the caloric leaves them in the ſame manner, tho' more ſlowly, and they are equally reduced to the temperature of the ſurrounding bodies. This property has been called *the equilibrium of caloric*. The only way therefore to confine or accumulate this ſubſtance in a body, is to ſurround it with bodies which are hotter than itſelf.

† *Sur le Feu*, chap. vi.
‡ *Phil. Tranſ.* 1786, Part I.

247 The particles of caloric repel each other.

4. The equilibrium of caloric ſeems evidently to prove that its particles repel each other. This repulſion will cauſe them when accumulated in any place to fly off in every direction, and to continue to ſeparate till they are oppoſed by caloric in other bodies of the ſame relative denſity with themſelves, which, by repelling them in its turn, compels them to continue where they are. The caloric in bodies therefore is in what has been called by Mr Pictet a ſtate of *tenſion* (C). Its particles are actuated by a force which would make them ſeparate to an indefinite diſtance, were they not confined by the oppoſite force of the caloric which ſurrounds them. The *equilibrium* therefore depends on the balancing of two oppoſite forces; the repulſion between the particles of caloric in the body, which tends to diminiſh the temperature; and the repulſion between the caloric of the body and the ſurrounding caloric, which tends to raiſe the temperature. When the firſt force is greater than the ſecond, as is the caſe when the temperature of a body is higher than that of the ſurrounding bodies, the caloric flies off, and the body becomes colder. When the laſt force is ſtronger than the firſt, as is the caſe when a body is colder than thoſe which are around it, the particles of its caloric are obliged to approach nearer each other, new caloric enters to occupy the ſpace which they had left, and the body becomes hotter. When the two forces are equal, the bodies are ſaid to be of the ſame temperature, and no change takes place *.

* See *Pictet ſur le Feu*, ch. i.

It is the action of theſe oppoſite forces which makes the thermometer a meaſure of temperature. When applied to any body, it continues to riſe or fall till the caloric in it and in the body to which it is applied are of the ſame tenſion, and then it remains ſtationary. The thermometer therefore merely indicates that the temperature of the body to which it is applied is equal to its own. It is obvious that, in order to obtain the real temperature of bodies, the thermometer ſhould be ſo ſmall that the quantity of caloric, which enters or leaves it, may not materially affect the reſult.

This property of caloric ſeems to be the cauſe of the elaſticity of the gaſes, in which, as we ſhall ſhew afterwards, it exiſts in great quantities. Perhaps it is the cauſe of elaſticity in general; for we have no demonſtrative evidence that the particles of elaſtic bodies repel each other (D), and we are certain that all of them contain caloric. Perhaps alſo it is owing to this repulſive property of caloric that the particles of no body actually touch each other; for the leſs caloric we leave in a body, the nearer its particles approach to one another. The expanſion of bodies by caloric ſeems alſo to depend on the ſame property. The particles of caloric uniting with thoſe of the body, endeavour to drag them along when they recede from each other. The expanſion

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(B) There was a curious fact concerning dilatation obſerved by Mr de Luc. A braſs rod which he uſed as a thermometer became in ſummer *habitually* longer; that is to ſay, that after being for ſome time lengthened by heat, it did not contract by the application of cold to its old length, but continued ſomewhat longer. In winter the contrary phenomenon took place. After being contracted for ſome time by cold, it did not return to its old length on the application of heat, but kept ſomewhat ſhorter. A leaden rod ſhewed theſe effects in a greater degree. Glaſs has not this quality. De Luc ſuſpects that this property is inverſely as the elaſticity of bodies. Glaſs is perfectly elaſtic, and lead is leſs elaſtic than braſs.—*Journ. de Phyſ.* xviii. 369.

(C) The phraſe was firſt uſed by Mr Volta.

(D) We acknowledge that ſeveral philoſophers of the firſt rank, Æpinus for inſtance, and Boſcovich, have ſuppoſed that the particles of all bodies both attract and repel each other: but we cannot help thinking it rather improbable (if it be poſſible) that two ſuch oppoſite properties ſhould exiſt together.

248
Bodies become lighter by being heated,

ſion of bodies therefore ought to be inverſely as their coheſion, and directly as the tenſion of the caloric which they contain. This property of caloric ſeems likewiſe to afford an explanation of a very curious fact, which was firſt, we believe, mentioned by De Luc in his Treatiſe on the Modifications of the Atmoſphere, and afterwards aſcertained by Dr George Fordyce, that bodies become abſolutely lighter by being heated. He took a glaſs globe three inches in diameter, with a ſhort neck, and weighing 451 grains; puured into it 1700 grains of water from the New river, London, and then ſealed it hermetically. The whole weighed $2150\frac{11}{12}$ grains at the temperature of 32°. It was put for twenty minutes into a freezing mixture of ſnow and ſalt till ſome of it was frozen; it was then, after being wiped firſt with a dry linen cloth, next with clean waſhed dry leather, immediately weighed, and found to be $\frac{1}{60}$th of a grain heavier than before. This was repeated exactly in the ſame manner five different times. At each, more of the water was frozen and more weight gained. When the whole water was frozen, it was $\frac{3}{10}$ths of a grain heavier than it had been when fluid. A thermometer applied to the globe ſtood at 10°. When allowed to remain till the thermometer roſe to 32°, it weighed $\frac{2}{10}$ths of a grain more than it did at the ſame temperature when fluid. We ſhall ſhew afterwards that ice contains leſs caloric than water of the ſame temperature with it. The balance uſed was nice enough to mark $\frac{1}{1000}$ part of a grain *. Morveau, too, found, much about the ſame time, that water put into veſſels hermetically ſealed, weighed more when frozen than when fluid †: and Mr Chauſſier found, that two pounds of ſulphuric acid were three grains heavier when frozen than after they had recovered their fluidity ‡.

249
And why.

Now, if the particles of caloric repel each other, bodies which contain it in great quantities muſt be ſomewhat repelled by each other. The more replete therefore that any body is with caloric, the more it will be repelled by the earth, which always contains a great quantity; and this repulſion muſt in ſome degree counteract its gravitation. This explanation was firſt ſuggeſted, we believe, by Dr Black.

250
Caloric movesmore readily upwards than downwards

The ſame property explains another curious fact diſcovered by Mr Pictet of Geneva, that caloric moves more readily vertically upwards than downwards. He took a tube of tinplate, two inches in diameter and 44 in length, and encloſed in it a bar of copper four lines in diameter and 33 inches in length, which was placed and fixed exactly in its axis. This tube was exhauſted of air, by means of an air-pump, till the manometer § ſtood at the height of four lines. It was incloſed in another tube of paſteboard, except about two inches, exactly in the middle, to which place the ſun's rays were directed for half an hour by means of a concave mirror. The ends of the copper bar were ſcooped out into concave hemiſpheres; and into each of theſe the bulb of a very ſenſible thermometer was fixed. The tube was placed vertically. The higheſt thermometer, which we ſhall call A, roſe to 95°, a hundred and one ſeconds before the loweſt B. The thermometer B roſe no higher than 95°; but the thermometer A reached 121,75°. To ſee whether this difference was owing to the thermometers, the tube was inverted, and conſequently the higheſt thermometer in the former experiment was loweſt in this. The thermometer B now roſe from 49 to 97,25 in 2810″; the thermometer A in 2763″, or 47″ ſooner than B. It was evident from this reſult, that the thermometer A was more ſenſible than the thermometer B by 47″. If this be ſubtracted from 101″, the former difference, it will leave 54″, as the difference reſulting from poſition. Theſe experiments were repeated with only this difference, that round the ends of the bar and the bulbs of the thermometers (but without touching the bulbs) ſome folds of oiled paper were wrapped to confine the caloric. The ſuperior thermometer A roſe from 50° to 106,25° in 34 minutes, which was 93′ ſooner than the inferior B: it roſe to 110,75°, the thermometer B only to 106,25°. The tube being reverſed, the thermometer A, which was now loweſt, roſe from 46° to 115,25° in 40′ 30″, or forty ſeconds ſooner than the thermometer B. This ſubtracted from 93″, as formerly, leaves 53″ for the difference of ſituation. The ſuperior thermometer mounted after the burning-glaſs was removed 0,45°, remained ſtationary for 80″, and after five minutes had only deſcended 0,45°: the other did not aſcend at all; in one minute it deſcended 0,225°, and in 6′ 8′ it deſcended 2,47°. In 22′ 50″ the inferior deſcended 63,725°, the ſuperior 61,475° *. From theſe experiments, it is obvious that the particles of caloric move ſomewhat faſter, and in ſomewhat greater quantity, upwards than downwards; owing, doubtleſs, to the repulſive power of the caloric in the earth. The ſmall quantity of air that remained in the tube may perhaps be ſuppoſed ſufficient to account for the difference, without allowing any ſuch tendency upwards in caloric. But it is evident from the experiments of the Florentine academicians on the ſame ſubject, with tubes full of air, that even when in great abundance, that fluid hardly affected the riſing of the ſuperior thermometer: ſurely then its effect muſt be altogether imperceptible when ſo little of it remained; and in the third and fourth experiments the oiled paper prevented any of the heated air from approaching the thermometer.

251
Conducting power of bodies:

5. If we take a bar of iron and a piece of ſtone of equal dimenſions, and putting one end of each into the fire, apply either thermometers or our hands to the other, we ſhall find the extremity of the iron ſenſibly hot long before that of the ſtone. Caloric therefore does not paſs through all bodies with the ſame celerity and eaſe. The power that bodies have to allow it a paſſage through them is called their *conducting power*; thoſe that allow it to paſs with facility, are called *good conductors*; thoſe through which it paſſes with difficulty, are called *bad conductors*; and thoſe which do not allow it to paſs at all, *non-conductors*.

252
Of wood and charcoal;

It is probable that all ſolids conduct heat in ſome degree, at leaſt this is the caſe with every one at preſent known. Wood and charcoal are exceeding bad conductors of caloric (E). Count Rumford informs us, that a piece of

* *Phil. Tranſ.* 1785, Part II.

† *Journ. de Phyſ.* 1785, Oct.

‡ *Journ. de Savans*, 1785, p. 493.

§ See *Manometer* in this Suppl.

* *Pictet ſur le Feu*, chap. 2.

(E) This fact merits the attention of chemiſts. It is obvious, that when metallic oxides are ſurrounded with charcoal powder, their temperature cannot be raiſed near ſo high as it otherwiſe would be. It is not unlikely that ſome part of the difficulty which has been experienced in attempting to reduce and fuſe ſeveral metallic ſubſtances may have been owing to this cauſe.

Caloric

of green oak plank was employed to ſtir the melted metal of which cannons were founding at Munich, and it was often allowed to remain a conſiderable time in the furnace; yet the caloric had penetrated to ſo inconſiderable a depth, that at the diſtance of $\frac{1}{20}$th of an inch below the ſurface, the wood did not ſeem to have been the leaſt affected by it; the colour remained unchanged, and it did not appear to have loſt even its moiſture *.

253
Of glaſs;

Glaſs, when not tranſparent (F), is alſo a very bad conductor: and this is the reaſon that it is ſo apt to crack on being heated or cooled ſuddenly; one part of it receiving or parting with its caloric before the reſt, expands or contracts, and deſtroys the coheſion.

254
Of metals;

Metals are the beſt conductors of caloric of all the ſolids hitherto examined. The conducting powers of all, however, are not equal. Dr Ingenhouſz procured cylinders of ſeveral metals exactly of the ſame ſize, and having coated them with wax, he plunged their ends into hot water, and judged of the conducting power of each by the length of wax-coating melted. From theſe experiments he concluded, that the conducting powers of the metals which he examined were in the following order †.

Silver,
Gold,
Copper, } nearly equal.
Tin, }
Platinum, }
Iron, } much inferior to the others.
Steel, }
Lead, }

255
Of ſtones and ſolids capable of melting.

Next to metals ſtone ſeems to be the beſt conductors; but this property varies conſiderably in different ſtones. Bricks are much worſe conductors than moſt ſtones. All ſolids capable of being melted become non-conductors the moment they are heated to the melting point: the caloric enters them eaſily enough, but it remains in them.

256
Whether fluids be conductors of caloric.

A queſtion has lately been agitated among philoſophers, Whether fluids be conductors of caloric? No doubt was entertained of their being not only conductors, but good conductors, till the publication of Count Rumford's Eſſays, in which the author contends, with much plauſibility of reaſoning, that though fluids *carry*, they do not *conduct* heat; or, in other words, let it paſs freely from one particle to another.

257
What led him to this opinion.

In a ſet of experiments on the communication of heat, he made uſe of thermometers of an uncommon ſize. Having expoſed one of theſe (the bulb of which was near four inches in diameter) filled with alcohol to as great a heat as it could ſupport, he placed it in a window to cool where the ſun happened to be ſhining. Some particles of duſt had by accident been mixed with the alcohol: theſe being illuminated by the ſun, became perfectly viſible, and diſcovered that the whole liquid in the tube of the thermometer was in a moſt rapid motion, running ſwiftly in oppoſite directions upwards and downwards at the ſame time. The *aſcending* current occupied the axis, the *deſcending* current the ſides of the tube. When the ſides of the tube were cooled by means of ice, the velocity of both currents was accelerated. It diminiſhed as the liquid cooled; and when it had acquired the temperature of the room, the motion ceaſed altogether. This experiment was repeated with lintſeed oil, and the reſult was preciſely the ſame. Theſe currents were evidently produced by the particles of the liquid going individually to the ſides of the tube, and giving out their caloric. The moment they did ſo, their ſpecific gravity being increaſed, they fell to the bottom, and of courſe puſhed up the warmer part of the fluid, which was thus forced to aſcend along the axis of the tube. Having reached the top of the tube, the particles gave out part of their caloric, became ſpecifically heavier, and tumbled in their turn to the bottom.

As theſe internal motions of fluids can only be diſcovered by mixing with them bodies of the ſame ſpecific gravity with themſelves, and as there is hardly any ſubſtance of the ſame ſpecific gravity with water which is not ſoluble in it, Count Rumford had recourſe to the following ingenious method of aſcertaining whether that fluid alſo followed the ſame law. The ſpecific gravity of water is increaſed conſiderably by diſſolving any ſalt in it; he added, therefore, potaſs to water till its ſpecific gravity was exactly equal to that of amber, a ſubſtance but very little heavier than pure water. A number of ſmall pieces of amber were then mixed with this ſolution, and the whole put into a glaſs globe with a long neck, which, on being heated and expoſed to cool, exhibited exactly the ſame phenomena with the other fluids. A change of temperature, amounting only to a very few degrees, was ſufficient to ſet the currents a-flowing; and a motion might at any time be produced by applying a hot or a cold body to any part of the veſſel. When a hot body was applied, that part of the fluid neareſt it aſcended; but it deſcended on the application of a cold body.

258
Proofs of the non-conducting power of water,

If caloric paſs through water only by the internal motion of its particles, as this experiment ſeems to prove, it is evident that every thing which embarraſſes theſe motions muſt retard its tranſmiſſion: and accordingly Count Rumford found this to be the caſe. He took a large lintſeed oil thermometer with a copper bulb and glaſs tube: the bulb was placed exactly in the centre of a braſs cylinder, ſo that there was a void ſpace between them all around 0,25175 of an inch thick. The thermometer was kept in its place by means of four wooden pins projecting from the ſides and bottom of the cylinder, and by the tube of it paſſing through the cork ſtopper of the cylinder. This cylinder was filled with pure water, then held in melting ſnow till the thermometer fell to 32°, and immediately plunged into a veſſel of boiling water. The thermometer roſe from 32° to 200° in 597″. It is obvious that all the caloric which ſerved to raiſe the thermometer muſt have made its way through the water in the cylinder. The experiment was repeated exactly in the ſame manner; but the water in the cylinder, which amounted to 2276 gr. had 192 gr. of ſtarch boiled in it, which rendered it much leſs fluid. The thermometer now took 1109″ to riſe from 32° to 200°. The ſame experiment was again repeated with the ſame quantity of pure water, having

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* *Rumford's Eſſays*, ii. 229.

† *Journ. de Phyſ.* 1789, p. 68.

(F) When tranſparent, it tranſmits caloric.

192 gr. of eiderdown mixed with it, which would merely tend to embarraſs the motion of the particles. A quantity of ſtewed apples were alſo in another experiment put into the cylinder. The following Tables exhibit the reſult of all theſe experiments.

Time the Caloric was in paſſing into the Thermometer.

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

Time the Caloric was in paſſing out of the Thermometer.

Temperature.	Through the Water and Starch.	Thro' the Water and Eiderdown.	Through ſtewed Apples.	Through pure Water.
	Seconds.	Seconds.	Seconds.	Seconds.
Therm. fell from 200° to 40° in	1548	1541	1749½	1032
Therm. fell 80°, *viz.* from 160° to 80°, in	468	460	520	277

Now neither the ſtarch nor the eiderdown could produce any alteration in the water except impeding its internal motions; conſequently whatever impedes theſe motions diminiſhes the conducting power of water. But this could not happen unleſs every individual particle actually went from the cylinder to the thermometer. Hence it follows that, if liquids be conductors, their conducting power is but ſmall when compared with their carrying power.

259 hewn to be inconcluſive.

All liquids, however, are capable of conducting caloric; for when the ſource of heat is applied to their ſurface, the caloric gradually makes its way downwards, and the temperature of every ſtratum gradually diminiſhes from the ſurface to the bottom of the liquid. The increaſe of temperature in this caſe is not owing to the carrying power of the liquid. By that power caloric may indeed make its way upwards through liquids, but certainly not downwards. Liquids then are conductors of caloric.

Count Rumford, indeed, has drawn a different concluſion from his experiments. He fixed a cake of ice in the bottom of a glaſs jar, covered one-fourth inch thick with cold water. Over this was poured gently a conſiderable quantity of boiling water. Now if water were a non-conductor, no caloric could paſs through the cold water, and conſequently none of the ice would be melted. The melting of the ice, then, was to determine whether water be a conductor or not. In two hours about half the ice was melted. This one would think, at firſt ſight, a deciſive proof that water is a conductor. But the Count has fallen upon a very ingenious method of accounting for the melting of the ice, without being under the neceſſity (as he tells us) of renouncing his theory that fluids are non-conductors.

It is well known that the ſpecific gravity of water at 40° is a maximum: if it be either heated above 40°, or cooled down below 40°, its denſity diminiſhes. Therefore, whenever a particle of water arrives at the temperature of 40°, it will ſink to the bottom of the veſſel. Now as the water next the ice was at 32°, it is evident that whenever any part of the hot water was cooled down to 40°, it would ſink, diſplace the water at 32°, come into contact with the ice, and of courſe melt it. The Count's ingenuity, never without reſources, enabled him to prove completely, that the ice employed in his experiment was actually melted in that manner: for when he covered the ice partially with ſlips of wood, that part which was ſhaded by the wood was not melted; and when he covered the whole of the ice with a thin plate of tin, having a circular hole in the middle, only the part exactly under the hole was melted. From theſe facts it certainly may be concluded that the ice was melted by deſcending currents of water.

But the point to be aſcertained, is not whether there were deſcending currents, but whether water be a conductor or not. Now if water be a non-conductor, by what means was the hot water cooled down to 40°? Not at the ſurface; for the Count himſelf tells us, that there the temperature was never under 108°: not by the ſides of the veſſel; for the deſcending current in one experiment was exactly in the axis: and it follows irreſiſtibly, from the experiment with the ſlips of wood, that theſe deſcending currents fell equally upon every part of the ſurface of the ice; which would have been impoſſible if theſe currents had been cooled by the ſide of the veſſel. The hot water, then, muſt have been cooled down to 40° by the cold water below it; conſequently it muſt have imparted caloric to this cold water. If ſo, one particle of water is capable of abſorbing caloric from another; that is, *water is a conductor of caloric.* After the hot water has ſtood an hour over the ice, its temperature was as follows:

At the ſurface of the ice	40°
One inch above the ice	80
Two inches - -	118
Three inches - -	128
Four inches - -	130
Seven inches - -	131

How is it poſſible to account for this gradual diminution of heat as we approach the ice, if water be a non-conductor? The water, it may be ſaid, gives out caloric at its ſurface, falls down, and arranges itſelf according to its ſpecific gravity. If ſo, how comes it that there is only one degree of difference between the temperature at 4 and at 7 inches above the ice? Thus it appears that the Count's experiment, inſtead of demonſtrating that water is a non-conductor, rather favours the common opinion that it is a conductor.

260 Mercury and oil proved to be conductors.

The Count tried whether oil and mercury be conductors in the following manner: When water was frozen in a glaſs jar by means of a freezing mixture, Count Rumford obſerved that the ice firſt began to be formed at the ſides, and gradually increaſed in thickneſs; and that the water on the axis of the veſſel, which retained its fluidity longeſt, being compreſſed by the expanſion of the ice, was forced upwards, and when completely frozen, formed a pointed projection or nipple, which was ſometimes half an inch higher than the reſt of the ice. Upon ice frozen in this manner, he poured olive oil, previouſly cooled down to 32°, till it ſtood at the height of three inches above the ice. The veſſel was ſurrounded as high as the ice with a mixture of pounded ice and water. A ſolid cylinder of wrought iron, 1$\frac{1}{4}$th inch in diameter, and 12 inches long, provided with a hollow cylindrical ſheath of thick paper, was heated to the temperature of 210° in boiling water; and being ſuddenly introduced into its ſheath, was ſuſpended from the ceiling of the room, and very gradually let down into the oil, until the middle of the flat ſurface of the hot iron, which was directly above the point of conical projection of the ice, was diſtant from it only $\frac{2}{10}$ths of an inch. The end of the ſheath deſcended $\frac{1}{10}$th of an inch lower than the end of the hot metallic cylinder. Now it is evident, that if olive oil was a conductor, caloric would paſs down through it from the iron and melt the ice. None of the ice, however, was melted; and when mercury was ſubſtituted for oil, the reſult was juſt the ſame *; conſequently it follows that neither oil nor mercury is a conductor of heat.

But this experiment is by no means ſufficiently delicate to decide the point. If a thermometer be ſubſtituted inſtead of the nipple of ice, it always riſes ſeveral degrees; whence it follows that, even in this caſe, caloric paſſes downwards; ſo that the experiment is in fact favourable to the ſuppoſition that oil and mercury are conductors.

Count Rumford therefore has not proved that fluids are non-conductors of caloric; and that they are in truth conductors, the author of this article aſcertained in the following manner: The liquid of which the conducting power was to be examined was poured into a glaſs veſſel till it filled it about half way; then a hot liquid of leſs ſpecific gravity was poured over it. Thermometers were placed at the ſurface, in the centre, and at the bottom of the cold liquid; if theſe roſe, it followed that the liquid was a conductor, becauſe the caloric made its way downwards. For inſtance, to examine the conducting power of mercury, a glaſs jar was half filled with that liquid metal, and boiling water then poured over it. The thermometer at the ſurface began immediately to riſe, then the thermometer at the centre, and laſtly that at the bottom. The firſt roſe to 118°, the ſecond to 90°, and the third to 86°: the firſt reached its maximum in 1′, the ſecond in 15′, the third in 25′. The conducting power of water was tried in the ſame manner with hot oil poured over it; and the reſult was ſimilar.

Fluids, then, as far as experiments have been made, are conductors of caloric as well as ſolids; and hence it follows that caloric is capable of making its way thro' all bodies with which we are acquainted. In this reſpect it differs from all other ſubſtances, even from light, which, as far as we know, cannot make its way through all bodies.

261
Tranſmiſſion of caloric radiant heat.

The motion of caloric through bodies is indeed of two kinds: Through ſome it ſeems to move with the ſame rapidity as through free ſpace; whilſt through others, as we have ſeen, it moves ſlowly. When it moves through a body with undiminiſhed velocity, it is ſaid to be *tranſmitted* through it; and when its velocity is prodigiouſly diminiſhed, it is ſaid to be *conducted*. Air, and all tranſparent bodies hitherto examined, have the property of *tranſmitting* caloric through them; though ſome of them, as glaſs, do not tranſmit it till after they have combined with a certain proportion of it: and probably no body tranſmits it unleſs a greater quantity enter than is capable of combining with it in the ſtate in which the body is placed. The phenomena of the tranſmiſſion of caloric are exactly ſimilar to the tranſmiſſion of light, and admit of preciſely the ſame explanation. What Scheele and ſeveral other chemiſts have called *radiant heat*, is nothing elſe than tranſmitted caloric; as has been completely proved by Dr Herſchel. See *Thermometric Spectrum* in this *Supplement*.

262
Specific caloric of bodies, what.

6. If equal quantities of water and of mercury be placed at the ſame diſtance from a fire, the mercury will become hot much ſooner than the water. After a ſufficient interval, however, both of them acquire the ſame temperature. Now caloric flows into all bodies while they continue of a lower temperature than thoſe around them, and it flows with equal rapidity into all bodies of the ſame conducting powers, as is the caſe with theſe two fluids: But if equal quantities of caloric were conſtantly flowing into the mercury and the water, and yet the water took a longer time to become hot than the mercury, it muſt require a greater quantity of caloric to raiſe water to a given temperature than it does to raiſe mercury. Bodies that require a greater quantity of caloric to raiſe them to a particular temperature than other bodies require, are ſaid to have a greater *capacity* for caloric. That the capacity for caloric is different in different bodies, was firſt obſerved by Dr Black. Dr Irvine afterwards inveſtigated the ſubject, and Dr Crawford publiſhed a great number of experiments on it in his *Treatiſe on Heat.* Profeſſor Wilcke of Stockholm alſo diſcovered the ſame property of bodies. He called the quantity of caloric neceſſary to raiſe the temperature of ſubſtances a given number of degrees, their *ſpecific caloric;* a term which we ſhall alſo employ, becauſe the phraſe *capacity for caloric* is liable to a great deal of ambiguity, and has introduced confuſion into this ſubject (F). If two ſubſtances of unequal temperatures, as water at 100° and alcohol at 50°, be mixed together, the mixture will be of a temperature different both from that of the water and the alcohol, the water will become colder and the alcohol hotter: the water will give out caloric to the alcohol till both are reduced to the ſame temperature. Now if it requires juſt as much caloric to raiſe alcohol a certain number of degrees as it does to raiſe water the ſame number, that is, if theſe two fluids are of the ſame ſpecific caloric, it is evident that the temperature of the mixture will be juſt 75°; for as ſoon as the water has given out 25° of caloric, the alcohol has acquired 25°, conſequently both will be reduced to the ſame temperature, and will remain ſtationary; but if the ſpecific caloric of the water be greater than that of the alcohol, the temperature of the mixture will be higher than 75°; for 25° of

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* Rumford, Eſſay vii. part ii. chap. 1.

(F) The term *ſpecific caloric* has been uſed in a different ſenſe by Seguin. He uſed it for the *whole caloric* which a body contains.

of caloric in that caſe would raiſe alcohol more than 25°. If the ſpecific caloric of water be ſo much greater than that of alcohol, that what raiſes water 20° will raiſe alcohol 30°; then the temperature after mixture will be 80°, becauſe when the water has given out 20°, the alcohol will have riſen 30°, and of courſe both will be of the ſame temperature. On the contrary, if the ſpecific caloric of alcohol were greater than that of water, the temperature of the mixture would be under 75°. If the ſame quantity of caloric that raiſed alcohol 20° raiſed water 30°, then the temperature of the mixture would be 70°. Thus the ratios of the ſpecific caloric of bodies may be diſcovered by mixing them together at different temperatures.

263 Experiments on ſpecific caloric by Wilcke. The firſt ſet of experiments on this ſubject, in point of time, were probably thoſe of Mr Wilcke. They were firſt publiſhed in the Stockholm Tranſactions for 1781, but had been made long before. The manner in which they were conducted is exceedingly ingenious, and they furniſh us with the ſpecific caloric of many of the metals. The metal on which the experiment was to be made was firſt weighed accurately (generally one pound was taken), and then being ſuſpended by a thread, was plunged into a large veſſel of tinplate, filled with boiling water, and kept there till it acquired a certain temperature, which was aſcertained by a thermometer. Into another ſmall box of tinplate exactly as much water at 32° was put as equalled the weight of the metal. Into this veſſel the metal was plunged, and ſuſpended in it ſo as not to touch its ſides or bottom; and the degree of heat, the moment the metal and water were reduced to the ſame temperature, was marked by a very accurate thermometer. He then calculated what the temperature would have been if a quantity of water equal in *weight* to the metal, and of the ſame temperature with it, had been added to the ice-cold water inſtead of the metal.

Let M be a quantity of water at the temperature C, m another quantity at the temperature c, and let their common temperature after mixture be x; according to a rule demonſtrated long ago by Richman, $x=\frac{MC+mc}{M+m}$. In the preſent caſe the quantities of water are equal, therefore M and m are each $= 1$; C, the temperature of the ice-cold water $= 32$: therefore $\frac{MC+mc}{M+m} = \frac{32+c}{2}$. Now c is the temperature of the metal. Therefore if 32 be added to the temperature of the metal, and the whole be divided by 2, the quotient will expreſs the temperature of the mixture, if an equal weight of water with the metal, and of the ſame temperature with it, had been added to the ice-cold water inſtead of the metal.

He then calculated what the temperature of the mixture would have been, if, inſtead of the metal, a quantity of water of the ſame temperature with it, and equal to the metal in *bulk*, had been added to the ice-cold water. As the weights of the ice-cold water and the metal are equal, their volumes are inverſely as their ſpecific gravities. Therefore the volume of ice-cold water is to a quantity of hot water equal in volume to the metal, as the ſpecific gravity of the metal to that of the water. Let M = volume of cold water, m = volume of hot water, g = ſpecific gravity of the metal, 1 = ſpecific gravity of water; then $m : M :: 1 : g$; hence $m = \frac{M}{g} =$ (M being made $= 1$) $\frac{1}{g}$. Subſtituting this value of m in the formula, $\frac{MC+mc}{M+m} = x$, in which $M = 1$ and $C = 32$, x will be $= \frac{32g+c}{g+1}$. Therefore if the ſpecific gravity of the metal be multiplied by 32, and the temperature of the metal be added, and the ſum be divided by the ſpecific gravity of the metal + 1, the quotient will expreſs the temperature to which the ice-cold water would be raiſed by adding to it a volume of water equal to that of the metal, and of the ſame temperature with it.

He then calculated how much water at the temperature of the metal it would take to raiſe the ice-cold water the ſame number of degrees which the metal had raiſed it. Let the temperature to which the metal had raiſed the ice-cold water be = N, if in the formula $\frac{MC+mc}{M+m} = x$, x be made = N, $M = 1$, $C = 32$, m will be $= \frac{N-32}{c-N}$. Therefore if from the temperature to which the ice-cold water was raiſed by the metal 32 be ſubtracted, and if from the temperature of the metal be ſubtracted the temperature to which it raiſed the water, and the firſt remainder be divided by the laſt, the quotient will expreſs the quantity of water of the temperature of the metal which would have raiſed the ice-cold water the ſame number of degrees that the metal did.

Now $\frac{N-32}{c-N}$ expreſſes the ſpecific caloric of the metal, that of water being = 1. For (neglecting the ſmall difference occaſioned by the difference of temperature) the weight and volume of the ice-cold water are to the weight and volume of the hot water as 1 to $\frac{N-32}{c-N}$, and the number of particles of water in each are in the ſame proportion. But the metal is equal in weight to the ice-cold water; it muſt therefore contain as many particles of matter; therefore the quantity of matter in the metal muſt be to that in the hot water as 1 to $\frac{N-32}{c-N}$. But they give out the ſame quantity of caloric; which, being divided equally among their particles, gives to each particle a quantity of caloric inverſely as the bulks of the metal and water; that is, the ſpecific caloric of the water is to that of the metal as 1 to $\frac{N-32}{c-N}$ (G).

We ſhall now give a ſpecimen or two of his experiments, and the calculations founded on them, as above deſcribed.

Gold

(G) We have altered all theſe formulas to make them correſpond with Fahrenheit's thermometer. They are a good deal ſimpler when the experiments are made with Celſius's thermometer, as Mr Wilcke did. In it the freezing point is zero; and conſequently inſtead of 32 in the formula, 0 is always ſubſtituted.

Gold. *Specific Gravity* 19,040.

Number of experiments.	Temperature of the metal.	Temperature to which the metal raiſed the water at 32°.	Temper. to which it would have been raiſed by a quantity of water equal in weight and heat to the metal.	Temperature to which it would have been raiſed by water equal in bulk and temperature to the metal.	Denominator of the fraction $\frac{N-32}{c-N}=\frac{1}{\frac{c-N}{N-32}}$, the numerator being 1.
1	163,4°	38,3°	97,7°	38,555°	19,857
2	144,5	37,4	88,25	37,58	19,833
3	127,4	36,5	79,7	36,68	20,500
4	118,4	36,05	75,2	36,15	20,333
5	103,1	35,6	65,75	35,42	18,750
6	95	34,45	63,5	35,06	19,000

Mean 19,712

Lead. *Specific Gravity* 11,456.

Number of experiments.	Temperature of the metal.	Temperature to which the metal raiſed the water at 32°.	Temperature to which the water would have been raiſed by a quantity of water equal in weight and heat to the metal.	Temperature to which the water would have been raiſed by water equal in bulk and temperature to the metal.	Denominator of the fraction $\frac{1}{\frac{c-N}{N-32}}$
1	186,8	38,3	109,4	44,425	23,571
2	181,40	37,85	106,7	43,473	24,538
3	165,2	37,4	98,6	42,692	23,666
4	163,4	37,4	97,7	42,548	23,333
5	136,4	36,5	84,2	40,344	22,200
6	131	36,05	81,5	39,947	24,700
7	126,5	36,05	79,25	39,585	22,333
8	107,6	35,15	69,8	38,339	23,000
9	94,1	34,7	63,05	36,985	22,000

Mean 23,515

It is needleſs to add, that the laſt column marks the denominator of the ſpecific caloric of the metal, the numerator being always 1, and the ſpecific caloric of water being 1. Thus the ſpecific caloric of gold is $\frac{1}{19,712}$. In exactly the ſame manner, and by taking a mean of a number of experiments at different temperatures, did Mr Wilcke aſcertain the ſpecific caloric of a number of other bodies. He aſcertained at the ſame time, that the ſpecific caloric of a body did not vary with the temperature, but continued always the ſame. This will appear evident from the experiments on gold and lead above exhibited.

264 Crawford, Next, in point of time, and not inferior in ingenious contrivances to enſure accuracy, were the experiments of Dr Crawford, made by mixing together bodies of different temperatures. Theſe were publiſhed in his *Treatiſe on Heat*.

265 Lavoiſier and La Place, Several experiments on the ſpecific caloric of bodies were made alſo by Lavoiſier and De la Place, which, from the well-known accuracy of theſe philoſophers, cannot but be very valuable.

Their method was exceedingly ſimple and ingenious; it was firſt ſuggeſted by De la Place. An inſtrument was contrived, to which Lavoiſier gave the name of *calorimeter*. It conſiſts of three circular veſſels nearly inſcribed into each other, ſo as to form three different apartments, one within the other. Theſe three we ſhall call the *interior*, *middle*, and *external cavities*. The interior cavity *ffff* (ſee ſection of the inſtrument fig. 4.), into which the ſubſtances ſubmitted to experiment are put, is compoſed of a grating or cage of iron wire, ſupported by ſeveral iron bars. Its opening or mouth LM is covered by the lid HG, which is compoſed of the ſame materials. The middle cavity *bbbb* is filled with ice. This ice is ſupported by the grate *m m*, and under the grate is placed a ſieve. The external cavity *a a a a* is alſo filled with ice. We have mentioned already, that no caloric can paſs through ice. It can enter ice, indeed, but it remains in it, and is employed in melting it. The quantity of ice melted, then, is a meaſure of the caloric which has entered into the ice. The exterior and middle cavities being filled with ice, all the water is allowed to drain away, and the temperature of the interior cavity to come down to 32°. Then the ſubſtance, the ſpecific caloric of which is to be aſcertained, is heated a certain number of degrees, ſuppoſe to 212°, and then put into the interior cavity encloſed in a thin veſſel. As it cools, it melts the ice in the middle cavity. In proportion as it melts, the water runs through the grate and ſieve, and falls through the conical funnel *c c d* and the tube *x y* into a veſſel placed below to receive it. The external cavity is filled with ice, in order to prevent the external air from approaching the ice in the middle cavity and melting part of it. The water produced from it is carried off through the pipe ST. The external air ought never to be below 32°, nor above 41°. In the firſt caſe, the ice in the middle cavity might be cooled too low; in the laſt, a current of air flows through the machine and carries off ſome of the caloric. By putting various ſubſtances at the ſame temperature into this machine, and obſerving how much ice each of them melted in cooling down to 32°, it was eaſy to aſcertain the ſpecific caloric of each. Thus, if water, in cooling from 212 to 32, melted one pound of ice, and mercury ,029 of a pound; the ſpecific caloric of water was one, and that of mercury ,029. This appears by far the ſimpleſt method of making experiments on this ſubject; and muſt alſo be the moſt accurate, provided we can be certain that all the melted ſnow flows into the receiver. But from an experiment of Mr Wedgewood, one would be apt to conclude that this does not happen. He found that the melted ice, ſo far from flowing out, actually *froze* again, and choaked up the paſſage.

A table of the ſpecific caloric of various bodies was likewiſe drawn up by Mr Kirwan, and publiſhed by Magellan in his Treatiſe on Heat. 266 And Kirwan.

From all theſe ſources we have drawn up the following table, which exhibits at one view the ſpecific caloric of thoſe bodies on which experiments have hitherto been made. 267 Reſult of theſe experiments.

We have added to it a column, expreſſing the ſpecific caloric of equal bulks of the ſame bodies; which ſeems to be a more accurate way of conſidering this ſubject, and indeed the only way in which the phraſe *capacity for caloric* is intelligible. This column was formed by multiplying the ſpecific caloric of equal weights of the various ſubſtances into their reſpective ſpecific gravities.

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

Bodies.	Specific Gravity.	Specific Caloric of equal Weight.	Specific Caloric of equal Volumes.
I. Gases*.			
Hydrogen gas - -	0,000094	21,4000	0,00214
Oxygen gas - - -	0,0034	4,7490	0,006411
Common air - - -	0,00122	1,7900	0,002183
Carbonic acid gas -	0,00183	1,0459	0,001930
Steam - - - - - -		1,5500	
Azotic gas - - -	0,00120	0,7036	0,000952
II. Liquids.			
Water - - - - - -	1,0000	1,0000	1,0000
Carbonat of ammonia †		1,851	
Arterial blood* - -		1,030	
Cows milk* - - -	1,0324	0,9999	1,0322
Sulphuret of ammonia†	0,818	0,9940	0,8130
Venous blood* - -		0,8928	
Solution of brown ſugar†		0,8600	
Nitric acid ‡ - - -		0,844	
Sulphat of magneſia 1 Water 8 †		0,844	
Common ſalt 1 Water 8 †		0,832	
Nitre 1 Water 8 ‡ - - -		0,8167	
Muriat of ammonia 1 Water 1,5 †		0,779	
Tartar 1 Water 237,3 † -		0,765	
Solution of potaſs † -	1,346	0,759	1,2216
Sulphat of iron 1 Water 2,5 †		0,734	
Sulphat of ſoda 1 Water 2,9 †		0,728	
Oil of olives † - -	0,9153	0,710	0,6498
Ammonia† - - - -	0,997	0,7080	0,7041
Muriatic acid† - -	1,122	0,6800	0,763
Sulphuric acid 4 Water 5 ‡		0,6631	
Alum 1 Water 4,45 † - -		0,649	
Nitric acid 9⅓ Lime 1 ‡ -		0,6181	
Nitre 1 Water 3 † - - -		0,646	
Alcohol * - - -	0,8371	0,6021	0,4993
Sulphuric acid § - -	1,840	0,5968	1,120
Nitrous acid† - -	1,355	0,576	0,780
Linſeed oil† - - -	0,9403	0,528	0,4964
Spermaceti oil * - -		0,5000	
Oil of turpentine † -	0,9910	0,472	0,4132
Vinegar† - - - -		0,3870	0,3966
Lime 9 Water 16 ‡ - -		0,3346	
Mercury ¶ - - -	13,568	0,3100	4,123
Diſtilled vinegar † -		0,1030	0,1039
III. Solids.			
Ice † - - - - - -		0,9000	
Ox-hide with the hair *		0,787	
Lungs of a ſheep * -		0,769	
Lean of ox-beef * -		0,7400	
Rice * - - - - - -		0,5050	
Horſe beans * - -		0,5020	
Duſt of the pine tree *		0,5000	
Peaſe * - - - - - -		0,4920	
Wheat * - - - - -		0,4770	
Barley * - - - - -		0,4210	
Oats * - - - - - -		0,4160	
Pitcoal * - - - - -		0,2777	
Charcoal * - - - -		0,2631	
Chalk * - - - - -		0,2564	
Ruſt of iron * - -		0,2500	
White oxide of antimony waſhed * - - -		0,2270	
Oxide of copper nearly freed from air * -		0,2272	
Quicklime (*c*) - -		0,2199	
Stoneware † - - -		0,195	
Agate ** - - - - -	2,648	0,195	0,517
Cryſtal ‡ - - - - -	3,189?	0,1929	0,6151
Cinders * - - - - -		0,1923	
Swediſh glaſs ** - -	2,386	0,187	0,448
Aſhes of cinders * -		0,1885	
Sulphur † - - - - -	1,99	0,183	0,3680
Flint glaſs † - - - -	3,3293	0,174	0,5792
Ruſt of iron nearly freed from air * - - -		0,1666	
White oxide of antimony ditto * - - -		0,1666	
Aſhes of the elm * -		0,1402	
Oxide of zinc nearly free from air * - - -		0,1369	
Iron (*d*) - - - - -	7,876	0,1264	0,993
Braſs (*d*) - - - - -	8,358	0,1141	0,971
Copper (*d*) - - - -	8,784	0,1121	1,027
Sheet iron ‡ - - -		0,1099	
Oxide of lead and tin *		0,102	
Gun-metal ‖ - - -		0,1100	
White oxide of tin nearly free from air * -		0,0990	
Zinc (*d*) - - - - -	7,154	0,0981	0,735
Aſhes of charcoal * -		0,0909	
Silver ** - - - - -	10,001	0,082	0,833
Yellow oxide of lead nearly freed from air *		0,0680	
Tin (*e*) - - - - - -	7,380	0,0661	0,444
Antimony (*d*) - -	6,107	0,0637	0,390
Gold ** - - - - -	19,040	0,050	0,966
Lead (*e*) - - - - -	11,456	0,0424	0,487
Biſmuth ** - - - -	9,861	0,043	0,427

7. If

(H) The ſpecific caloric of the ſubſtances marked * was aſcertained by Dr Crawford, thoſe marked † by Mr Kirwan, ‡ by Lavoiſier and La Place, ** by Wilcke, ‖ by Count Rumford. § Is the mean of Crawford, Kirwan, and Lavoiſier; ¶ mean of Lavoiſier and Kirwan; (*c*) mean of Crawford and Lavoiſier; (*d*) mean of Wilcke and Crawford; (*e*) mean of Wilcke, Crawford, and Kirwan.

268 Latent caloric, or

-. If a quantity of ice, at a low temperature, ſuppoſe at 20°, be ſuſpended in a warm room, it will become gradually leſs cold, as may be diſcovered by means of a thermometer, till it reaches the temperature of 32°; but there it ſtops. The ice, however, diſſolves ſlowly; and at the end of ſeveral hours, when it is all juſt melted, the thermometer ſtill ſtands at 32°. After this it begins to riſe, and ſoon reaches the temperature of the room. Here the ice continues for ſeveral hours colder than the air around it. Caloric muſt then be continually flowing into it; yet it does not become hotter: it is changed, however, into water. Ice, therefore, is converted into water by a quantity of caloric uniting with it. This caloric has been called *latent caloric*, becauſe its preſence is not indicated by the thermometer.

269 Caloric of fluidity.

It might, perhaps with more propriety, as Profeſſor Pictet obſerves *, be called *caloric of fluidity;* for there are other caſes in which caloric exiſts in bodies without raiſing their temperature. This very important diſcovery was made by Dr Black as early as 1757, and ſeems to have led the way to all the ſubſequent diſcoveries in this part of chemiſtry, which have almoſt completely changed the appearance of the ſcience: for the diſcovery that caloric may exiſt in bodies while the thermometer cannot indicate its preſence, is one of the ſtrongeſt links in the chain of facts by which the nature of combuſtion was aſcertained.

The caloric which unites with ice, and renders it fluid, appears again during the act of *freezing*. If a quantity of water be carried into a room where the temperature is below the freezing point, ſuppoſe at 20°, it cools gradually down to 32°; but it becomes no colder till it is all frozen, which takes up ſome time. The moment it is all converted into ice, it begins again to cool, and ſoon reaches the temperature of the room. In this caſe, the water is ſurrounded by a cold atmoſphere; it muſt therefore be giving out caloric conſtantly; yet it does not become colder till it is all frozen, that is to ſay, till it has loſt all its *caloric of fluidity*.

Dr Black proved, by a very accurate experiment, that the quantity of *caloric of fluidity* is ſufficient to raiſe the ſame quantity of water 140°.

All ſolids become fluid by abſorbing a quantity of caloric. Landriani proved that this is the caſe with ſulphur, alum, nitre, and ſeveral of the metals †; and it has been found to be the caſe with every ſubſtance hitherto examined. Fluidity, therefore, is owing to a union between the ſolid and a certain quantity of caloric.

The late Dr Irvine of Glaſgow advanced a theory on this ſubject different from that of Dr Black. The ſpecific caloric of water being greater than that of ice, it requires a greater quantity of caloric to raiſe it to a given temperature than it does to raiſe ice. The caloric does not therefore become *latent;* it only ſeems to do ſo from the greater ſpecific caloric of water. This theory was zealouſly adopted by Dr Crawford. Dr Black obſerved very juſtly, that it did not account for the production of fluidity at all. The ſpecific caloric of water is indeed greater than that of ice; but how is the ice convered into water? This is an objection which the advocates for Dr Irvine's, or Dr Crawford's, theory (as it has been improperly called) will not eaſily anſwer. Let us now examine whether this theory accounts for the apparent loſs of caloric. It follows from Mr Kirwan's experiments, that the ſpecific caloric of water is to that of ice as 10 to 9 (1). Dr Black proved, that as much caloric entered the ice as would have raiſed it, had it been water, 140°. Let us ſuppoſe that it would only have raiſed the ice 140°; in that caſe the melted ice ought to have been of the temperature of 158°, for 10 : 9 : : 140 : 126; but it was only 32°: Therefore 126° of caloric have diſappeared, and cannot be accounted for by the change of ſpecific caloric. Nor can the accuracy of Dr Black's experiment be ſuſpected: it has been repeated in every part of the world, and varied in every poſſible way. We cannot doubt, therefore, that caloric unites with ſubſtances, and cauſes them to become fluid, or that *there is in fact a caloric of fluidity different from ſpecific caloric.*

270 Caloric of evaporation.

Water alſo is converted into *ſteam* by uniting with caloric. Dr Black put an iron veſſel, containing four ounces of water at the temperature of 53°, upon a caſt-iron table which was red hot. The water roſe to the boiling point in three minutes; but it did not afterwards become any hotter. It evaporated, however, in 18 minutes; and the ſteam was preciſely at the temperature of 212°. During the firſt three minutes, it received 159° of caloric, and as much muſt have been entering it during every three minutes while the evaporation continued, as the temperature was always much lower than that of the table. This caloric, inſtead of raiſing the temperature of the water, was employed in converting it into ſteam. There is alſo, therefore, a quantity of latent caloric in ſteam. It might, as Mr Pictet obſerves, be called, with propriety, *caloric of evaporation*. This caloric appears again if the ſteam be condenſed. If it be made to paſs, for inſtance, through a pipe ſurrounded with cold water, it is condenſed in the pipe, and drops out from it in the form of water. The caloric of the ſteam enters into the water around the pipe, and the quantity of it in degrees may be diſcovered by the number of degrees which it raiſes that water. By an experiment of this kind, it was proved, that the caloric of evaporation would be ſufficient to heat water red hot, were it employed only in raiſing its temperature, inſtead of converting it into ſteam. It is therefore at leaſt equal to 800°. Mr Watt ſhewed afterwards that it was 920°.

Even ſpontaneous evaporation, as Dr Black firſt obſerved, is owing to the ſame cauſe: and this explains why bodies cool when water is evaporated from their ſurface;

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* *Sur le Feu*, ch. 1.

† *Jour. de Phyſ.* xxvi.

(1) We do not know how this was aſcertained: Not by mixing water and ice ſurely; becauſe that would be taking for granted the thing to be proved; becauſe it would give a very different reſult; and what is ſtill worſe, the ſpecific caloric in that caſe would differ according to the temperature and the quantity of water. To give an inſtance: Mr Gadolin concludes, from 180 experiments made by mixing hot water and ice, that the ſpecific caloric of ice is to that of water only as 1 to 2 *; and had he varied the quantities and the temperatures, he might have obtained ſeveral other ratios.

* *Ann de Chim.* xi. 27.

ſurface; a fact which has been long known, and which has been employed in warm countries to diminiſh the temperature of liquids, and even to convert them into ice (K). That water is evaporated by uniting with caloric, and not by ſolution in air, has been proved very completely by De Luc in his Treatiſe on Meteorology.

The evaporation of alcohol, ether, and every other ſubſtance on which experiments have been made, has been found owing to the ſame cauſe. Bodies, therefore, are converted into vapour by uniting with caloric.

271 Real zero, what.

8. If caloric, as has been ſhewn, exiſts in bodies at the loweſt temperature which we are able to procure, and if it exiſts in them while the thermometer cannot diſcover its preſence—is there any method of aſcertaining its abſolute quantity in bodies? At what degree would a thermometer ſtand (ſuppoſing the thermometer capable of meaſuring ſo low) were the body to which it is applied totally deprived of caloric? or what degree of the thermometer correſponds to the real zero?

The firſt perſon (as far as we know), at leaſt ſince men began to think accurately on the ſubject, who conceived the poſſibility of determining this queſtion, was Dr Irvine of Glaſgow. He invented a theorem, in order to aſcertain the real zero, which has, we know not for what reaſon, been aſcribed by ſeveral writers to Mr Kirwan. He took it for granted (and the fact is proved by all the experiments hitherto made) that the ſpecific caloric of bodies continued the ſame in every degree of temperature, as long as they remained in the ſame ſtate, that is to ſay, as long as they continued either ſolid or fluid or in a ſtate of vapour; but that the ſpecific caloric of the ſame body while ſolid was leſs than while fluid, and leſs while fluid than while in a ſtate of vapour. He took it for granted, too, that the 140 degrees of caloric which entered ice during its ſolution without raiſing its temperature, entered merely in conſequence of the increaſed ſpecific caloric of the water, and that they were exactly proportional to this increaſed ſpecific caloric. He took it for granted, likewiſe, that the ſpecific caloric of bodies was proportional to

272 Irvine's theorem to diſcover it.

(K) Galen informs us, that the ancient Egyptians were accuſtomed to put water previouſly boiled into earthen jars, and expoſe them all night on the upper part of their houſes to the air. Before ſunriſe theſe veſſels were put into the ground, moiſtened on the outſide with water, and then ſurrounded with freſh plants; by which means the water was preſerved cool during the whole day. *Comment. in lib.* vi. *Hippoc. de morbis vulgar.* 4. 10. p. 396.

By a ſimilar proceſs, water, in the Eaſt Indies, is converted into ice.

The following ſingular paſſage, which has been pointed out to us by the ingenious Dr Barclay, lecturer on anatomy in Edinburgh, furniſhes a ſtriking proof that the ancients were led, by a very different method of reaſoning, to deduce, from their philoſophical theory of the four elements, concluſions concerning the nature of heat not very different from thoſe of the moderns.

" Sic enim res ſe habet, ut omnia, quæ alantur et quæ creſcant, contineant in ſe vim caloris; ſine qua neque ali poſſent nec creſcere. Nam omne, quod eſt calidum et igneum, cietur et agitur motu ſuo: quod autem alitur et creſcit, motu quodam utitur certo et æquabili; qui quandiu remanet in nobis, tamdiu ſenſus et vita remanet: refrigerato autem et extincto calore, occidimus ipſi et exſtinguimur. Quod quidem Cleanthes his etiam argumentis docet, quanta vis inſit caloris in omni corpore: negat enim ullum eſſe cibum tam gravem, quin is nocte et die concoquatur; cujus etiam in reliquiis ineſt calor his quas natura reſpuerit. Jam verò venæ et arteriæ micare non deſinunt, quaſi quodam igneo motu; animadverſumque ſæpe eſt, cùm cor animantis alicujus evolſum ita mobiliter palpitaret, ut imitaretur igneam celeritatem. Omne igitur quod vivit, ſive animal ſive terra editum, id vivit propter incluſum in eo calorem. Ex quo intellegi debet, eam caloris naturam, vim habere in ſe vitalem per omnem mundum pertinentem. Atque id faciliùs cernemus, toto genere hoc igneo, quod tranat omnia, ſubtiliùs explicato. Omnes igitur partes mundi (tangam autem maxumas) calore fultæ ſuſtinentur. Quod primùm in terrena natura perſpici poteſt. Nam et lapidum conflictu atque tritu elici ignem videmus; et recenti foſſione

—— *terram fumare calentem;*

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

" Longa eſt oratio, multæque rationes, quibus doceri poſſit, omnia, quæ terra concipiat, ſemina, quæque ipſa ex ſe generata ſtirpibus infixa contineat, ea temperatione caloris et oriri et augeſcere. Atque aquæ etiam admixtum eſſe calorem, primùm ipſe liquor, tum aquæ declarat effuſio: quæ neque conglaciaret frigoribus, neque nive pruinaque concreſceret, niſi eadem ſe admixto calore liquefacta et dilapſa diffunderet. Itaque et aquilonibus reliquiſque frigoribus dureſcit humor: et idem viciſſim mollitur tepefactus et tabeſcit calore. Atque etiam maria agitata ventis ita tepeſcunt, ut intellegi facilè poſſit, in tantis illis humoribus eſſe incluſum calorem. Nec enim ille externus et adventicius habendus eſt tepor, ſed ex intimis maris partibus agitatione excitatus: quod noſtris quoque corporibus continget, cùm motu atque exercitatione recaleſcunt. Ipſe verò aër, qui natura eſt maxumè frigidus, minime eſt expers caloris. Ille verò et multo quidem calore admixtus eſt: ipſe enim oritur ex reſpiratione aquarum: earum enim quaſi vapor quidam aër habendus eſt. Is autem exiſtit motu ejus caloris, qui aquis continetur. Quam ſimilitudinem cernere poſſumus in his aquis, quæ efferveſcunt ſubditis ignibus. Jam verò reliqua quarta pars mundi, ea et ipſa tota natura fervida eſt, et ceteris naturis omnibus ſalutarem impertit et vitalem calorem. Ex quo concluditur, cùm omnes mundi partes ſuſtineantur calore, mandum etiam ipſum ſimili parique natura in tanta diuturnitate ſervari: eoque magis, quòd intellegi debet, calidum illud atque igneum ita in omni fuſum eſſe natura, ut in eo inſit procreandi vis et cauſſa gignendi, à quo et animantia omnia, et ea quorum ſtirpes terra continentur, et naſci ſit neceſſe et augeſcere. *Cicero de natura Deorum*, lib. ii. c. 9 *et* 10.

to their *abſolute caloric*, or to all the caloric which exiſted in each.

On theſe data he reaſoned in the following manner: Let A be a body in a ſtate of fluidity; B the ſame body in a ſtate of ſolidity. If the ſpecific caloric of A and of B be known, and if it be known how many degrees the caloric, diſengaged during the change of B into A, would raiſe the temperature of A, it may be found by an eaſy proceſs how many degrees all the caloric contained in B would raiſe the temperature of A; and the ſum of theſe two numbers will repreſent in degrees the whole quantity of caloric in A: for the quantity of caloric in A muſt be juſt equal to the caloric in B, together with what entered into it in paſſing from the ſtate of B to that of A. Let the ſpecific caloric of A be 6, that of B 1; and let the quantity of caloric diſengaged during the change of A into B be ſufficient to raiſe the temperature of A 500°. If the ſpecific caloric be proportional to the abſolute caloric, it muſt contain exactly 6 times as much caloric as B. The 500° which entered into A when it changed its ſtate, muſt be juſt 5 times as great as all the caloric of B; becauſe when added to the caloric of B, it formed the caloric in A, which is juſt 6 times as great as the caloric in B. Therefore to diſcover the caloric in B, we have only to divide 500 by 5, or, which is the ſame thing, to ſtate this proportion 6—1 : 500 : : 1 : 100. The caloric in B, therefore, in this caſe is juſt as much as would raiſe the temperature of A 100°. Therefore, if to 100°, the caloric of B, be added 500°, = caloric diſengaged in the paſſage of A to B, this will give 600°, = to all the caloric in A. Therefore, in all caſes, the difference between the numbers expreſſing the ſpecific caloric of the ſolid and fluid, is to the number expreſſing the ſpecific caloric of the ſolid, as the quantity of caloric diſengaged during the paſſage of the fluid into a ſolid is to the quantity of caloric in the fluid.

Dr Crawford embraced this theorem; and concluded, from a number of experiments made on purpoſe to aſcertain the fact, that the real zero was 1268° below 0, or 1300° below the freezing point.

273 Examined,

This ſubject deſerves to be conſidered with attention. If this theorem in fact furniſhes us with the real zero, it is one of the moſt important diſcoveries which has ever been made in chemiſtry; but if it proceeds on erroneous principles, it will only involve us in endleſs mazes of error and abſurdity.

In the firſt place, if the real zero has any meaning at all, it muſt ſignify the degree to which the thermometer (ſuppoſing it could be uſed) would ſink on being applied to a body which contained no heat. It muſt therefore be a fixed point; and were the theorem which we are examining well founded, experiments upon every different ſubſtance, if conducted with accuracy, would lead to the ſame reſult. Let us ſee whether this be the caſe.

From Dr Crawford's experiments, it follows, as we have ſeen, that the real zero is 1268° below 0.

Mr Kirwan, from comparing the ſpecific caloric of water and ice, fixed the real zero at 1048° below 0.

From the experiments of Lavoiſier and La Place on a mixture of water and quicklime, in the proportion of 9 to 16, it follows, that the real zero is 2736° below 0.

From their experiments on a mixture of 4 parts of ſulphuric acid and 3 parts of water, it follows, that the real zero is 5803,4° below 0.

Their experiments on a mixture of 4 parts of ſulphuric acid and 5 of water, place it at 2073,3° below 0.

Their experiments on $9\frac{1}{3}$ parts of nitric acid and 1 of lime, place it at $\frac{1889}{-0{,}01783}$ below 32°*.

Theſe reſults differ from one another ſo enormouſly, and the laſt of them, which makes the real zero a negative quantity, is ſo abſurd, that they are alone ſufficient to convince us that the data on which they are founded are not true. Should it be ſaid that their difference is not owing to any defect in the theorem, but to inaccuracies in making the experiments—we anſwer, that the theorem itſelf is founded on ſimilar experiments; and if experiments of this nature, even in the hands of the moſt accurate chemiſts, cannot be freed from ſuch enormous errors, how can we depend on any conſequences deduced from them? and where, then, is our evidence for the truth of the theorem?

But, farther, there is no proof whatever that the ſpecific caloric of bodies is proportional to their abſolute caloric. The ſpecific caloric of iron is greater than that of water, or even azotic gas; yet ſurely it is very improbable that iron contains more abſolute caloric than either of theſe ſubſtances.

If the ſpecific caloric of bodies has any meaning at all, it can only be, that the ſame quantity of caloric raiſes the temperature of one body a greater number of degrees than it does another. When we ſay that the ſpecific caloric of A is = 6, and that of B = 1, what do we mean, unleſs that the quantity of caloric which raiſes B 6° raiſes A only 1°, or that what raiſes B 60° or 600°, raiſes A only 10° or 100°? When we ſay that the ſpecific caloric of water is 10, and that of ice 9, do we not mean, that the quantity of caloric which raiſes the ice 10° or 100°, raiſes water only 9° or 90°? Yet during the change of ice into water, 140° of caloric enter it without raiſing its temperature; a quantity greater than what can be accounted for by the difference of ſpecific caloric by 126°. The quantity that diſappears, therefore, is *not* proportional to the difference of ſpecific caloric; and therefore any theory which depends on that ſuppoſition cannot be well founded. When water is converted into ſteam, 800° of caloric diſappear, yet the ſpecific caloric of ſteam is to that of water, according to Dr Crawford's own experiments, only as 155 to 100: ſo that no leſs than 283° diſappear, which cannot be accounted for according to this theory.

274 And found inſufficient.

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

275 Caloric exiſts in bodies

9. If there be no body without caloric, if it exiſts in different quantities in different bodies, even when their temperatures are the ſame, and while the thermometer cannot indicate its preſence—in what ſtate does it exiſt in them? We cannot ſurely ſuppoſe that it is contained by them juſt as water is contained by a veſſel of wood or metal, or that they are filled with it in the ſame manner that a hollow globe of tinplate perforated with holes is filled with water when it is plunged into a quantity of that liquid; or that bodies are filled with caloric merely becauſe they are immerſed in an ocean of caloric. Were that the caſe, the ſpecific and abſolute caloric of bodies would always be proportional; and they would of neceſſity be inverſely as the ſpecific gravity of the reſpective bodies; becauſe the leſs the ſpecific gravity, the more room would be left for the particles

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

ticles of caloric. But this is by no means the caſe: the ſpecific gravity of iron, for inſtance, is greater than that of tin, yet the ſpecific caloric of iron is more than double that of tin: the ſpecific gravity of oxygen gas is greater than that of common air, yet the ſpecific caloric of the firſt of theſe ſubſtances is more than three times as great as that of the other. There muſt be ſomething, therefore, in bodies themſelves quite different from, and unconnected with, the vacuities between their particles, which diſpoſes ſome to admit more caloric than others. And what can that be but a diſpoſition in different bodies to unite with a greater or a ſmaller quantity of caloric, and to retain it with more or leſs firmneſs according to their *affinity* for it? Dr Black pointed out, long ago, by diſcovering latent heat, that caloric unites with bodies; and this ſeems to be the only real key for unfolding the actions of this extraordinary ſubſtance. If caloric be matter, can it be deſtitute of that property which all other matter poſſeſſes, we mean attraction? And if it poſſeſſes attraction, muſt it not combine with thoſe bodies that attract it juſt as other bodies combine with each other? Muſt there not be formed a chemical union between caloric and other ſubſtances, which can only be broken by chemical means, by preſenting a third body which has a greater affinity either for the caloric or the body to which it is united, than they have for each other?

276 In a ſtate of chemical combination.

277 Proved to be the caſe in liquids, vapours,

That it unites chemically with ſome bodies, at leaſt, cannot be doubted, as we have ſhewn already, that whenever a ſolid is converted into a liquid, a quantity of caloric enters, and remains in it; and that both the ſolid and the caloric loſe their characteriſtic properties. This is preciſely what takes place in every chemical union. All liquids, therefore, conſiſt of ſolids combined with caloric. We have ſeen, too, that liquids are converted into vapours by the very ſame proceſs. There are therefore, at leaſt, two very large claſſes of bodies, liquids and vapours, in which we are certain that caloric exiſts in a ſtate of chemical combination.

278 And gaſes;

There is another claſs of bodies which reſembles vapours in almoſt all their properties: theſe are the gaſes. Like them, they are inviſible and elaſtic, and capable of indefinite expanſion. Is it not probable, then, that the gaſes alſo, as well as the vapours, owe their properties to caloric? that they alſo conſiſt of their reſpective baſes combined with that ſubtile ſubſtance? This probability has been reduced to certainty by an experiment of Lavoiſier. By adding two tubes to the calorimeter formerly deſcribed, he contrived to make known quantities of air to paſs through the interior cavity, and to ſupport combuſtion. He found, that when a pound of oxygen gas was made to combine in this manner with phoſphorus, as much caloric was diſengaged as melted 87½ pounds of ice*. Now every pound of ice abſorbs as much caloric in the act of melting as is ſufficient to raiſe a pound of water 140°. Therefore the whole caloric diſengaged was ſufficient to raiſe a pound of water 12250°. All this could not have come from the phoſphorus, becauſe it had been converted into a liquid, and muſt therefore have abſorbed inſtead of parted with caloric, and becauſe the quantity of caloric diſengaged in all caſes of combuſtion is proportional, not to the combuſtible,,but to the oxygen abſorbed. Oxygen gas, then, is compoſed of oxygen and caloric: and if this be the caſe with one gas, why not with all?

We may conclude, therefore, that the gaſes, as well as liquids and vapours, owe their form to the caloric which they contain. The only difference between them and vapours is, that the latter return to their liquid ſtate by the mere action of cold; whereas moſt of the gaſes reſiſt the loweſt temperature which it has been poſſible to apply. It was natural to expect, that if caloric combined chemically with bodies, its affinity would be different for different ſubſtances, and that its affinity for ſome bodies would be ſo great that it would not leave them to combine with any other. It was natural to expect this, becauſe it is the caſe with every other ſubſtance with which we are acquainted. The difference, then, between the gaſes and vapours is not ſurpriſing. The affinity of the former for caloric is not only much greater than that of the latter, but much greater than that of any other ſubſtances.

279 And to be the cauſe of their gaſeous form.

It is owing to this ſtrong affinity between oxygen, hydrogen, and azot and caloric, that they cannot be obtained except in a gaſeous form: and we ſhall deſcribe ſeveral other ſubſtances afterwards exactly in the ſame circumſtances. Had we any ſubſtance poſſeſſed of a greater affinity for caloric than they have, we ſhould be able, by preſenting it, to deprive them of their gaſeous form. Doubtleſs there is a difference in the affinity between theſe bodies themſelves and caloric; but as all of them are already ſaturated, this difference cannot be diſcovered. If we could obtain them uncombined with caloric, that is to ſay, in a concrete ſtate, it would be eaſy to aſcertain this point. Suppoſe, for inſtance, that hydrogen had the ſtrongeſt affinity for caloric, and that we poſſeſſed it in a concrete ſtate—it would be eaſy, by preſenting it to the other gaſes, to deprive their baſes of the caloric with which they are united, and thus to obtain them alſo uncombined with any other ſubſtance.

280 Why caloric appears during combuſtion,

But though we are acquainted with no ſubſtance that has a greater affinity for caloric than the baſes of the gaſes, there are many ſubſtances which have a greater affinity for theſe baſes than caloric has. When any ſuch ſubſtance is preſented, the baſe combines with it, and the caloric is left at liberty. Thus, when phoſphorus is preſented to oxygen gas, the phoſphorus and oxygen unite together, and the caloric flies off. We are now, therefore, able to anſwer one of the queſtions propoſed at the end of the ſecond chapter, Whence comes the caloric which appears during combuſtion? It is ſeparated from the oxygen, which leaves it in order to enter into a new combination.

281 And during many chemical combinations.

The caloric alſo, which ſometimes appears when two bodies combine together, is ſet at liberty exactly in the ſame manner. When ſulphuric acid and water, for inſtance, are mixed together, a very conſiderable heat is produced; a good deal of caloric, therefore, becomes ſenſible. In this caſe, the water combines with the acid, and at the ſame time lets go the caloric with which it was formerly combined, and becomes denſer. In the ſame manner, to give another inſtance, when water is poured upon quicklime, a very great quantity of caloric becomes manifeſt. The water in this caſe combines with the quicklime, and aſſumes a concrete form, and of courſe lets go the caloric with which it was previouſly united.

282 Why certain mixtures produce cold.

10. It is no uncommon thing in nature to obſerve two bodies, after combining together, manifeſting a much ſtronger affinity for a third body than either of

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* Lavoiſier, p. i. ch. 9.

them had while ſeparate. Thus, ſilver has no perceptible affinity for ſulphuric acid, neither has oxygen; but unite them together, and they combine with that acid very readily. A great many inſtances of the ſame kind might be produced. Were there ſubſtances, then, which, after combining together, have a greater affinity for caloric than any of them had while ſeparate, this ought not to ſurpriſe us, becauſe the ſame phenomenon is often obſerved in other bodies. Now this is actually the caſe with regard to caloric. Mix together, for inſtance, common ſalt and ſnow, the mixture inſtantly becomes liquid, and ſo cold, that it ſinks the thermometer down to zero. In this caſe, the ſnow and ſalt united have a much ſtronger affinity for caloric than either of them had while ſeparate; they attract it therefore from other bodies with which they happen to be in contact, till they have obtained a doſe ſufficient for their ſaturation; and this ſaturation they manifeſt by becoming liquid. It is for this reaſon that all ſalts produce cold during their ſolution in water, when the freezing point of the ſolution formed is below that of water. All ſuch ſolutions have a ſtrong affinity for caloric; they therefore attract it till they are ſaturated, which appears by their becoming fluid. A number of experiments have been lately made in order to procure artificial cold by means of ſuch combinations. The moſt complete ſet of experiments of that nature with which we are acquainted, is thoſe of Mr Walker, publiſhed in the Philoſophical Tranſactions for 1795. We ſhall preſent the reſult of his experiments in the following Table:

Table of Freezing Mixtures.

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

In order to produce theſe effects, the ſalts employed muſt be freſh cryſtallized, and newly reduced to a very fine powder. The veſſels in which the freezing mixture is made ſhould be very thin, and juſt large enough to hold it, and the materials ſhould be mixed together as quickly as poſſible. The materials to be employed in order to produce great cold ought to be firſt reduced to the temperature marked in the table, by placing them in ſome of the other freezing mixtures; and then they are to be mixed together in a ſimilar freezing mixture. If, for inſtance, we wiſh to produce a cold = — 46, the ſnow and diluted nitric acid ought to be cooled down to 0, by putting the veſſel which contains each of them into the 12th freezing mixture in the above table, before they are mixed together. If a ſtill greater cold is required, the materials to produce it are to be brought to the proper temperature by being previouſly placed in the ſecond freezing mixture. This proceſs is to be continued till the required degree of cold has been procured *.

283
Subſtances which contain moſt caloric.

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

traction

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* Walker, *Phil. Tranſ.* 1795.

traction of theſe particles for each other—we cannot ſuppoſe it annihilated: It muſt therefore be the more powerful the greater the quantity of caloric combined in any body is. Probably, then, there is moſt caloric combined with gaſes, leſs with fluids, and leaſt with ſolids. It does not follow, however, from this, that the quantity of caloric combined with any body is proportional to the diſtance between its particles, becauſe that may depend on other cauſes. Thus, though hydrogen gas is much rarer than oxygen gas, it does not follow that hydrogen is combined with more caloric than oxygen, becauſe the rarity may be owing to the ſmaller coheſive force of the particles of hydrogen allowing a ſmaller quantity of caloric to produce a greater effect.

284
Caloric may be added indefinitely to bodies,

If caloric unites *only* chemically with bodies, there ought to be a certain point of ſaturation between it and the ſubſtances with which it combines, becauſe this takes place in all other chemical combinations. Oxygen gas, for inſtance, conſiſts of a certain quantity of oxygen united with caloric. Now if this gas be a *chemical* compound, the two ingredients ought to ſaturate each other in ſuch a manner, that no more of either could be admitted. But it cannot be denied, that more caloric can ſtill be added to oxygen gas, for its temperature may be raiſed at pleaſure as high as we think proper. This, at firſt ſight, ſeems to be an inſuperable objection to the theory, that caloric only combines chemically with bodies. It ought to be remembered, however, that caloric is not ſingular in this reſpect. There are other bodies in nature, and bodies too which certainly combine with other ſubſtances only by affinity, which exhibit the very ſame phenomenon. Water is capable of combining with ſulphuric acid and many other ſalts almoſt in any proportion, at leaſt no limits have hitherto been obſerved. Oxygen, too, combines with almoſt every body in various proportions: We have ſeen, that with almoſt every metal it forms at leaſt two different oxides. Why then may not caloric be capable of uniting in the ſame manner? Allowing, therefore, that it were impoſſible to explain why bodies are capable of combining with caloric after ſaturation, this could be no objection to the theory that it only unites chemically with bodies, becauſe the ſame phenomenon is exhibited by other bodies which it cannot be doubted combine only by means of affinity.

285
And why.

The manner in which theſe other combinations are formed has been already hinted, and ſhall be conſidered more fully afterwards; at preſent we ſhall only attempt to explain the action of caloric. Let us ſuppoſe, then, that caloric is preſented to oxygen; that they combine together in a certain proportion, and ſaturate each other. The product of this combination is oxygen gas; a ſubſtance poſſeſſed of properties very different from thoſe of caloric or oxygen in a concrete ſtate; it is incapable of being decompoſed by any merely mechanical method, and exhibits all the appearances of a ſimple ſubſtance. Let us therefore conſider this compound for a moment as a ſimple ſubſtance. May it not ſtill have an affinity for caloric? and will it not, in that caſe, unite with it? Oxygen gas and caloric have an affinity for each other; accordingly when preſented to one another they combine in a certain proportion, and form a new compound, differing from oxygen gas, properly ſo called, in elaſticity, ſpecific gravity, and ſeveral other particulars. The affinity, however, between oxygen gas and caloric is much feebler than that between oxygen and caloric; for the new compound is eaſily broken, and the caloric abſorbed by many other ſubſtances. We can even conceive this new compound ſtill to have an affinity for caloric, to unite with it, and to form another compound, the affinity between the ingredients of which is ſtill feebler. And in this manner may the indefinite increaſe of temperature be accounted for.

286
Cauſe of the different conducting powers of different bodies.

Subſtances may be conceived to be conductors of caloric inverſely as their affinity for it. Good conductors may have very little affinity for caloric; and for that reaſon it may be eaſily forced through them by the repulſion of its own particles. But thoſe ſubſtances which have a great affinity for caloric, combine with it the moment it is preſented to them; and conſequently it cannot paſs through them. Thus, when it is preſented to ice, the affinity between the two ſubſtances is ſo great, that the caloric unites with the very firſt particles of ice which it meets with. The particles behind theſe cannot receive any caloric, except by attracting it from the particles with which it has already combined. But the affinity of one particle of ice for caloric cannot be greater than that of another particle of ice: and the union of two bodies cannot be broken by a force not greater than that which unites them; therefore the caloric cannot paſs from one particle to another. Conſequently, ſuppoſing all the particles to keep their places, no new caloric could enter. Juſt as when a piece of marble is put into ſulphuric acid, the cruſt of ſulphat of lime which very ſoon covers it prevents the acid from getting to the particles of marble within. But as ſoon as a particle of ice unites with caloric, water, the new compound, leaves its ſtation, and allows the caloric a paſſage to the other particles.

In the ſame manner, when caloric is preſented to water, it combines with the outermoſt ſtratum of particles, and forms with them a compound which cannot be decompoſed by the other particles of the water, becauſe their affinity for caloric is no greater than that of the particles already united with it. No more caloric, then, could gain admiſſion, were it not that (the ſpecific gravity of the new compound being inferior to that of the uncombined water) it immediately changes its place, and allows another ſtratum of particles to occupy its room. Theſe unite with caloric, and are diſplaced in their turn. And in this manner the proceſs goes on, till all the particles have combined with caloric; or, which is the ſame thing, till the whole of the water is heated.

287
How heat paſſes thro' ſolids.

But ſuppoſing the firſt ſtratum of particles to remain in their place after their union with caloric, we can conceive an affinity ſtill to ſubſiſt between the new compound, thus formed, and caloric. In that caſe the new compound, which we ſhall call A, would combine with an additional doſe of caloric, and form a ſecond compound B, differing in ſeveral reſpects from the firſt. We can conceive alſo the affinity between the firſt compound A and caloric to be inferior to that between water and caloric. In that caſe, the ſecond ſtratum of particles of water would ſeparate the additional doſe with which the firſt ſtratum had united. In this manner would two ſtratums of particles combine with caloric. The firſt ſtratum of particles would combine with another doſe of caloric, and form a ſecond compound B as before. But this compound could not now be decompoſed by the ſecond ſtratum of particles, becauſe they had already united with a doſe of caloric; and therefore their affinity for a new doſe could be no greater than that of the firſt ſtratum of particles. The proceſs of heating could go on no farther. But we can conceive the ſecond compound B, into which the firſt ſtratum has entered, ſtill to have an affinity for caloric, to combine with a doſe of it, and to form with it a third compound C. We can conceive, at the ſame time, the affinity between the ſecond compound B and caloric to be leſs than that between the firſt compound A and caloric. In that caſe, the ſecond ſtratum of particles would take this laſt doſe from the firſt ſtratum, and form with it a ſecond compound B. The third ſtratum of particles, which is ſtill uncombined with caloric, would now attract this new doſe from the ſecond ſtratum, and combine with it. And, ſuppoſing the caloric ſtill flowing towards the water, the firſt ſtratum would again form the third compound C, by uniting with a freſh doſe: this new doſe would be again attracted by the ſecond ſtratum, and the firſt ſtratum would again form the third compound C, by uniting witb another doſe of caloric. Thus three ſtratums of particles would be combined with caloric; the firſt ſtratum would contain three doſes, the ſecond ſtratum two, and the third one. The proceſs of heating would again ſtop; becauſe now the affinity of the ſecond ſtratum is no greater than that of the firſt, nor the affinity of the third ſtratum greater than that of the ſecond, nor that of the fourth than that of the third. But we can conceive an affinity ſtill to ſubſiſt between caloric and the third compound C, into which the firſt ſtratum has entered, and this affinity, at the ſame time weaker than that between the ſecond compound B and caloric. In that caſe they would combine and form a fourth compound D. This new doſe would be attracted by the ſecond ſtratum of particles, which would combine with it and form the third compound C; the third ſtratum would attract it from the ſecond, and form with it the ſecond compound B; and the fourth ſtratum would attract it from the third, and enter into the firſt compound A. The firſt ſtratum would again enter into the fourth compound D; which would be again decompoſed by the ſecond ſtratum; and the compound formed by the ſecond ſtratum, by the third ſtratum. The fourth compound D would be again formed by the firſt ſtratum, and again decompoſed by the ſecond ſtratum. It would be formed a third time, and could not now be decompoſed. Four ſtratums of particles would now have combined with caloric: the firſt ſtratum with four doſes; the ſecond, with three doſes; the third, with two; and the fourth, with one. We can conceive this proceſs to go on exactly in the ſame manner, till all the particles of water have combined with a doſe of caloric. In that caſe, the quantity of caloric combined with every ſtratum of particles would form a regular decreaſing ſeries from that part of the water at which the caloric enters to that part which is fartheſt diſtant from it. The proceſs of heating would go on very ſlowly; and the heat of that part of the water which is fartheſt diſtant from the ſource of caloric could never be nearly equal to that of the part which is neareſt to that ſource. This ſeems in fact to be the manner in which all thoſe ſolids are heated which are bad conductors of caloric: in all probability it is the way in which all ſolids are heated.

288 Bodies cool each other reciprocally, That caloric combines with bodies merely by means of affinity, ſeems at firſt ſight contrary to fact; for there is no ſubſtance whatever which may not be cooled indefinitely merely by ſurrounding it with other bodies which are colder than itſelf. Place a piece of hot iron, for inſtance, in cold water, it is very ſoon cooled down to the temperature of that liquid. This ſeems plain enough; the attraction of water for caloric is greater than that of iron: but reverſe the experiment; put hot water within cold iron, and the water is cooled in its turn down to the temperature of the iron: ſo that the iron alſo has a greater affinity for caloric, as well as the water; which is abſurd.

289 And why. But it ought to be remembered, that caloric not only poſſeſſes affinity, but that it has another property alſo, of which every other ſpecies of matter, except perhaps light, ſeems to be deſtitute, a repulſion between its own particles. It is neceſſary for all organiſed bodies, and probably for all bodies, that they ſhould poſſeſs a certain quantity of caloric; and on this account the greateſt care has been taken to ſecure its equal diſtribution. This ſeems to be one uſe at leaſt of its repulſive power; a power which is never deſtroyed, however cloſely caloric is united with other bodies. We have ſhewn already, that this power is increaſed by diminiſhing the quantity of ſurrounding caloric; and when thus increaſed to a certain degree, it may at laſt equal, and even exceed, the affinity between the caloric and the bodies to which it is united; and in that caſe part of the caloric would neceſſarily fly off. It ſeems to be in this manner that bodies reciprocally cool each other, and that they have always a tendency to an equilibrium of temperature. Thus ſteam by cold is converted into water, and water into ice. And the affinity between bodies and that caloric which is employed in regulating the temperature ſeems to be ſo weak, that the repulſion between the particles of caloric eaſily overcomes it, and reſtores the equilibrium. But the affinity between ſome ſubſtances and caloric is ſo great, that no diminution of temperature has been found ſufficient to overcome it. This is the caſe, as we have already ſeen, with oxygen gas.

290 Cauſe of the difference in the ſpecific caloric of bodies. The ſpecific caloric of bodies ſeems to depend on two things; their affinity for caloric, and the diſtance between their particles. For what is temperature but the diſpoſition of a body to part with caloric? The more caloric a body is diſpoſed to part with, we call its temperature the higher; the leſs it parts with when a colder body is applied, its temperature is ſaid to be the lower. If oxygen gas parts with no caloric to a thermometer which ſtands at —10°, we ſay its temperature is —10; yet we know that even then it contains, in all probability, much more caloric than the mercury in the thermometer does. Now the ſtronger the affinity between any ſubſtance and caloric, the greater quantity of caloric will be required before the repulſion between its particles is ſufficient to overcome this attraction; conſequently the more caloric is neceſſary to raiſe it a given number of degrees. And the farther diſtant the particles of bodies are, the farther from one another muſt the particles of caloric be to which they are united; and conſequently the weaker muſt be the repulſion between them.

We cannot deny how new this theory of the action of caloric will appear to thoſe who have been accuſtomed ed to look upon Dr Crawford's opinions on this ſubject as fully proved; nor do we pretend that it can be reconciled with theſe opinions. But this, we hope, is no proof of its falſehood. We think it can be fairly deduced from Dr Black's doctrine of latent heat: we know, too, that Bergman believed caloric capable of combining chemically with bodies: and Morveau has not only embraced the ſame opinion, but ſeems to affirm, that all the combinations into which caloric enters are chemical *. And were this queſtion to be decided by authority, we appeal to all the world, whether other three men could be produced to whoſe deciſions one would more willingly ſubmit (1). We do not, however, mean to reſt its evidence on authority; let it be compared with facts, and put to the teſt of experiment; and by its correſpondence with theſe let it ſtand or fall.

* Encyc. Method. Chim. art. Affinité.

291 Caloric haſtens ſolution, and increaſes the ſolvent power of water.

12. Caloric both haſtens the ſolution of ſalts in water, and increaſes the ſolvent power of the water; for water diſſolves a much greater quantity of almoſt every ſalt when hot than when cold. The reaſon that caloric produces theſe effects is obvious from thoſe properties of it which have been deſcribed. It haſtens ſolution by putting the particles of the fluid in motion, and thus bringing all of them in their turn into contact with the ſalt: for only thoſe particles can act as ſolvents which are in contact with the ſalt. It increaſes the ſolvent power of the fluid by combining with it, and forming a compound which has a greater affinity for the ſalt, and which therefore diſſolves more of it than the fluid alone would have done. This new compound is deſtroyed by cooling; and then the additional doſe of the ſalt which had been diſſolved is precipitated.

13. We ſhould come now to the conſideration of the two remaining queſtions propoſed at the end of the ſecond chapter, Why do bodies combine with oxygen at one temperature and not at another? And why is caloric neceſſary to produce this union? But as the difficulty of theſe queſtions is not inferior to their importance, we ſhall delay any attempt to anſwer them till we come to treat of *affinity*.

292 Methods of obtaining caloric.

14. It now only remains to conſider the methods by which caloric may be obtained in a ſenſible ſtate. Theſe methods may be reduced to four; combuſtion, percuſſion, friction, and light: the laſt of which ſhall be conſidered afterwards.

293 Combuſtion explained.

We have ſeen already, that the combuſtion of *ſimple combuſtibles and metals* is merely their combination with oxygen, during which the oxygen parts with the caloric with which it was formerly united. Now the very ſame thing takes place in other combuſtions. The combuſtible unites with oxygen, which at the ſame time gives out its caloric. The change then which the combuſtible body ſuffers is not owing to the action of caloric on it, but to its combining with oxygen. The very ſame change can be brought about without any of the uſual phenomena which attend combuſtion, ſimply by preſenting the oxygen combined with ſome other body inſtead of caloric. Nitric acid, for inſtance, is a body which contains in it a good deal of oxygen: If phoſphorus be mixed with this acid, it attracts part of the oxygen, and, without any of the uſual phenomena which attend combuſtion, is converted into phoſphoric acid. Strictly ſpeaking, then, combuſtion is nothing elſe but the combination of oxygen with the burning body, and the term might therefore be uſed in every caſe where ſuch an union takes place; and in this ſenſe indeed it is now employed by ſeveral writers. But the term *combuſtion* is in common language confined to thoſe caſes where the oxygen was previouſly combined with caloric, and where a quantity of heat and light become ſenſible; and perhaps it would be better, in order to prevent ambiguity, never to employ it in any other ſenſe. We are not yet abſolutely certain that caloric and light may not become ſenſible in other combinations beſides thoſe into which oxygen enters. There are other ſubſtances beſides oxygen capable of combining with caloric; for inſtance, hydrogen and azot: and unleſs their affinity for caloric be greater than for any other ſubſtance, they may be capable of combining with other ſubſtances, and ſeparating from caloric, at leaſt the impoſſibility of this has never yet been demonſtrated. It is improper, therefore, to appropriate the word *combuſtion* to the combinations of oxygen, till it can be ſhewn that the phenomena uſually denoted by that name are never owing to any other cauſe. There is even one caſe in which theſe phenomena preſent themſelves, in which we are next to certain that oxygen has no ſhare. There is an affinity between ſulphur and iron, and a high temperature promotes their union. When theſe ſubſtances are mixed together, and heated till they juſt begin to appear red hot, they combine together, and at the ſame time, as the Dutch chemiſts firſt obſerved, a good deal of caloric and light is evolved. The very ſame phenomena appear in a vacuum, or in any kind of air whatever. The explanation of them is very ſimple and obvious. The ſulphur or the iron, or perhaps both, had previouſly been combined with a quantity of caloric; and when they united together, this caloric of courſe ſeparated from them.

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

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

The theory of combuſtion adopted by the earlier chemiſts was very different from the preceding. Stahl, as has been already explained, conſidered combuſtion in every inſtance as owing to the ſeparation of phlogiſton; and this opinion ſoon became univerſal. He conſidered phlogiſton as the ſame thing with the element of fire; which was capable both of becoming fixed in bodies, and of exiſting in a ſtate of liberty. Two of its properties in this laſt ſtate were heat and light. The heat and the light, then, which became ſenſible during combuſtion, were nothing elſe, according to Stahl, but two properties of phlogiſton or the element of fire. Macquer, to whoſe illuſtrious labours ſeveral of the moſt important branches of chemiſtry owe their exiſtence, was, we believe, the firſt perſon who perceived a ſtriking defect in this theory of Stahl. Sir Iſaac Newton had proved that light is a body; it was abſurd, therefore, to make it a mere property of phlogiſton or the element of fire. Macquer accordingly conſidered phlogiſton as nothing elſe but light fixed in bodies. This opinion was embraced by a great number of the moſt diſtin-

296 Improved by Macquer,

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(1) The ſame opinion has been embraced by Seguin, Pictet, Gadolin, and ſeveral other philoſophers. We did not mention them, becauſe the theory given above differs in a few particulars from theirs. But we have derived much inſtruction from their ingenious writings; and many of the facts which we have given were obtained from them.

diſtinguiſhed chemiſts; and many ingenious arguments were brought forward to prove its truth. But if phlogiſton be only light fixed in bodies, whence comes the heat that manifeſts itſelf during combuſtion? Is this heat merely a property of light? Dr Black proved that heat is capable of combining with, or becoming fixed in bodies which are not combuſtible, as in ice and water; and concluded of courſe, that it is not a property but a body. From that time heat or caloric was conſidered by the greateſt number of chemiſts as a diſtinct ſubſtance from phlogiſton.

297 Prieſtley,

Soon after this, a phenomenon, which had been obſerved from the earlieſt ages, and which probably, for that very reaſon, had been neglected, began to be attended to; that combuſtibles would not burn except in contact with air. Dr Prieſtley obſerved, that the air in which combuſtibles had been ſuffered to burn till they were extinguiſhed, had undergone a very remarkable change; for no combuſtible would afterwards burn in it, and no annimal could breathe it without ſuffocation (K). He concluded, as Dr Rutherford had done before him, that this change was owing to phlogiſton; that the air had combined with that ſubſtance; and that air was neceſſary to combuſtion, by attracting the phlogiſton, for which it had a ſtrong affinity. If ſo, phlogiſton could not be light any more than caloric; for if it ſeparated from the combuſtible merely by combining with air, it could not ſurely diſplay itſelf in the form of light. The queſtion then recurred with double force, What is phlogiſton? Dr

298 And Crawford.

Crawford, of whoſe ingenious experiments on the ſpecific caloric of bodies we have already given an account, without attempting to anſwer this queſtion, made a conſiderable improvement in the theory of combuſtion, by ſuppoſing that the phlogiſton of the combuſtible combined with the air, and at the ſame time ſeparated the caloric and light with which that fluid had been previouſly united. The heat and the light, then, which appeared during combuſtion, exiſted previouſly in the air. This theory was very different from Stahl's, and certainly a great deal more ſatisfactory. But ſtill

299 Kirwan's theory of phlogiſton

the queſtion, What is phlogiſton? remained to be anſwered. Mr Kirwan, who had already raiſed himſelf to the firſt rank among chemical philoſophers by many important diſcoveries, and many ingenious inveſtigations of ſome of the moſt difficult parts of chemiſtry, attempted to anſwer this queſtion, and to prove that phlogiſton was the ſame with hydrogen *. The ſubject was now brought to a ſtate capable of the moſt complete deciſion. Does hydrogen actually exiſt in all combuſtible ſubſtances? and is it ſeparated from them

300 Refuted.

during every combuſtion? The French chemiſts who anſwered his treatiſe, ſhewed that this is by no means the caſe; and that therefore there was no proof whatever of the identity of phlogiſton and hydrogen. And Mr Kirwan in conſequence, with that candour which diſtinguiſhes ſuperior minds, gave up his opinion as untenable.

301 Exiſtence of phlogiſton diſproved.

Mr Lavoiſier had already put the queſtion, What proof is there of the exiſtence of phlogiſton at all? There is only this ſingle proof, that ſubſtances after combuſtion are different from what they formerly were. That this difference takes place is certainly true; but it is owing, not to the ſeparation of any ſubſtance, but to the combination of one. It follows, therefore, that there is no proof whatever of the exiſtence of any ſuch ſubſtance as *phlogiſton* in nature; and of courſe we muſt conclude that no ſuch ſubſtance exiſts (L).

302 Production of caloric by percuſſion,

15. It is well known that heat is produced by the percuſſion of hard bodies againſt each other. When a piece of iron is ſmartly and quickly ſtruck with a hammer, it becomes red hot; and the production of ſparks by the colliſion of flint and ſteel is too familiar a fact to require being mentioned. No heat, however, has ever been obſerved to follow the percuſſion of liquids, nor of ſoft bodies which eaſily yield to the ſtroke.

303 Owing partly to condenſation,

It has long been known, that hammering increaſes the denſity of metals. The ſpecific gravity of iron before hammering is 7,788; after being hammered, 7,840: that of platinum before hammering is 19,50; after it, 23,00. Now condenſation diminiſhes the ſpecific caloric of bodies. After one of the clay pieces uſed in Wedgewood's thermometer has been heated to 120°, it is reduced to one half of its former bulk, though it has loſt only two grains of its weight, and its ſpecific caloric is at the ſame time diminiſhed one third †. But we cannot conceive the ſpecific caloric of a body to be diminiſhed without its giving out at the ſame time a quantity

* In his *Treatiſe on Phlogiſton.*

* *T. Wedgewood, Phil. Tranſ.* 1792.

(K) Theſe very obſervations had been made almoſt a century before by Mayow; but chemiſtry was then in its infancy; little attention was paid to them, and they had been forgotten.

(L) Mr Lavoiſier was therefore the author of what is called the *antiphlogiſtic theory* in chemiſtry, or the theory which accounts for the phenomena of chemiſtry without the aſſiſtance of phlogiſton. It has been ſo called in oppoſition to the theory of Stahl, which explained every thing by means of *phlogiſton*, and which is therefore called the *phlogiſtic theory*.

Some chemiſts have affected to omit Lavoiſier's name altogether, when they ſpoke of the antiphlogiſtic theory. According to them, that theory was founded upon the experiments and diſcoveries of other chemiſts, and Lavoiſier had no other merit but that of bringing it into public notice.

That Mr Lavoiſier, virtually at leaſt, claimed ſeveral of the diſcoveries of others, we are ſorry to be under the neceſſity of acknowledging; and that many of the experiments, brought forward to diſprove the exiſtence of phlogiſton, were firſt made by others, is known to all the world: but it is equally evident, that the firſt perſon who actually formed the theory was Lavoiſier; and ſurely the merit lies in that. It is not thoſe who collect the ſtones, and the timber, and the mortar, but he who lays the plan, and ſhews how to put the materials together, that is in reality the builder of the houſe. Who did not know, as well as Newton, that a ſtone fell to the ground, and that the planets revolved round the ſun? and yet, who but Newton could have formed the theory of gravitation? We would not be underſtood to detract any thing from the merit of the other illuſtrious philoſophers who have adorned the preſent age, many of whom are at leaſt equal, and ſome of them ſuperior to Lavoiſier: But we are afraid that envy, or ſome worſe motive, guided the pen of *one* at leaſt of the moſt active and virulent antagoniſts of that illuſtrious and unfortunate philoſopher. It muſt not, however, be concealed, that his theory of combuſtion is incomplete. See COMBUSTION in this *Supplement*.

quantity of caloric; and we know for certain that caloric is evolved during condenſation. A thermometer placed within a condenſer riſes ſeveral degrees every time air is thrown in *. We can even ſee a reaſon for this. When the particles of a body are forced nearer each other, the repulſive power of the caloric combined with them is increaſed, and conſequently a part of it will be apt to fly off. Now, after a bar of iron has been heated by the hammer, it is much harder and brittler than before. It muſt then have become denſer, and conſequently muſt have parted with caloric. It is an additional confirmation of this, that the ſame bar cannot be heated a ſecond time by percuſſion until it has been expoſed for ſome time to a red heat. It is too brittle, and flies to pieces under the hammer. Now brittleneſs ſeems in moſt caſes owing to the abſence of the uſual quantity of caloric. Glaſs *unannealed*, or, which is the ſame thing, that has been cooled very quickly, is always extremely brittle. When glaſs is in a ſtate of fuſion, there is a vaſt quantity of caloric accumulated in it, the repulſion between the particles of which muſt of courſe be very great; ſo great indeed, that they would be diſpoſed to fly off in every direction with inconceivable velocity, were they not confined by an unuſually great quantity of caloric in the ſurrounding bodies: conſequently if this ſurrounding caloric be removed, the caloric of the glaſs flies off at once, and more caloric will leave the glaſs than otherwiſe would leave it, becauſe the velocity of the particles muſt be greatly increaſed. Probably then the brittleneſs of glaſs is owing to the deficiency of caloric; and we can ſcarcely doubt that the brittleneſs of iron is owing to the ſame cauſe, if we recollect that it is removed by the application of new caloric. Part therefore of the caloric which appears in conſequence of percuſſion ſeems to proceed from the body ſtruck; and this is doubtleſs the reaſon why thoſe bodies, the denſity of which is not increaſed by percuſſion, as liquids and ſoft ſubſtances, are not heated at all.

* *Darwin, Phil. Tranſ.* 1788.

304
And partly to combuſtion.

We ſay *part* of the caloric, becauſe, often at leaſt, part of it is probably owing to another cauſe. By condenſation, as much caloric is evolved as is ſufficient to raiſe the temperature of ſome of the particles of the body high enough to enable it to combine with the oxygen of the atmoſphere. The combination actually takes place, and a great quantity of additional caloric is ſeparated by the decompoſition of the gas. That this happens during the colliſion of flint and ſteel cannot be doubted; for the ſparks produced are merely ſmall pieces of iron heated red hot by uniting with oxygen during their paſſage through the air, as any one may convince himſelf by actually examining them. Mr Lane has ſhewn that iron produces no ſparks in the vacuum of an air-pump; but Mr Kirwan has obſerved that they are produced under common ſpring water; and we know that iron at a certain temperature is capable of decompoſing water.

305
Sparks emitted by quartz ſtones on ciſion.

When quartz, rock-cryſtal (M), or other very hard ſtones, are ſtruck againſt one another they emit ſparks. If they be often made to emit ſparks above a ſheet of white paper, there are found upon it a number of ſmall black bodies, not very unlike the eggs of flies. Theſe bodies are hard but friable, and when rubbed on the paper leave a black ſtain. When viewed with a microſcope, they ſeem to have been melted. Muriatic acid changes their colour to a green, as it does that of lavas *. Theſe ſubſtances evidently produced the ſparks by being heated red hot. Lamanon (N) ſuppoſes that they are particles of quartz combined with oxygen. Were that the caſe, the phenomenon would be preciſely ſimilar to that which is produced by the colliſion of flint and ſteel. That they are particles of quartz cannot be doubted; but to ſuppoſe them combined with oxygen is contrary to all experience: for theſe ſtones never ſhew any diſpoſition to combine with oxygen even when expoſed to the moſt violent heat. La Metherie made experiments on purpoſe to ſee whether Lamanon's opinion was well founded; but they all turned out unfavourable to it. And Mongé aſcertained, that the particles deſcribed by Lamanon were pure cryſtal unaltered, with a quantity of black powder adhering to them. He concludes accordingly, that theſe fragments had been raiſed to ſo high a temperature during their paſſage through the air, that they ſet fire to all the minute bodies that came in their way †. We muſt therefore either ſuppoſe that all the caloric was produced by mere condenſation, which is not probable, or acknowledge that we cannot explain the phenomenon.

* *Lamanon, Journ. de Phyſ.* 1785.

306
Cauſe of this unknown.

† *Ann. de Chim.* xvi. 206.

307
Emiſſion of caloric on friction,

16. Caloric is not only produced by percuſſion, but alſo by friction. Fires are often kindled by rubbing pieces of dry wood ſmartly againſt one another. It is well known that heavy loaded carts ſometimes take fire by the friction between the axle-tree and the wheel. Now in what manner is the caloric evolved or accumulated by friction? Not by increaſing the denſity of the bodies rubbed againſt each other, as happens in caſes of percuſſion; for heat is produced by rubbing ſoft bodies againſt each other, the denſity of which therefore cannot be increaſed by that means, as any one may convince himſelf by rubbing his hand ſmartly againſt his coat. It is true, indeed, that heat is not produced by the friction of liquids, but then they are too yielding to

308
Not owing to condenſation,

(M) Theſe ſtones are compoſed of almoſt pure ſilica.

(N) This ingenious and unfortunate young man, to whom we are indebted for theſe facts, fell a victim to his ardour for knowledge. He accompanied La Perouſe in his laſt voyage, and was murdered with the moſt ſavage cruelty, together with La Langle and ſeveral others, by the natives of the iſland of Maouna. When a man of genius, anxious to acquire honeſt fame, and a man too ſo nobly diſintereſted as Lamanon, thus falls prematurely before he has attained the object of his wiſhes,

> " Cut off from nature's and from glory's courſe!
> " Which never mortal was ſo fond to run,"

who can withhold the tribute of regret and admiration, when they

> —— " Conjecture what he might have proved,
> " And think life only wanting to his fame."

to be ſubjected to ſtrong friction. It is not owing to the ſpecific caloric of the rubbed bodies decreaſing; for Count Rumford found that there was no ſenſible decreaſe *, nor, if there were a decreaſe, would it be ſufficient to account for the vaſt quantity of heat which is ſometimes produced by friction.

309 Nor to decreaſe of ſpecific caloric,

Count Rumford took a cannon caſt ſolid and rough as it came from the foundery; he cauſed its extremity to be cut off, and formed, in that part, a ſolid cylinder attached to the cannon $7\frac{3}{4}$ inches in diameter and $9\frac{8}{10}$ inches long. It remained joined to the reſt of the metal by a ſmall cylindrical neck. In this cylinder a hole was bored 3,7 inches in diameter and 7,2 inches in length. Into this hole was put a blunt ſteel borer, which by means of horſes was made to rub againſt its bottom; at the ſame time a ſmall hole was made in the cylinder perpendicular to the bore, and ending in the ſolid part a little beyond the end of the bore. This was for introducing a thermometer to meaſure the heat of the cylinder. The cylinder was wrapt round with flannel to keep in the heat. The borer preſſed againſt the bottom of the hole with a force equal to about 10,000 lb. avoirdupois, and the cylinder was turned round at the rate of 32 times in a minute. At the beginning of the experiment the temperature of the cylinder was 60°; at the end of 30 minutes, when it had made 960 revolutions, its temperature was 130°. The quantity of metallic duſt or ſcales produced by this friction amounted to 837 grains. Now, if we were to ſuppoſe that all the caloric was evolved from theſe ſcales, as they amounted to juſt $\frac{1}{948}$ part of the cylinder, they muſt have given out 948° to raiſe the cylinder 1°, and conſequently 66360° to raiſe it 70° or to 130°, which is certainly incredible †.

310 Nor to combuſtion;

Neither is the caloric evolved during friction owing to the combination of oxygen with the bodies themſelves or any part of them. By means of a piece of clock-work, Mr Pictet made ſmall cups (fixed on the axis of one of the wheels) to move round with conſiderable rapidity, and he made various ſubſtances rub againſt the outſides of theſe cups, while the bulb of a very delicate thermometer placed within them marked the heat produced. The whole machine was of a ſize ſufficiently ſmall to be introduced into the receiver of an air-pump. By means of this machine a piece of adamantine ſpar was made to rub againſt a ſteel cup in air: ſparks were produced in great abundance during the whole time, but the thermometer did not riſe. The ſame experiment was repeated in the exhauſted receiver of an air-pump (the manometer ſtanding at four lines); no ſparks were produced, but a kind of phoſphoric light was viſible in the dark. The thermometer did not riſe. A piece of braſs being made to rub in the ſame manner againſt a much ſmaller braſs cup in air, the thermometer (which almoſt filled the cup) roſe 0,3°, but did not begin to riſe till the friction was over. This ſhews us that the motion produced in the air carried off the caloric as it was evolved. In the exhauſted receiver it began to riſe the moment the friction began, and roſe in all 1,2°. When a bit of wood was made to rub againſt the braſs cup in the air, the thermometer roſe 0,7°, and on ſubſtituting alſo a wooden cup it roſe 2,1°, and in the exhauſted receiver 2,4°, and in air condenſed to $1\frac{1}{2}$ atmoſpheres it roſe 0,5° *. If theſe experiments be not thought concluſive, we have others to relate, which will not leave a doubt that the heat produced by friction is not connected with the decompoſition of oxygen gas. Count Rumford contrived, with his uſual ingenuity, to encloſe the cylinder above deſcribed in a wooden box filled with water, which effectually excluded all air, as the cylinder itſelf and the borer were ſurrounded with water, and at the ſame time did not impede the motion of the inſtrument. The quantity of water amounted to 18,77 lbs. avoirdupois, and at the beginning of the experiment was at the temperature of 60°. After the cylinder had revolved for an hour at the rate of 32 times in a minute, the temperature of the water was 107°; in 30 minutes more it was 178°; and in 2 hours and 30 minutes after the experiment began, the water *actually boiled*. According to the computation of Count Rumford, the caloric produced would have been ſufficient to heat 26,58 lbs. avoirdupois of ice-cold water boiling hot; and it would have required 9 wax candles of a moderate ſize, burning with a clear flame all the time the experiment laſted, to have produced as much heat. In this experiment all acceſs of water into the hole in the cylinder where the friction took place was prevented. But in another experiment, the reſult of which was preciſely the ſame, the water was allowed free acceſs *.

311 And conſequently at preſent inexplicable.

The caloric, then, which appears in conſequence of friction, is neither produced by an increaſe of the denſity, nor by an alteration in the ſpecific caloric of the ſubſtances expoſed to friction, nor is it owing to the decompoſition of the oxygen of the atmoſphere.—Whence then is it derived? This queſtion we are altogether unable to anſwer. We cannot, however, think that the concluſion which Count Rumford is diſpoſed to draw from his experiments is warranted by the premiſes. He ſuppoſes, that becauſe we cannot explain the manner that caloric is accumulated by friction, there is no ſuch ſubſtance as caloric at all, but that it is merely a *peculiar kind of motion*. We would beg leave to aſk, how the facts mentioned in the former part of this chapter, many of which were furniſhed by this ingenious philoſopher himſelf, and all of which combine to render the exiſtence of caloric as a ſubſtance probable, can be deſtroyed and ſet aſide, merely becauſe there are other phenomena in nature connected with caloric which cannot be accounted for? Were it poſſible to prove that the accumulation of caloric by friction is *incompatible* with its being a ſubſtance, in that caſe Count Rumford's concluſion would be a fair one; but this ſurely has not been done. We are certainly not yet ſufficiently acquainted with the laws of the motion of caloric (allowing it to be a ſubſtance) to be able to affirm with certainty that friction could not cauſe it to accumulate in the bodies rubbed. This we know at leaſt to be the caſe with electricity. Nobody has been hitherto able to demonſtrate, in what manner it is accumulated by friction; and yet this has not been thought a ſufficient reaſon to deny its exiſtence.

312 This no proof that caloric is not a body.

313 Analogy between caloric and electricity.

Indeed there ſeems to be a very cloſe analogy between caloric and electric matter. Both of them tend to diffuſe themſelves equally, both of them dilate bodies, both of them fuſe metals, and both of them kindle combuſtible ſubſtances. Mr Achard has proved, that electricity can be ſubſtituted for caloric even in thoſe caſes where its agency ſeems peculiarly neceſſary; for he found that, by conſtantly ſupplying a certain quantity of the electric fluid, eggs could be hatched juſt as when they are kept

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* Nicholſon's Journ. ii. 106.

† Ibid.

* Pictet ſur le Feu, ch. 9.

* Nicholſon, ibid.

kept at the temperature of 103°. An accident indeed prevented the chickens from actually coming out; but they were formed and living, and within two days of burſting their ſhell. Electricity has alſo a great deal of influence on the heating and cooling of bodies. Mr Pictet exhauſted a glaſs globe, the capacity of which was 1200,199 cubic inches, till the manometer within it ſtood at 1,75 lines. In the middle of this globe was ſuſpended a thermometer which hung from the top of a glaſs rod fixed at the bottom of the globe, and going almoſt to its top. Oppoſite to the bulb of this thermometer two lighted candles were placed, the rays of which, by means of two concave mirrors, were concentrated on the bulb. The candles and the globe were placed on the ſame board, which was ſupported by a non-conductor of electricity. Two feet and a half from the globe there was an electrifying machine, which communicated with a braſs ring at the mouth of the globe by means of a metallic conductor. This machine was kept working during the whole time of the experiment; and conſequently a quantity of electric matter was conſtantly paſſing into the globe, which formed an atmoſphere not only within it, but at ſome diſtance round, as was evident from the imperfect manner in which the candles burned. When the experiment began the thermometer ſtood at 49,8°. It roſe to 70,2° in 732″. The ſame experiment was repeated, but no electric matter thrown in; the thermometer roſe from 49,8° to 70,2° in 1050″; ſo that the electricity haſtened the heating almoſt a third. In the firſt experiment the thermometer roſe only to 71,3°. but in the ſecond it roſe to 77°. This difference was doubtleſs owing to the candles burning better in the ſecond than the firſt experiment; for in other two experiments made exactly in the ſame manner, the maximum was equal both when there was and was not electric matter preſent. Theſe experiments were repeated with this difference, that the candles were now inſulated, by placing their candleſticks in diſhes of varniſhed glaſs. The thermometer roſe in the electrical vacuum from 52,2° to 74,7° in 1050″; in the ſimple vacuum in 965″. In the electrical vacuum the thermometer roſe to 77°; in the ſimple vacuum to 86°. It follows from theſe experiments, that when the globe and the candles communicated with each other, electricity haſtened the heating of the thermometer; but that when they were inſulated ſeparately, it retarded it *. One would be apt to ſuſpect the agency of electricity in the following experiment of Mr Pictet: Into one of the braſs cups formerly deſcribed, a ſmall quantity of cotton was put to prevent the bulb of the thermometer from being broken. As the cup turned round, two or three fibres of the cotton rubbed againſt the bulb, and without any other friction the thermometer roſe five or ſix degrees. A greater quantity of cotton being made to rub againſt the bulb, the thermometer roſe 15 degrees †.

314 lectricity nay be an gent in the eating of odies by iction.

We do not mean to draw any other concluſion from theſe facts, than that electricity is very often concerned in the heating of bodies, and that probably ſome ſuch agent is employed in accumulating the heat produced by friction. Suppoſing that electricity is actually a ſubſtance, and taking it for granted that it is different from caloric, does it not in all probability contain caloric as well as all other bodies? Has it not a tendency to accumulate in all bodies on friction, whether conductors or non-conductors? May it not then be accumulated in theſe bodies which are rubbed againſt one another? or, if they are good conductors, may it not paſs through them during the friction in great quantities? May it not part with ſome of its caloric to theſe bodies, either on account of their greater affinity or ſome other cauſe? and may not this be the ſource of the caloric which appears during friction?

Chap. VI. *Of* Light.

315 Newtonian theory of light.

By means of *light* bodies are rendered viſible. Light has been conſidered as a ſubſtance compoſed of ſmall particles moving in ſtraight lines from luminous bodies with inconceivable rapidity. The diſcoveries of Newton eſtabliſhed this opinion on the firm baſis of mathematical demonſtration; and ſince his time it has been generally embraced. Huyghens, indeed, and Euler, advanced another (o). They conſidered light as a ſubtile fluid, filling all ſpace, which rendered bodies viſible by its undulations. But they ſupported their hypotheſis rather by ſtarting objections to the theory of Newton, than by bringing forward direct proofs. Their objections, even if valid, inſtead of eſtabliſhing their own opinions, would prove only that the phenomena of light are not completely underſtood; a truth which no man will refuſe to acknowledge, whatever ſide of the queſtion he adopts. Newton and his diſciples, on the contrary, have ſhewn that the known phenomena of light are *inconſiſtent* with the undulations of a fluid, and have brought forward a great number of direct arguments, which it has been impoſſible to anſwer, in ſupport of their theory. It can hardly be doubted, therefore, that the Newtonian theory of light is the true one.

316 Velocity of light.

Dr Bradley, who, by a number of very accurate experiments, and a proceſs of reaſoning peculiarly ingenious, diſcovered the aberration of light of the fixed ſtars, has ſhewn from it that the velocity of light is to that of the earth in its orbit as 10313 to 1. Light therefore moves at the rate of 195218 miles in a ſecond.

317 Diviſible into ſeven rays.

Light, by means of a priſm, may be ſeparated into ſeven rays, differing from each other in colour; red, orange, yellow, green, blue, indigo, violet. None of theſe are capable of farther decompoſition. Marat, indeed, pretended that he had reduced them to three; but his experiments are now known to have been merely philoſophical frauds.

318 Differing in refrangibility.

When light paſſes obliquely into a denſer medium, it is *refracted towards* the perpendicular; when into a rarer, *from* the perpendicular. Sir Iſaac Newton diſcovered that the rays differed in their refrangibility in the order in which they have been named, the red being the leaſt, the violet the moſt refrangible. Mr Blair has obſerved, that the ratios of the refrangibility of the different rays, though not their order, vary ſomewhat in different mediums *.

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

* *Pictet ſur* e *Feu*. ch. 6.

† *Ibid.* ch. 9.

* *Edinburgh Phil. Tranſ.* iii.

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

parallel to which it is moving, it is bent *towards* it; when it paſſes at a greater diſtance, it is bent *from* it. The firſt of theſe properties is called *inflection*, the ſecond *deflection*. Now the rays differ in theſe properties in the order in which they were named; the red being *moſt*, the violet *leaſt*, inflexible and deflexible. This was ſuſpected by David Rittenhouſe *, but was firſt demonſtrated by the ingenious experiments of Mr Brougham †.

319 Inflection, deflection,

When light falls upon a viſible body, ſome of it is reflected back; and the more poliſhed or the whiter any ſurface is, the more light it reflects. The rays of light differ alſo in reflexity, the red being the moſt, the violet the leaſt reflexible. This diſcovery we owe to the ſame ingenious gentleman ‡.

320 And reflexity.

Theſe properties of light conſtitute the ſubject of Optics; to which we refer thoſe who wiſh to ſee them inveſtigated. We mention them here becauſe they prove that light is acted on by other bodies, that it is ſubjected to the laws of attraction, and conſequently that it poſſeſſes *gravity*.

2. The particles of light ſeem alſo, like thoſe of caloric, to poſſeſs the property of repelling one another; at leaſt their rapid motion, in all directions, from luminous bodies, ſeems to be owing to ſome ſuch property.

321 Light capable of entering bodies,

3. Light is capable of entering into bodies, and remaining in them, and of being afterwards extricated without any alteration. Father Beccaria, and ſeveral other philoſophers, have ſhewn us by their experiments, that there are a great many ſubſtances which become luminous after being expoſed to the light. This property was diſcovered by carrying them inſtantly from the light into a dark place, or by darkening the chamber in which they were expoſed. Moſt of theſe ſubſtances, indeed, loſe this property in a very ſhort time, but they recover it again on being expoſed to the light; and this may be repeated as often as we pleaſe. We are indebted to Mr Canton for ſome very intereſting experiments on this ſubject, and for diſcovering a compoſition which poſſeſſes this property in a remarkable degree. He calcined ſome common oyſter ſhells in a good coal fire for half an hour, and then pounded and ſifted the pureſt part of them. Three parts of this powder were mixed with one part of the flowers of ſulphur, and rammed into a crucible which was kept red hot for an hour. The brighteſt parts of the mixture were then ſcraped off, and kept for uſe in a dry phial well ſtopped. When this compoſition is expoſed for a few ſeconds to the light, it becomes ſufficiently luminous to enable a perſon to diſtinguiſh the hour on a watch by it. After ſome time it ceaſes to ſhine, but recovers this property on being again expoſed to the light. Light then is not only acted upon by other bodies, but it is capable of uniting with them, and afterwards leaving them without any change.

It is well known that light is emitted during combuſtion; and it has been objected to this concluſion, that theſe bodies are luminous only from a ſlow and imperceptible combuſtion. But ſurely combuſtion cannot be ſuſpected in many of Father Beccaria's experiments, when we reflect that one of the bodies on which they were made was his own hand, and that many of the others were altogether incombuſtible; and the phenomena obſerved by Mr Canton are alſo incompatible with the notion of combuſtion. His pyrophorus ſhone only in conſequence of being expoſed to light, and loſt that property by being kept in the dark. It is not expoſure to light which cauſes ſubſtances capable of combuſtion at the temperature of the atmoſphere to become luminous, but expoſure to air. If the ſame temperature continues, they do not ceaſe to ſhine till they are conſumed; and if they ceaſe, it is not the application of light, but of caloric, which renders them again luminous: but Canton's pyrophorus, on the contrary, when it had loſt its property of ſhining, did not recover it by the application of heat, except it was accompanied by light. The only effect which heat had was to increaſe the ſeparation of light from the pyrophorus, and of courſe to ſhorten the duration of its luminouſneſs. Two glaſs globes, hermetically ſealed, containing each ſome of this pyrophorus, were expoſed to the light and carried into a dark room. One of them, on being immerſed in a baſon of boiling water, became much brighter than the other, but in ten minutes it ceaſed to give out light; the other remained viſible for more than two hours. After having been kept in the dark for two days, they were both plunged into a baſon of hot water; the pyrophorus which had been in the water formerly did not ſhine, but the other became luminous, and continued to give out light for a conſiderable time. Neither of them afterwards ſhone by the application of hot water; but when brought near to an iron heated ſo as ſcarcely to be viſible in the dark, they ſuddenly gave out their remaining light, and never ſhone more by the ſame treatment: but when expoſed a ſecond time to the light, they exhibited over again preciſely the ſame phenomena; even a lighted candle and electricity communicated ſome light to them. Surely theſe facts are altogether incompatible with combuſtion, and fully ſufficient to convince us that light alone was the agent, and that it had actually entered into the luminous bodies.

It has been queſtioned, indeed, whether the light emitted by pyrophori be the ſame with that to which they are expoſed. Mr Wilſon has proved, that in many caſes at leaſt it is different, and in particular that on many pyrophori the blue rays have a greater effect than any other, and that they cauſe an extrication of red light. Mr de Groſſer has ſhewn the ſame thing with regard to the diamond, which is a natural pyrophorus *. Still, however, it cannot be queſtioned that the luminouſneſs of theſe bodies is owing to expoſure to light, and that the phenomenon is not connected with combuſtion.

322 And of being combined with them.

But light appears capable, not only of entering into bodies, but of combining with them chemically. The phenomena of the phoſphori ſeem to be inſtances of this, and a great many facts concur to prove that light enters into the compoſition of oxygen gas. When vegetables grow in the light, they give out oxygen gas; but no oxygen is extricated in the dark, even though heat be applied †. From this it is evident, that the ſeparation of this gas from plants, or perhaps the decompoſition of the water which they contain, depends upon the action of light; and that as this decompoſition is chemical, the light to produce it muſt either combine with the oxygen or the hydrogen, or at leaſt contribute to the combination of ſome other ſubſtance with one or other of them. When the oxides of gold or ſilver are expoſed to light, they are reduced to the metallic ſtate ‡, and at the ſame time a quantity of oxygen gas is extricated.

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* *Tranſ. Philad.* ii.

† *Phil. Tranſ.* 1796.

‡ *Phil. Tranſ.* 1796.

* *Jour. de Phyſ.* xx. 270.

† *Prieſtley and Ingenhouſz.*

‡ *Scheele.*

cated[*]. In this caſe, it is evident that the light muſt either combine with the oxygen or the metals. If a quantity of nitric acid be expoſed for ſome time to the light, it becomes yellow, as is well known, and a quantity of oxygen gas is found floating on its top. If it be now carried to a dark place, the oxygen is gradually abſorbed, and the acid becomes colourleſs. In this caſe, nitric acid is decompoſed by means of light, and reſolved into *nitrous acid* and oxygen gas. The light muſt therefore have combined either with the nitrous acid or the oxygen. But no change whatever appears to have been produced in the nitrous acid; for if it be obtained in the dark by any other proceſs, it has preciſely the ſame properties. The oxygen, on the contrary, is converted into a *gas*. It is more probable, then, that the light has combined with the oxygen than with the acid. Hence there is reaſon to ſuſpect that light makes one of the ingredients of oxygen gas. Caloric has already been ſhewn to make another ingredient.

323
Light which appears during combuſtion ſuppoſed combined with oxygen gas.

During combuſtion, a quantity of light as well as caloric is almoſt always evolved. We muſt conclude, therefore, that light makes a part of the compoſition either of the combuſtibles themſelves, or of the oxygen gas with which they unite. We have already ſhewn that oxygen gas probably contains light; and this probability is confirmed by another fact. Subſtances may be combined with oxygen without the emiſſion of any light, provided the oxygen be not in the ſtate of a gas. If phoſphorus, for inſtance, be put into nitric acid, it attracts oxygen, and is converted into phoſphoric acid without the emiſſion of any light. Now if the light which appears during combuſtion had been combined with the combuſtible, it ought to appear in all caſes when that combuſtible is united with oxygen, whether the oxygen has previouſly been in the ſtate of a gas or not. But as this is not the caſe, we may certainly infer, that the light which appears during combuſtion is extricated, not from the combuſtible, but from the oxygen gas. And this ſeems at preſent to be the opinion of the greater number of philoſophers.

But we muſt acknowledge, that this concluſion is not without its difficulties, and difficulties, too, which, in the preſent ſtate of chemiſtry, it does not ſeem poſſible to ſurmount.

324
Difficulties attending this opinion.

In the firſt place, it is evident, that light *may* be produced during combuſtion, though the oxygen be not in the ſtate of a gas: For if nitric acid be poured upon oil of turpentine, the oil takes fire, and burns with the greateſt rapidity, and a great deal of light is emitted. This combuſtion is occaſioned by the oxygen of the acid combining with the ingredients of the oil. It follows, therefore, if the light emitted was previouſly combined with the oxygen, that oxygen muſt contain light when not in the ſtate of a gas. Mr Prouſt has ſhewn that a great variety of ſimilar combuſtions may be produced. But what is very remarkable, by proper caution the very ſame combinations may be made to take place without the viſible emiſſion of any light. In that caſe they take place very ſlowly, as happens alſo when phoſphorus decompoſes nitric acid; ſo that the emiſſion or non-emiſſion of light ſeems to depend not upon the ſtate of the oxygen, ſo much as upon the rapidity or ſlowneſs of the combination. It is true, indeed, as the late Dr Hutton of Edinburgh obſerved, that light may be emitted in theſe ſlow combinations though it be not viſible; and this is very probably the caſe: but then the proof is deſtroyed that light exiſts in oxygen gas, from its not appearing during combinations in which the oxygen did not exiſt previouſly in a gaſeous ſtate.

In the ſecond place, the colour of the light emitted during combuſtion differs almoſt always according to the combuſtible. During the combuſtion of phoſphorus, tin, and zinc, the light emitted is white; during that of ſulphur and biſmuth, blue. Now if this light were united with the oxygen, why does it not appear always of the ſame colour, whatever be the combuſtible?

In the laſt place, the phenomena of phoſphori ſhew that light is capable of entering into other bodies as well as oxygen gas; and the emiſſion of light on the colliſion of two flint ſtones, when no oxygen gas can be decompoſed, is a proof of the ſame kind, which cannot be got over.

In the preſent ſtate of chemiſtry, therefore, it cannot be concluded, that the light emitted during combuſtion does not exiſt in the combuſtibles as well as in the oxygen.

325
Light heats bodies.

4. Light has the property of heating bodies. All bodies, however, are not heated by it. Thoſe which are perfectly tranſparent, or which allow all the light to paſs throw them, ſuffer no alteration in their temperature. Thus light may be concentrated upon water or glaſs without producing any effect. Neither does it produce much change upon thoſe bodies (mirrors for inſtance) that reflect all or nearly all the light which falls upon them. And the ſmallneſs of the alteration of temperature is always proportional to the fineneſs of the poliſh, or, which is the ſame thing, to the quantity of light which is reflected. So that we have reaſon to conclude, that if a ſubſtance could be procured which reflected all the light that fell upon it, the temperature of ſuch a ſubſtance would not be at all affected by light falling upon it. Dr Franklin expoſed upon ſnow pieces of cloth of different colours (white, red, blue, black) to the light of the ſun, and found that they ſunk deeper, and conſequently acquired heat, in proportion to the darkneſs of their colour. Now it is well known that dark-coloured bodies, even when equally expoſed to the light, reflect leſs of it than thoſe which are light-coloured. But ſince the ſame quantity falls upon each, it is evident that dark-coloured bodies muſt abſorb and retain more of it than thoſe which are light-coloured. That ſuch an abſorption actually takes place is evident from the following experiment. Mr Thomas Wedgewood placed two lumps of luminous or phoſphoreſcent marble on a piece of iron heated juſt under redneſs. One of the lumps of marble which was blackened over gave out no light; the other gave out a great deal. On being expoſed a ſecond time in the ſame manner, a faint light was ſeen to proceed from the clean marble, but none at all could be perceived to come from the other. The black was now wiped off, and both the lumps of marble were again placed on the hot iron: The one that had been blackened gave out juſt as little light as the other[*]. In this caſe, the light which ought to have proceeded from the luminous marble diſappeared: it muſt therefore have been ſtopped in its paſſage out, and retained by the black paint. Now black ſubſtances are thoſe which abſorb the moſt light, and they are the bodies which are moſt heated by expoſure to light. Cavallo obſerved, that a

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[*] Berthollet.

[*] Phil. Tranſ. 1792.

thermometer with its bulb blackened ſtands higher than one which has its bulb clean, when expoſed to the light of the ſun, the light of day, or the light of a lamp *. Mr Pictet made the ſame obſervation; and took care to aſcertain, that when the two thermometers were allowed to remain for ſome time in a dark place, they acquired preciſely the ſame height. He obſerved, too, that when both thermometers had been raiſed a certain number of degrees, the clean one fell a good deal faſter than the other †. But it is not a ſmall degree of heat alone which can be produced by means of light. When its rays are concentrated by a burning-glaſs, they are capable of ſetting fire to combuſtibles with eaſe, and even of producing a temperature at leaſt as great, if not greater, than what can be procured by the moſt violent and beſt conducted fires. In order to produce this effect, however, they muſt be directed upon ſome body capable of abſorbing and retaining them; for when they are concentrated upon tranſparent bodies, or upon fluids, mere air for inſtance, they produce little or no effect whatever. We may conclude, therefore, in general, that in all caſes when light produces heat it is abſorbed.

326
Heat renders bodies luminous,

5. All bodies become luminous when their temperature is raiſed a certain number of degrees. No fact is more familiar than this; ſo well known indeed is it, that little attention has been paid to it. When a body becomes luminous by being heated in a fire, it is ſaid in common language to be *red hot*. It follows from all the experiments hitherto made, that the temperature at which they become red hed hot is nearly the ſame in all bodies.—It ſeems to be pretty near 800°. A red hot body continues to ſhine for ſome time after it has been taken from the fire and put into a dark place. The conſtant acceſſion, then, either of light or heat is not neceſſary for the ſhining of bodies: but if a red hot body be blown upon by a ſtrong current of air, it ceaſes to ſhine immediately ‡. Conſequently the moment the temperature of a body is diminiſhed by a certain number of degrees, it ceaſes to be luminous.

Whenever a body reaches the proper temperature, it becomes luminous, independent of any contact of air; for a piece of iron wire becomes red hot while immerſed in melted lead §.

327
Except the gaſes.

To this general law there is one remarkable exception. It does not appear that the gaſes become luminous even at a much higher temperature. The following ingenious experiment of Mr T. Wedgewood ſeems to ſet the truth of this exception in a very clear point of view. He took an earthen ware tube B (fig. 5.), bent ſo in the middle that it could be ſunk, and make ſeveral turns in the large crucible C, which was filled with ſand. To one end of this tube was fixed the pair of bellows A; at the other end was the globular veſſel D, in which was the paſſage F, furniſhed with a valve to allow air to paſs out, but none to enter. There was another opening in this globular veſſel filled with glaſs, that one might ſee what was going on within. The crucible was put into a fire; and after the ſand had become red hot, the air was blown through the earthen tube by means of the bellows. This air, after paſſing through the red hot ſand, came into the globular veſſel. It did not ſhine; but when a piece of gold wire E was hung at that part of the veſſel where the earthen ware tube entered, it became faintly luminous. A proof, that though the air was not luminous, it had been hot enough to raiſe other bodies to the ſhining temperature.

328
Inquiry into the cauſe of theſe phenomena.

6. Thus it appears that light and heat reciprocally produce each other; that the fixation of light in bodies always produces heat, and that the application of a ſufficiently ſtrong heat always occaſions the extrication of light. Are heat and light, then, owing to the ſame cauſe? Does light become caloric merely by being fixed in bodies? and does caloric aſſume the appearance of light whenever it is extricated from them? In ſhort, are caloric and light merely names for the ſame ſubſtance, called *caloric* when it is fixed in bodies, and *light* when in a ſtate of liberty?

To theſe queſtions it may be anſwered, That if caloric and light were one and the ſame ſubſtance, they ought to produce preciſely the ſame effects. Now this is not the caſe: a black body is not heated ſooner by mere caloric than any other, though the contrary takes place when both are expoſed to the light *. Heat cannot make growing vegetables exhale oxygen gas, though light does it almoſt inſtantaneouſly. When oxy-muriatic acid (a compound of oxygen and muriatic acid) is expoſed to the light, a quantity of oxygen gas flies off, and nothing remains but common muriatic acid. Light then decompoſes this acid; for if you wrap up a bottle in black cloth, ſo as to exclude light, and then expoſe it equally to the ſun, no ſuch decompoſition takes place. Now this decompoſition cannot be produced by mere caloric. If the acid be heated, it ſimply evaporates without being altered. Chaptal has proved (P), that the rays of light directed on certain parts of glaſſes, containing ſolutions of ſalts, cauſe them to cryſtallize in that part in preference to any other †. Theſe obſervations have been confirmed and extended by Mr Dorthes ‡. Now caloric produces no ſuch effects, nor has the temperature any influence on the phenomenon.

Theſe facts are ſufficient to ſhew that light and caloric, even when they have entered into bodies, produce different effects, and that therefore they have different properties (Q). But if the only difference between them were, that the one is in a ſtate of liberty, the other in that of combination, the moment light entered a body it ought to be no longer light but caloric, and conſequently ought to produce preciſely the ſame effects with caloric: And ſince this is not the caſe, we are warranted ſurely to conclude that light and caloric are not the ſame, but

* Phil. Tranſ. 1780.

† Sur le Feu, ch. 4.

‡ T. Wedgewood, Phil. Tranſ. 1792.

§ Id. ibid.

* T. Wedgewood. Phil. Tranſ. 1792.

† Mem. Toulouſe, iii.

‡ Ann. de Chim. ii. 32.

(P) Petit made the ſame obſervations in 1722. See *Memoirs of the Academy of Sciences* for that year, p. 95. and 331.

(Q) We muſt acknowledge, however, that the following ingenious experiments of Profeſſor Pictet might be adduced, to prove that light and caloric poſſeſs at leaſt *one* property in common, that of moving in ſtraight lines.

He placed two concave mirrors of tin, of nine inches focus, at the diſtance of twelve feet two inches from one another. In the focus of one of them he placed a ball of iron two inches in diameter, heated ſo as not to be viſible but different ſubſtances (R). How then does caloric occaſion the appearance of light, and light that of caloric?

349
Suppoſed owing to the mutual repulſion of light and caloric.

We have ſeen already, that there is no body in nature which does not contain caloric; and light has ſuch an influence upon every thing, it produces ſuch important changes upon the animal and vegetable kingdoms, it can be extricated from ſuch a vaſt number of bodies, that in all probability we may conclude with regard to it alſo, that it exiſts in all, or in almoſt all, the bodies in nature. We have no means of aſcertaining either the quantity of light or of caloric that exiſts in bodies; but if we were to judge from the quantity which appears during combuſtion, we muſt reckon it very conſiderable. Now, may there not exiſt a repulſion between the particles of caloric and light? It is not eaſy, at leaſt, to ſee why light flies off during combuſtion with ſuch rapidity, if this be not the caſe. If ſuch a repulſion actually exiſts, it will follow that caloric and light cannot be accumulated in the ſame body beyond a certain proportion. If the caloric exceed, it will tend to drive off the light; if the light, on the contrary, happens to prevail, it will diſplace the caloric.

If caloric and light actually exiſt in all bodies, there muſt be an affinity between them and all other bodies; and this affinity muſt be ſo great, as to render ineffectual the repulſion which exiſts between light and caloric. Let us ſuppoſe now, that theſe two ſubſtances exiſt in all bodies in certain proportions, it will follow, that the more either of caloric or light is added to any body, the ſtronger muſt the repulſion between their particles become; and if the accumulation be ſtill going on, this repulſion will ſoon become great enough to balance their affinity for the body in which they exiſt, and conſequently will diſpoſe them to fly off. If caloric, for inſtance, be added to a body, whenever the body arrives at a certain temperature it becomes luminous, becauſe part of the light which was formerly combined with it is driven off. This temperature muſt depend partly upon the affinity between the body and caloric, and partly upon its affinity for light. Pyrophori, for inſtance, the affinity between which and light does not ſeem to be very great, become luminous at a very moderate temperature. This is the caſe with the pyrophorus of Canton. A great many hard bodies become luminous when they are expoſed to a moderate heat; fluor, for inſtance, carbonat of barytes, ſpar, ſea-ſhells, and a great many others, which are enumerated by Mr Thomas Wedgwood *.

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

Iron,
Copper,
Silver,
Gold.

They

* *Phil. Tranſ.* 1792, p. i.

† *Ibid.*

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viſible in the dark; in the other was placed the bulb of a thermometer. In ſix minutes the thermometer roſe from 4° to 14° (*Reaumur*). A lighted candle, which was ſubſtituted for the ball of iron, made the thermometer riſe in one experiment from 4,6° to 14°; in another, from 4,2° to 14,3°. In this caſe both light and heat appeared to act. In order to ſeparate them, he interpoſed between the two mirrors a plate of clear glaſs. Before the interpoſition of the glaſs, the thermometer had riſen from 2° to 12°, where it was ſtationary. After the interpoſition of the glaſs it ſunk in nine minutes to 5,7°; and when the glaſs was again removed it roſe in ſeven minutes to 11,1°; yet the light which fell on the thermometer did not ſeem at all diminiſhed by the glaſs. Mr Pictet therefore concluded, that the caloric had been *reflected* by the mirror, and that it had been the cauſe of the riſe of the thermometer. In another experiment, a glaſs matraſs was ſubſtituted for the iron ball, nearly of the ſame diameter with it, and containing 2044 grains of boiling water. Two minutes after a thick ſcreen of ſilk, which had been interpoſed between the two mirrors, was removed, a Fahrenheit's thermometer, which was in the other focus, roſe from 47° to $50\frac{1}{8}$; and the moment the matraſs was removed from the focus the thermometer again deſcended. On repeating the experiment, with this variation, that the bulb of the thermometer was blackened, it roſe from $51\frac{1}{8}$ to $55\frac{1}{3}$.

The mirrors of tin were now placed at the diſtance of 90 inches from each other; the matraſs with the boiling water in one of the foci, and a very ſenſible air thermometer in the other, every degree of which was equal to $\frac{1}{20}$th of a degree of Reaumur. Exactly in the middle ſpace between the two mirrors, there was placed a very thin common glaſs mirror, ſuſpended in ſuch a manner that either ſide could be turned towards the matraſs. When the poliſhed ſide of this mirror was turned to the matraſs, the thermometer roſe only 0,5°; but when the ſide covered with tinfoil, and which had been blackened with ink and ſmoke, was turned toward the matraſs, the thermometer roſe 3,5°. In another experiment, when the poliſhed ſide of the mirror was turned to the matraſs the thermometer roſe 3°, when the other ſide 9,2°. On rubbing off the tinfoil, and repeating the experiment, the thermometer roſe 18°. On ſubſtituting for the glaſs mirror a piece of thin white paſteboard of the ſame dimenſions with it, the thermometer roſe 10°. On putting a matraſs full of ſnow into one of the foci (the mirrors in this experiment were $10\frac{1}{2}$ feet diſtant from each other), the air thermometer *ſunk* ſeveral degrees, and roſe again when the matraſs was removed. When nitric acid was poured on the ſnow, the thermometer ſunk 5° or 6° lower.

Taking it for granted that theſe experiments proved the motion of caloric in ſtraight lines like light, Mr Pictet endeavoured to diſcover the velocity of its motion. For this purpoſe he placed two concave mirrors at the diſtance of 69 feet from each other; the one of tin as before, the other of plaſter gilt, and 18 inches in diameter. Into the focus of this laſt mirror he put the air thermometer, and the bullet of iron heated as before into that of the other. A few inches from the face of the tin mirror there was placed a thick ſcreen, which was removed as ſoon as the bullet reached the focus. The thermometer roſe the inſtant the ſcreen was removed, without any perceptible interval: hence he concluded, that the time caloric takes in moving 69 feet is too ſhort to be meaſured. See *Pictet ſur le Feu*, chap. iii.

(R) See more on this ſubject under *Thermometric Spectrum* in this *Supplement*.

They become luminous, therefore, when expoſed to the ſame degree of heat, in the following order:

Gold,
Silver,
Copper,
Iron.

Now the ſmaller the ſpecific caloric of any body is, the leſs muſt be the quantity of caloric neceſſary to raiſe it a given number of degrees; the ſooner therefore muſt it arrive at the temperature at which it gives out light. It was natural to expect, then, if the emiſſion of light from a body by the application of heat be owing to the repulſion between caloric and light, that thoſe bodies ſhould become luminous ſooneſt in which that repulſion increaſes with the greateſt rapidity; and this we ſee is preciſely the caſe. The only queſtion to be determined before drawing this concluſion is, Whether the ſame quantity of caloric entered all of them? That depends upon their conducting power, which, according to Ingenhouſz, is in the following order:

Silver,
Gold,
Copper,
Iron.

We ſee, then, that this conducting power is nearly in the order in which theſe metals become luminous; ſo that the greateſt quantity of caloric would enter thoſe which become ſooneſt luminous. Now this is juſt what ought to happen, provided the expulſion of light from a luminous body, by the application of heat, be owing to the repulſion between the particles of caloric and light.

The repulſion between the different rays of light and caloric does not ſeem to be equal; the repulſion between the blue rays and caloric ſeems to be greater than that between the red rays and caloric; and the repulſion between all the rays and caloric ſeems to be directly as their refrangibility: accordingly, when heat is applied to a body, the blue rays eſcape ſooner, and at a lower temperature, than the red rays and others which are moſt refrangible. When ſulphur, for inſtance, is burnt at a low temperature, the colour of the flame is blue; and when examined by the priſm, it is found to conſiſt of the violet, indigo, blue, and ſometimes of a ſmall quantity of the green rays*; but when this ſubſtance is burnt at a high temperature, the colour of the flame is white, all the rays ſeparating together. When bodies have continued to burn for ſome time, they may be ſuppoſed to have loſt the greater part of the moſt refrangible rays; hence the red appearance of bodies, charcoal for inſtance, that have burnt for ſome time, the only rays which remain to ſeparate being the orange, yellow, and red†.

The blue rays ſeem not only to repel caloric with greater force, but likewiſe to have a greater affinity for other bodies than the red rays have; for they decompoſe the oxide of ſilver (or rather the muriat of ſilver) much ſooner, and to a greater extent, than the red rays‡: hence we ſee the reaſon why the application of the blue rays to Mr Wilſon's pyrophori and to the diamond cauſes an extrication of red rays.

We have ſeen already, that the gaſes are not heated red hot by the application of heat. It would follow from this, that the gaſes do not contain light: but the contrary is certain; for light is actually extricated during the combuſtion of hydrogen, and muſt therefore have exiſted either in the oxygen or hydrogen gas, or in both. Probably therefore the reaſon that heat does not extricate light from the gaſes is, that the affinity between their baſes and light is exceedingly ſtrong: it would therefore require a more than uſual temperature to produce its extrication; and on account of the great dilatability of theſe gaſes, which always tends to diminiſh the repulſion between the caloric and light, this temperature cannot be applied. It is eaſy to ſee, upon the ſuppoſition that there exiſts a repulſion between caloric and light, why the accumulation of light ſhould produce heat, and why light only occaſions heat in thoſe bodies that abſorb it.

Such is the theory of the cauſe of the reciprocal extrication of light and caloric by the application of theſe ſubſtances reſpectively to bodies, which has been propoſed by ſeveral ingenious chemiſts (s); and we acknowledge frankly, that it appears to us by far the moſt plauſible of all the explanations of this phenomenon with which we are acquainted.

330
Objections to which this theory is liable.

It is not, however, beyond the reach of objections, and objections too, we are afraid, altogether incompatible with its truth. Were the repulſion between caloric and light the only cauſe of the luminouſneſs of hot bodies, the continual application of heat would ſurely in time ſeparate the whole of the light which was combined with the body, and then it would ceaſe to be luminous altogether; but we have no reaſon to ſuppoſe that bodies ever ceaſe to become luminous by the continued application of heat. Claveus kept melted, and conſequently red hot, gold for months in a furnace; but he does not ſay that its luminouſneſs was diminiſhed, far leſs deſtroyed; and had ſuch a remarkable phenomenon taken place, certainly he would not have failed to inform us; but ſo far from that, he expreſsly ſays that it ſuffered no alteration (T) §.

Whether light would continue to extricate a great deal of caloric during ſo long a time, has never been tried: but we have no reaſon for ſuppoſing that its power to produce that effect is ever exhauſted; for bodies, after being expoſed to the ſun for years, and even for ages, are juſt as much heated by it as ever. But theſe effects, far from being inexhauſtible, ought, according to the theory, to come very ſpeedily to an end. It is certainly probable, then, as other philoſophers have ſuppoſed, that though light and caloric are not preciſely one and the ſame ſubſtance, they are ſome how or other intimately connected, and are either compoſed of different proportions of the ſame ingredients, or the one enters into the compoſition of the other.

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* *Morgan, Phil. Tranſ.* 1785.

† *Ibid.*

‡ *Sennebier.*

§ *Shaw's Boyle*, iii. 268.

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

(T) A gentleman, to whom we mentioned this objection, obſerved, that in the caſe of bodies long expoſed to heat, the light which appears to proceed from them, might, in fact, be extricated from the atmoſphere by the caloric communicated to it from the heated body. This thought is new and ingenious, and might eaſily be put to the teſt of experiment. Some of the facts mentioned in the text are rather hoſtile to it; but ſhould it prove well founded, it would go far to remove moſt of the difficulties in which the theory of light is at preſent involved.

331 Scheele's theory of light and caloric.

One of the firſt theories of this kind (for the opinion of Stahl has been already diſcuſſed) was formed by Mr Scheele*, one of the moſt extraordinary men and greateſt philoſophers that ever exiſted. Without the aſſiſtance of education or of wealth, his genius burſt forth with aſtoniſhing luſtre; and at an age when moſt philoſophers are only riſing into notice, he had finiſhed a career of diſcoveries which have no parallel in the annals of chemiſtry. Whoever wiſhes to behold ingenuity combined with ſimplicity, whoever wiſhes to ſee the inexhauſtible reſources of chemical analyſis, whoever wiſhes for a model in chemical reſearches—has only to peruſe and to ſtudy the works of Scheele (T). After a vaſt number of experiments, conducted with aſtoniſhing ingenuity, he concluded, that caloric was compoſed of a certain quantity of oxygen combined with phlogiſton; that radiant heat, a ſubſtance which he ſuppoſed capable of being propagated in ſtraight lines like light, and not capable of combining with air, was compoſed of oxygen united with a greater quantity of phlogiſton, and light of oxygen united with a ſtill greater quantity. He ſuppoſed, too, that the difference between the rays depended upon the quantity of phlogiſton: the red, according to him, contained the leaſt; the violet, the moſt phlogiſton. By *phlogiſton* Mr Scheele ſeems to have meant *hydrogen*. It is needleſs therefore to examine his theory, as it is now known that the combination of hydrogen and oxygen forms not caloric but water (U). The whole fabric therefore has tumbled to the ground; but the importance of the materials will always be admired, and the ruins of the ſtructure ſhall remain eternal monuments of the genius of the builder.

* In his *Treatiſe on Fire.*

332 De Luc's theory.

Mr de Luc, ſo well known for his important meteorolgical labours, has advanced another theory†. According to him, light is a body which moves conſtantly in ſtraight lines, with ſuch rapidity that its gravitation towards other ſubſtances bears no ſenſible proportion to its motion. Light has the property of combining with another unknown ſubſtance, and the compound formed is caloric, which poſſeſſes very different properties from light. Caloric is conſtantly deſcribing helicoidal curves round an axis, which accounts for the ſlowneſs of its apparent motion. Light produces or increaſes heat, partly by increaſing the expanſive power of caloric, and partly by combining with the *unknown ſubſtance*, and forming new caloric; caloric, on the other hand, is always decompoſed when bodies become luminous. This theory is certainly ingenious, and would remove many of the difficulties which we at preſent labour under in attempting to explain the phenomena of caloric and light. It is, however, liable to other difficulties which could not be eaſily ſurmounted. But it is needleſs to examine theſe, as the theory itſelf is ſupported by no evidence whatever, and cannot therefore be admitted.

† In his *Idées ſur la Meteorologie.*

333 Hutton's theory.

Another theory has been advanced by the late Dr Hutton of Edinburgh (V); a man of undoubted genius, but of rather too ſpeculative a turn of mind, and who ſometimes involved himſelf in difficulties from his very ingenuity. All his writings diſplay evident marks of the profound philoſopher: they contain much inſtruction; and even his miſtakes are not without their uſe: but unfortunately his manner is ſo peculiar, that it is ſcarcely more difficult to procure the ſecrets of ſcience from Nature herſelf, than to dig them from the writings of this philoſopher. He ſuppoſes that there are two kinds of matter, gravitating matter and light; the laſt of which wants gravity, and conſequently neither poſſeſſes magnitude (W) nor momentum. Light has the power of being fixed in bodies; and then it becomes either caloric or phlogiſton, which differs in ſome particulars from caloric, but in what, the Doctor does not preciſely tell us.

Part of this theory we have examined already when we attempted to prove that light and caloric were different ſubſtances. The other part of the theory ſeems to involve a contradiction; for how could light become fixed in a body, unleſs it were attracted by it? and if light poſſeſſes attraction, it ſurely cannot be deſtitute of gravity; for what is gravity but *attraction* (X)?

THUS, notwithſtanding the ingenuity of the philoſophers who have attempted to inveſtigate this part of chemiſtry, the connection between light and caloric is ſtill unknown. We muſt content ourſelves, therefore, with conſidering them at preſent as diſtinct ſubſtances, and leave the ſolution of the many difficulties which at preſent perplex us to the more happy labours of future inquirers.

PART

(T) This Newton of chemiſtry died in 1786, at the age of 44. His moral character, according to Mr Erhart and others, who were the companions of his youth, and Meſſrs Gadolin, Eſpling, and thoſe who knew him in his latter days, was irreproachable and praiſe worthy. His outward appearance was not expreſſive of the great mind which lay concealed as it were under a veil. He ſeldom joined in the uſual converſations and amuſements of ſociety, having as little leiſure as inclination to do ſo; for what little time he had to ſpare from the hurry of his profeſſion (an apothecary), was conſtantly filled up in the proſecution of experiments. It was only when he received viſits from his friends, with whom he could converſe upon his favourite ſcience, that he indulged himſelf in a little relaxation. For ſuch friends he had a ſincere affection, as he had alſo for thoſe that lived at a diſtance, and even for ſuch as were not perſonally known to him. He kept up a regular correſpondence with Meſſrs Erhart, Meyer, Kirwan, Crell, and ſeveral other chemiſts. See *Crell's Life of Scheele.*

(U) This candid philoſopher afterwards acknowledged, that the proofs for the compoſition of water were complete: but we do not know exactly how he attempted to reconcile his theory of heat with the belief that water was compoſed of oxygen and hydrogen; two opinions which are certainly incompatible.

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

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

(X) We hope not to be accuſed of diſputing merely about the meaning of a word, till what is ſaid on this ſubject in the chapter of the preſent article, which treats of *Affinity*, has been examined.

PART II. OF COMPOUND BODIES.

Water.

TO thoſe bodies which are compoſed of *two ſimple ſubſtances* combined together, for want of a better name we have given the appellation of *compound bodies.* They may be reduced under five claſſes:

1. Water,
2. Alcohol,
3. Oils,
4. Alkalies,
5. Acids.

Theſe ſhall be the ſubject of the five following chapters; and we ſhall finiſh this part of the article with ſome obſervations on *Affinity*.

CHAP. I. *Of* WATER.

WATER is a well-known liquid, found in abundance in every part of the world, and abſolutely neceſſary for the exiſtence of animals and vegetables.

When pure, in which ſtate it can be obtained only by diſtillation, it is tranſparent, and deſtitute of colour, taſte, and ſmell.

334 Weight of water. A cubic foot of water, at the temperature of 55°, weighs, according to the experiments of Profeſſor Robiſon of Edinburgh (ſee SPECIFIC *Gravity*, Encycl.), 998,74 avoirdupois ounces, of 437,5 grains troy each, or only 1,26 ounces leſs than 1000 avoirdupois ounces; ſo that rain water, at the ſame temperature, will weigh pretty nearly 1000 ounces. The ſpecific gravity of water is always ſuppoſed = 1,000, and it is made the meaſure of the ſpecific gravity of every other body.

335 Ice. When water is cooled down to 32°, it aſſumes the form of ice. If this proceſs goes on very ſlowly, the ice aſſumes the form of cryſtalline needles, croſſing each other at angles either of 60° or 120°, as Mr de Mairan has remarked; and it has been often obſerved in large cryſtals of determinate figures. Ice, while kept at a temperature conſiderably below 32°, is very hard, and may be pounded into the fineſt duſt. It is elaſtic. Its ſpecific gravity is leſs than that of water.

336 Steam. When water is heated to the temperature of 212°, it boils, and is gradually converted into ſteam. Steam is an inviſible fluid like air, but of a leſs ſpecific gravity. It occupies about 1200 times the ſpace that water does. Its elaſticity is ſo great, that it produces the moſt violent exploſions when confined. It is upon this principle that the ſteam-engine has been conſtructed. See STEAM and *STEAM-Engine*, Encycl.

337 Boiling point of water. The phenomena of boiling are owing entirely to the rapid formation of ſteam at the bottom of the veſſel. The boiling point of water varies according to the preſſure of the atmoſphere. In a vacuum water boils at 90°; and when water is confined in Papin's digeſter, it may be almoſt heated red hot without boiling. The

338 Impregnated with various ſalts. mixture of various ſalts with water affect its boiling point conſiderably.. Mr Achard made a number of experiments on that ſubject . the reſult of which may be ſeen in the following Tables *:

CLASS I. *Salts which do not affect the Boiling Point.*

Sulphat of copper.

CLASS II. *Salts which raiſe the Boiling Point.*

A ſaturated ſolution of	Muriat of ſoda	Raiſes the boiling point	10,35°
	Sulphat of ſoda		5,6
	Sulphat of potaſs		0,9
A ſaturated ſolution of	Nitrat of potaſs	Raiſes the boiling point	3,5°
	Boracic acid		2,2
	Carbonat of ſoda		2,35

This augmentation varies with the quantity of ſalt diſſolved. In general, it is the greater the nearer the ſolution approaches to ſaturation.

CLASS III. *Salts which lower the Boiling Point.*

Borax,	In a ſmall quantity, lowers the boiling point - - - -	1,350°
	Saturated ſolution of, - -	0,22
Sulphat of magneſia,	In a ſmall quantity,	2,47
	Saturated ſolution of	1,1
Alum,	A very ſmall quantity of, - -	0,0
	A greater quantity, - -	0,7
	A ſaturated ſolution of, - -	0,0
Sulphat of lime,	in any proportion,	2,02
Sulphat of zinc,		0,45
Sulphat of iron,		0,22
Acetite of lead,		1,24

CLASS IV.

Muriat of ammonia,	Small quantity of, lowers the boiling point - - -	0,45
	Saturated ſolution of, raiſes do.	9,79
Carbonat of potaſs,	Small quantity of, lowers do.	0,45
	Saturated ſolution of, raiſes do.	11,2

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

340 Opinion about its nature. Water was believed by the ancients to be one of the four elements of which every other body is compoſed; and, according to Hippocrates, it was the ſubſtance which nouriſhes and ſupports plants and animals. That water was an unchangeable element continued to be believed till the time of Van Helmont, who made plants grow for a long time in pure water: From which experiment it was concluded, that water was convertible into all the ſubſtances found in vegetables.—Mr Boyle having digeſted pure water in a glaſs veſſel hermetically ſealed for above a year, obtained a quantity of earthy ſcales; and concluded, in conſequence, that he had converted it partly into an earth *. He obtained the ſame earth by diſtilling water in a tall glaſs veſſel over a ſlow fire †. Margraf repeated the experiment with the ſame reſult, and accordingly drew the ſame concluſion. But the opinion of theſe philoſophers was never very generally received. The laſt perſon who embraced it was probably Mr Waſelton, who publiſhed his experiments on the ſubject in the *Journal de Phyſique* for 1780. Mr Lavoiſier had proved, as early as 1773, that the glaſs veſſels in which the diſtillation was performed loſt a weight exactly equal to the earth obtained. Hence it follows irreſiſtibly, that the appearance of the earth, which was ſilica, proceeded from the decompoſition of the veſſels; for glaſs contains a large proportion of ſilica. It has been ſince ſhewn by Dr Prieſtley, that water always decompoſes glaſs when applied to its ſurface for a long time in a high temperature.

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

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* *Tranſ. Berlin*, 1785.

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

† *Ibid.* i. 267.

contributed more perhaps than any other to the advancement of the ſcience of chemiſtry, by furniſhing a key for the explanation of a prodigious number of phenomena. The evidence, therefore, on which it reſts, and the objections which have been made to it, deſerve to be examined with peculiar attention.

341
Hiſtory of the diſcovery of its compoſition.

The firſt perſon probably who attempted to diſcover what was produced by burning hydrogen gas was Scheele. He concluded, that during the combuſtion oxygen and hydrogen combined, and that the product was caloric.

In 1776 Macquer, aſſiſted by Sigaud de la Fond, ſet fire to a bottle full of hydrogen gas, and placed a ſaucer above the flame, in order to ſee whether any fuliginous ſmoke would be produced. The ſaucer remained perfectly clean; but it was moiſtened with drops of a clear liquid, which they found to be pure water *.

Next year Bucquet and Lavoiſier exploded oxygen and hydrogen gas, and made an attempt to diſcover what was the product; about the nature of which they had formed different conjectures. Bucquet had ſuppoſed that it would be carbonic acid gas; Lavoiſier, on the contrary, ſuſpected that it would be ſulphuric or ſulphurous acid. What the product was they did not diſcover; but they proved that no carbonic acid gas was formed, and conſequently that Mr Bucquet's hypotheſis was ill founded †.

In the beginning of the year 1781, Mr Warltire, at the requeſt of Dr Prieſtley, fired a mixture of theſe two gaſes contained in a copper veſſel; and obſerved, that after the experiment the weight of the whole was diminiſhed. Dr Prieſtley had previouſly, in the preſence of Mr Warltire, performed the ſame experiment in a glaſs veſſel. This veſſel became moiſt in the inſide, and was covered with a ſooty ſubſtance ‡, which Dr Prieſtley afterwards ſuppoſed to be a part of the mercury uſed in filling the veſſel §.

In the ſummer of 1781, Mr Henry Cavendiſh, who had been informed of the experiments of Prieſtley and Warltire, ſet fire to 500,000 grain meaſures of hydrogen gas, mixed with about 2½ times that quantity of common air. By this proceſs he obtained 135 grains of pure water. He alſo exploded 19,500 grain meaſures of oxygen gas with 37,000 of hydrogen gas, and obtained 30 grains of water, containing in it a little nitric acid. From theſe experiments he concluded that water was a compound.—Mr Cavendiſh muſt therefore be conſidered as the real diſcoverer of the compoſition of water. He was the firſt who aſcertained that water was produced by firing oxygen and hydrogen gas, and the firſt that drew the proper concluſion from that fact. Mr Watt, indeed, had alſo drawn the proper concluſion from the experiments of Dr Prieſtley and Mr Warltire, and had even performed a number of experiments himſelf to aſcertain the fact, before Mr Cavendiſh had communicated his; but he had been deterred from publiſhing his theory by ſome experiments of Dr Prieſtley, which appeared contrary to it ||. He has therefore a claim to the merit of the diſcovery; a claim, however, which does not affect Mr Cavendiſh, who knew nothing of the theory and experiments of that ingenious philoſopher.

Meanwhile, in the winter 1781-2, Mr Lavoiſier, who had ſuſpected that when oxygen and hydrogen gas were exploded, ſulphuric or ſulphurous acid was produced, made an experiment in order to aſcertain the fact, at which Mr Gingembre aſſiſted. They filled a bottle, capable of holding ſix pints (French), with hydrogen gas, to which they ſet fire, and then corked the bottle, after pouring into it 2 oz. (French) of lime-water. Through the cork there paſſed a copper tube, by means of which a ſtream of oxygen gas was introduced to ſupport the flame. Though this experiment was repeated three times, and inſtead of lime-water a weak ſolution of alkali and pure water were ſubſtituted, they could not obſerve any product whatever *. This reſult aſtoniſhed Mr Lavoiſier exceedingly: he reſolved, therefore, to repeat the experiment on a larger ſcale, and if poſſible with more accuracy. By means of pipes furniſhed with ſtop-cocks, he put it in his power to ſupply both gaſes as they ſhould be wanted, that he might be enabled to continue the burning as long as he thought proper.

The experiment was made by Lavoiſier and La Place on the 24th of June 1783, in the preſence of Meſſrs Le Roi, Vandermonde, ſeveral other academicians, and Sir Charles Blagden, who informed them that Mr Cavendiſh had already performed it, and that he had obtained water †. They continued the inflammation till all their ſtock of gaſes was waſted, and obtained about 295 grains of water, which, after the moſt rigid examination, appeared to be perfectly pure. From this experiment Lavoiſier concluded, that water was compoſed of oxygen and hydrogen. Mr Mongé ſoon after performed the ſame experiment, and obtained a ſimilar reſult: and it was ſoon after repeated again by Lavoiſier and Meuſnier on a ſcale ſufficiently large to put the fact beyond doubt ‡.

342
Proofs of the compoſition of water.

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

343
Experiment of Lavoiſier and Meuſnier.

With regard to the compoſition of water, we ſhall relate the celebrated experiment made by Lavoiſier and Meuſnier in the month of February 1785, in the preſence of a numerous deputation from the academy of ſciences, and ſo many other ſpectators, that it may he conſidered as having been performed in public. Every precaution was taken to enſure ſucceſs. The gaſes had been prepared with care, and held for ſome time over a ſolution of potaſs, in order to deprive them of any acidity which they might accidentally contain; and before entering into the glaſs globe where they were to be burnt, they were made to paſs over newly calcined potaſs, to deprive them of the water which they might happen to retain in ſolution. The hydrogen gas had been obtained by paſſing ſteam through iron at a white heat; the oxygen gas was procured from the red oxide of mercury. The combuſtion took place in a large glaſs globe, into which the gaſes were admitted by means of tubes furniſhed with ſtop-cocks; and the moſt ingenious contrivances were employed to aſcertain exactly the quantities of each which were conſumed (y). The whole machine is deſcribed at large by Mr Meuſnier in the Memoirs of the Academy of Sciences for 1782.

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

† *Mem. Par.* 1781, 470.

‡ *Prieſtley*, v. 395.

§ *Phil. Tranſ.* lxxiv. 332.

|| *Ibid.* lxxv. 130.

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

† *Ibid.* p. 472.

‡ *Ibid.* p. 474.

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

The quantities of gas employed, after deducting the 432 grains of reſiduum which were not conſumed, were 2794,76 grains of oxygen gas, and 471,125 of hydrogen gas. After taking from theſe 32,25 grains, = the humidity of which the oxygen gas was deprived by the calcined potaſs, and 44,25 grains, = the weight which the hydrogen loſt by the ſame proceſs, there remains altogether 3188,4 grains of gas.

The quantity of water obtained amounted to 3219 grains; the ſpecific gravity of which was to diſtilled water as 1,0051 to 1. This quantity was 30 grains more than the gas employed. The difference, no doubt, was owing to a ſmall error in eſtimating the weight of the gaſes; which indeed it is extremely difficult to avoid, as the weight is altered by the ſmalleſt difference of temperature. This water had a ſlight ſmell, and a taſte ſenſibly acid; it reddened ſlightly blue paper, and efferveſced with the carbonat of potaſs. 1152 grains of that water being ſaturated with potaſs, and evaporated to dryneſs, left 20 grains of a ſalt which melted on the fire like nitre. It follows from this experiment, that the quantity of acid contained in the whole water would not have been quite ſufficient to have formed 56 grains of nitre.

The reſiduum weighed, as has been already obſerved, 432 grains; its volume was equal to 444 grains of oxygen gas; it was diminiſhed by nitrous gas (z) preciſely as gas would be which contained 0,24 parts of oxygen: it rendered lime-water ſomewhat turbid, which indicated the preſence of carbonic acid gas.

From the compariſon of the weights, and volumes of the gaſes conſumed, it was concluded that water conſiſts of 0,85 parts, by weight, of oxygen, and 0,15 of hydrogen.

344 Experiment of Le Fevre de Gineau.

This experiment was ſoon after repeated by Mr Le Fevre de Gineau upon a ſtill larger ſcale, and in the preſence of a great number of ſpectators. It continued for no leſs than 12 days, and was performed with the moſt rigorous exactneſs of which experiments of that nature will admit *.

The oxygen gas employed, which had been procured from the black oxide of mangaueſe, occupied the ſpace of 35085,1 cubic inches, and weighed 18298,5 grains.

The hydrogen gas was obtained by diſſolving iron in diluted ſulphuric acid. Its volume was 7496,7 cubic inches, and its weight 4756,3 grains.

	Grains.
The two gaſes therefore amounted to -	23054,8
From which taking the reſiduum after combuſtion, which amounted to - -	2831,0
There remains for the quantity conſumed	20223,8
The water found in the glaſs globe after the combuſtion amounted to - - -	20139,0
And there were carried off by the reſiduum	54,0
In all - -	20193,0

Which is juſt 30 grains leſs than the weight of the gaſes which diſappeared, or $\frac{1}{657}$ part of their weight. This difference aroſe from the ſame difficulties which attended the experiment of Lavoiſier. As the errors are on different ſides, we are warranted to conclude that this was the caſe, and that it was not owing to any real difference between the gaſes and the product.

The water was examined in the preſence of Meſſrs Lavoiſier, Le Roi, Mongé, Berthollet, Bayen, and Pelletier. Its ſpecific gravity was to that of diſtilled water as 1,001025 to 1. It contained no ſulphuric nor muriatic acids; yet it had an acid taſte, and converted vegetable blues to a red. 6606 grains of it required for ſaturation 36 grains of carbonat of potaſs, and furniſhed by evaporation 26,5 grains of cryſtals of nitre. The whole water, therefore, would have required 109,7 grains of carbonat of potaſs for ſaturation.

This water affected lime-water a little; and it was found that the reſiduum of the gas contained ſome carbonic acid gas. This reſiduum formed a 19th part of the volume of the two gaſes employed, and an eight of their weight. It contained 462 grains of carbonic acid gas, or about $\frac{1}{8}$th part; the reſt was azotic gas, with about $\frac{1}{12}$th of oxygen.

This experiment gave the proportions of oxygen and hydrogen in water as follows:

Oxygen - - -	,848
Hydrogen - -	,152
	1,000

This is ſo near the determination of Mr Lavoiſier, that it muſt be conſidered as a very ſtrong confirmation of it.

345 Experiment of Seguin, Fourcroy, and Vauquelin.

In the year 1790, another ſimilar experiment was performed by Seguin, Fourcroy, and Vauquelin, in the preſence of a number of commiſſioners appointed by the Academy of Sciences. Every precaution was taken to aſcertain the quantity of gas employed with the utmoſt exactneſs, and to exclude all atmoſpherical air as completely as poſſible.

The hydrogen gas was procured by diſſolving zinc in ſulphuric acid diluted with 7 parts of water. The oxygen gas was obtained by diſtilling oxy-muriat of potaſs (A).

The quantity of hydrogen gas employed amounted to 862,178 grains troy. The quantity of oxygen gas amounted to 13475,198 cubic inches (French). Its purity was ſuch, that it contained three cubic inches of azotic gas in the 100. The whole gas, therefore, contained 404,256 cubic inches. There were likewiſe in the glaſs veſſel in which the combuſtion took place 15 cubic inches (French) of atmoſpheric air, which conſiſted of 11 cubic inches of azotic and four of oxygen gas. So that the whole oxygen gas employed amounted to 13074,942 cubic inches; and it contained beſides 415,256 cubic inches of azotic gas. They aſcertained by experiment, that a cubic inch of this oxygen gas, thus diluted with $\frac{3}{100}$ of azot, weighed ,4040 of a grain troy. Now, according to the experiments of Lavoiſier, a cubic inch (French) of azotic gas weighs only ,3646 of a grain troy. Conſequently the weight of pure oxygen gas is greater than ,4040; and by calculation they ſhewed it to amount to ,4051 of a grain troy. The weight of the whole oxygen gas employed, therefore, was 5296,659 grains troy; and that of the azotic gas mixed with it 151,402 grains troy.

The

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* Journ. de Phyſ. 1788, p. 457.

(z) This gas ſhall be afterwards deſcribed. It has the property of abſorbing almoſt inſtantaneouſly the oxygen gas with which it comes into contact. It is therefore often uſed, in order to diſcover how much oxygen gas exiſts in any mixture.

(A) A ſalt compoſed of oxy-muriatic acid and potaſs.

Water.

The combuſtion continued 185 hours; and during all that time our philoſophers never quitted the laboratory. The flame was exceedingly ſmall, and the heat produced by no means great. This was owing to the very ſmall ſtream of hydrogen, which was conſtantly flowing into the veſſel.

The water obtained amounted to 5943,798 grains troy, or 12 oz. 7 dwts. and 15,798 grains. It exhibited no mark of acidity, and appeared in every reſpect to be pure water. Its ſpecific gravity was to that of diſtilled water as 18671 to 18670; or nearly as 1,000053 to 1.

The reſiduum of gas in the veſſel after combuſtion amounted to 987 cubic inches (French); and on being examined, was found to conſiſt of the following quantities of gaſes :

Azotic gas, - - - - - -	467 cubic inches.
Carbonic acid gas, - - -	39
Oxygen gas, - - - - - -	465
Hydrogen gas, - - - -	16
Total - -	987

The weight of which is as follows :

Azotic gas, - - - - - - -	170,258 gr. troy.
Carbonic acid gas, - - - -	23,306
Oxygen gas, - - - - - - -	188,371
Hydrogen gas, - - - - -	0,530
Total, - -	382,465

Now the weight of the whole gaſes employed was, - - - - 6310,239 gr. troy.
That of the water obtained, and of the reſiduum, - - - - 6326,263

Or - - - - - - - - - 16,024 grains more than had been employed. This ſmall quantity muſt have been owing to common air remaining in the tubes, and other parts of the apparatus, in ſpite of all the precautions that were taken to prevent it ; if it did not rather proceed from unavoidable errors in their valuations.

	Gr. Troy
The quantity of azotic gas introduced was	151,178
The quantity found in the reſiduum was	170,258
There was therefore a ſurplus of - - -	19,080 gr.

As ſufficient precautions had been taken to prevent the introduction of carbonic acid gas, the quantity found in the reſiduum muſt have been formed during the proceſs. There muſt therefore have been a ſmall quantity of carbon introduced. Now zinc often contains carbon, and hydrogen has the property of diſſolving carbon : probably, then, the carbon was introduced in this manner. The carbonic acid found in the reſiduum amounted to 23,306 grains, which, according to Lavoiſier's calculation, is compoſed of 8,958 grains of carbon, and 14,348 grains of oxygen.

Subtracting theſe 8,958 grains of carbon, and the ,530 of a grain of hydrogen, which remained in the veſſel, from the total of hydrogen introduced, there will remain 852,690 grains for the hydrogen that diſappeared.

Subtracting the 14,348 grains of oxygen which entered into the compoſition of the carbonic acid, and the reſiduum of oxygen, which amounted to 188,371 grains, the quantity of oxygen that diſappeared will amount to 5093,940 grains.

Water.

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

Such are the principal experiments upon which the opinion is founded that water is a compound. Let us examine them, and ſee whether they are ſufficient to eſtabliſh that opinion. The circumſtances which chiefly claim our attention, and which have been chiefly inſiſted on, are theſe :

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Objections to the compoſition of water examined.

1. The whole of the gaſes was not conſumed.

2. In the reſiduum were found ſeveral ſubſtances which were not introduced, and which muſt therefore have been formed during the combuſtion.

3. The water obtained was ſeldom perfectly pure. It generally contained ſome nitric acid.

4. As only part of the gaſes were conſumed, and as all gaſes contain water in them, might not the gas which diſappeared have been employed in forming the other ſubſtances found in the reſiduum? and might not the water obtained have been merely what was formerly diſſolved in the gaſes, and which had been precipitated during the experiment?

That the whole of the gaſes was not conſumed will not ſurpriſe us, if we recollect that it is impoſſible for that to take place, allowing them to be perfectly pure, except they be mixed in preciſely the proper proportions ; and not even then, except every particle of them could be raiſed to the proper temperature. Now how can this be done in experiments of that nature ?

But how is it poſſible to procure a large quantity of gas completely pure ? And ſuppoſing it were poſſible, how can every particle of atmoſpheric air be excluded ? In the laſt experiment, notwithſtanding every precaution, 15 cubic inches (French) were admitted ; and there is reaſon to believe from the reſults, that the quantity was even conſiderably greater than this. But if any atmoſpheric air be admitted, there muſt be a reſiduum of azotic gas.

In the firſt experiment, it had been previouſly aſcertained that the oxygen gas employed contained $\frac{1}{12}$th of azotic, or about 233,05 grains ; and the reſiduum contained at moſt 329,1 grains, or 96,05 grains more than what had for certain pre-exiſted in the gaſes.

In the ſecond experiment, the azot in the reſiduum amounted at moſt to $\frac{1}{8}$th of the oxygen gas employed. But the oxygen was procured from the black oxide of manganeſe, which always yields a quantity of azot as well as of carbonic acid. It has been aſcertained, that the azot, mixed with oxygen gas procured in that manner, often exceeds $\frac{1}{8}$th.

In the third experiment, the azotic gas found in the reſiduum amounted to 170,258 grains; and the quantity contained in the gaſes before combuſtion amounted to 151,178 grains : the ſurplus, therefore, amounted to 19,08 grains.

Now, is it not much more probable that theſe inconſiderable quantities of azot, which in the laſt experiment amounted to no more than $\frac{1}{112}$ part by weight of the whole gas employed, pre-exiſted in the gaſes before the combuſtion began, though their extreme minuteneſs prevented them from being diſcovered, than that they were formed during the experiment : a ſup-

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[*] Ann. de Chim. viii. 225.

poſition which is directly contradicted by a great number of well aſcertained facts.

As to the carbonic acid gas, which in the ſecond experiment amounted to $\frac{1}{49}$th of the gaſes employed, it was evidently derived from the manganeſe, which almoſt conſtantly contains it. And when carbonic acid is once mixed with oxygen, it is difficult to ſeparate it by means of lime-water, except a large quantity be uſed, as Mr Cavendiſh has well obſerved. The reaſon is, that oxygen gas has the property of diſſolving carbonic acid, as Mr Welter has remarked *. Mr le Fevre de Gineau aſcertained by experiment, that 1870 cubic inches of oxygen gas, which did not affect lime-water, loſt between $\frac{1}{18}$th and $\frac{1}{40}$th of its weight when waſhed in *milk of lime* (B).

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

In a ſecond experiment, he previouſly waſhed the two gaſes in milk of lime, and the reſiduum after combuſtion contained *no* carbonic acid gas. In a third experiment he waſhed only the oxygen, and obtained products equally free from carbonic acid. It is certain, then, that the *carbonic acid* is but an accidental mixture. As to the carbonic acid of the third experiment above related, which amounted only to $\frac{1}{112}$ part of the gaſes employed, the ſource of it has been already pointed out.

As to the nitric acid, the quantity of nitre obtained in Mr Lavoiſier's experiment was 56 grains; which, according to Mr Kirwan's calculation, contain 30,156 grains of nitric acid; a quantity conſiderably leſs than $\frac{1}{100}$th part of the gaſes which diſappeared. In the ſecond experiment, the nitre obtained amounted to 80,7 grains; which, according to Kirwan, contain 43,456 grains of nitric acid, or leſs than $\frac{1}{459}$th part of the gaſes conſumed. Now, as nitric acid is compoſed of oxygen and azot, both of which were preſent in the veſſel, it is eaſy to ſee how it was produced. And that its production is merely accidental, and not neceſſary, is evident from the laſt experiment, in which no nitric acid was formed. It has been aſcertained, indeed, that the formation of this acid during theſe experiments is quite arbitrary. It never is formed when the combuſtion goes on ſo ſlowly as to produce but little heat, as Seguin has aſcertained †; becauſe oxygen and azot do not combine except at a high temperature. Nor is it formed even at a high temperature, as Mr Cavendiſh has proved ‡, except there be a deficiency of hydrogen; becauſe hydrogen has a ſtronger affinity for oxygen than azot has.

† *Ann. de Chim.* ix. 48.

‡ *Phil. Tranſ.* 1784.

The quantity of water obtained in the firſt experiment was juſt 30 grains more than the weight of the gaſes which had diſappeared: the water obtained in the ſecond was preciſely 30 grains leſs than the gaſes conſumed: and in the third experiment, the difference was only 16 grains. The quantities of gas operated upon were large; in all of the experiments ſeveral thouſand grains, and in one of them above 20 thouſand. Now, how is it poſſible that the water produced ſhould correſpond ſo exactly with the gaſes conſumed (for the differences are ſo ſmall as not to merit any attention), unleſs the water had been formed by the combination of theſe gaſes?

Dr Prieſtley, however, who made a great many experiments on this ſubject, drew from them a very different concluſion; and thought he had proved, that during the combuſtion the two gaſes combined, and that the combination was nitric acid. This theory was adopted, or rather it was ſuggeſted, by Mr Keir, who has ſupported it with a great deal of ingenuity *.

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

Let us examine theſe experiments of Dr Prieſtley †, and ſee whether they warrant the concluſions he has drawn from them. The gaſes were exploded in veſſels of copper. He found that the quantity of water obtained was always *leſs* than that of the gaſes which he had uſed. He obtained alſo a conſiderable quantity of nitric acid. In the experiment made on the largeſt quantity of the gaſes, and from which he draws his concluſions, the quantity of liquid obtained amounted to 442 grains. This liquid was examined by Mr Keir. It was of a green colour, 72 grains of brown oxide of copper were depoſited in it, and it contained a ſolution of nitrat of copper (copper combined with nitric acid). Mr Keir analyſed this liquor: It conſiſted of pure water and nitrat of copper; and Mr Keir concluded that the nitric acid formed amounted to $\frac{1}{20}$th of the oxygen gas employed. Mr Berthollet, however, has ſhewn that it could not have amounted to more than $\frac{1}{44}$th part ‡. Let us ſuppoſe, however, that it amounted to $\frac{1}{20}$th. A quantity of oxygen and hydrogen gas has diſappeared: What has become of them? They have combined, ſays Dr Prieſtley, and formed nitric acid. This nitric acid is only $\frac{1}{20}$th of their weight: Dr Prieſtley ſuppoſes, however, that it contains the whole oxygen and hydrogen that exiſted in theſe gaſes, and that all the reſt of the weight of theſe gaſes was owing to a quantity of water which they had held in ſolution. Oxygen gas, then (for we ſhall neglect the hydrogen, which Dr Prieſtley was not able to bring into view at all), is compoſed of one part of oxygen and 19 of water. Where is the proof of this? Dr Prieſtley informs us, that he aſcertained by experiment that half the weight of carbonic acid gas was pure water. Suppoſing the experiment accurate (C), what can be concluded from it? Surely to bring it forward in proof, that oxygen gas conſiſts of $\frac{19}{20}$th parts, or almoſt wholly of water, is downright trifling. It is impoſſible, therefore, from Dr Prieſtley's experiments, allowing his ſuppoſitions and conjectures their utmoſt force, to account for the diſappearing

† *Phil. Tranſ.* 1788.

‡ *Ann de Chim.* iii. 86.

(B) Lime mixed with water till it is of the thickneſs of *milk*, or rather of *cream*.

(C) He informs us that the carbonat of barytes does not yield its carbonic acid by means of heat (this Dr Hope has ſhewn to be a miſtake); but that, when the vapours of water are paſſed over it, the gas is diſengaged: and he determines, by the water miſſing, how much has combined with the gas. According to him, 60 grains of water enter into the compoſition of 147 grains of gas. But, beſides aſſigning too ſmall a weight to the gas, he forgot that its temperature was high, and that therefore it was capable of combining with much more water than in its uſual ſtate: nor did he aſcertain whether more of this water was depoſited on the veſſels; and yet, by neglecting this precaution, Morveau has ſhewn that Mr Kirwan, in a ſimilar experiment, obtained a reſult nine times greater than it ought to have been. *Encycl. Method. Chim.* art. *Air.*

pearing of the two gaſes, or the appearance of the water, without admitting that this liquid was actually compoſed of oxygen and hydrogen. If we add to this, that no oxygen gas has hitherto (as far as we know at leaſt) been procured abſolutely free from ſome admixture of azot, and that his oxygen was always procured either from red oxide of lead, or from black oxide of mangaueſe, or red oxide of mercury, all of which ſubſtances yield a conſiderable proportion of azot; that in one experiment, in which he obſerves that his oxygen was *very pure*, as it had been obtained from red oxide of mercury, Mr Berthollet (D) aſcertained, by actually making the experiment, that part of the *very ſame* oxide which Dr Prieſtley had employed yielded a gas, $\frac{2}{3}$d of which was azot *; if we add, that it has been proved beyond the poſſibility of doubt, and to Dr Prieſtley's own ſatisfaction, that nitric acid is compoſed of oxygen and azot—we ſhall find it no difficult matter to explain the origin of that acid in Dr Prieſtley's experiments: and if we recollect that in Seguin's experiment, upon a much larger ſcale indeed than Dr Prieſtley's, no nitric acid at all was formed, it will be impoſſible for us to believe for a moment that the compound formed by oxygen and hydrogen is nitric acid. Thus Dr Prieſtley's experiments rather confirm than deſtroy the theory of the compoſition of water. We obtain from them, however, one curious piece of information, that the preſence of copper increaſes the quantity of nitric acid formed. This curious fact, with a variety of others of a ſimilar nature, will perhaps afterwards claim our attention; but at preſent we muſt conſider another theory which this phenomenon ſuggeſted, and which was firſt propoſed, we believe, by Mr de la Metherie (E).

* *Ann. de Chim.* iii. 94.

Had the French chemiſts, it has been ſaid, employed copper veſſels in their experiments, they would have obtained three times the quantity of nitric acid. This acid, therefore, muſt in their experiments have been decompoſed, after having been formed, for want of a baſe to combine with; and the azot which appeared in the reſiduum was owing to this decompoſition. Hydrogen and oxygen, therefore, do not form water, but azot (F). Let us examine the experiment of Mr Le Fevre by this theory, as the quantity of azot was accurately aſcertained. The nitric acid obtained amounted to 43,456 grains; three times that quantity is 130,368 grains, into which 23054 grains of gas were converted; which is impoſſible. Or even ſuppoſing that the decompoſition had been going on during the whole experiment, which is directly contrary to Dr Prieſtley's experiments, and which there is no reaſon whatever to ſuppoſe, but every reaſon againſt—ſtill the whole azot amounted only to $\frac{1}{8}$th of the quantity of gas employed, allowing this gas to have contained no azot, which was evidently not the caſe. It appears, then, that this hypotheſis, even if it could be admitted, would be totally inadequate to account for the phenomena. But if we were to examine it by Mr Seguin's experiment, its abſurdity would be ſtill more glaring. In that experiment the azotic gas amounted to only 19 grains, and the quantity of gas which diſappeared was 5946 grains: ſo that were the hypotheſis true, oxygen and hydrogen gas would conſiſt of one part of oxygen and hydrogen and 312 parts of water; a ſuppoſition ſo enormouſly abſurd, that it is impoſſible for any perſon even to advance it.

It is impoſſible, therefore, for the phenomena which attend the combuſtion of oxygen and hydrogen gas to be accounted for in any way conſiſtent with common ſenſe, except we ſuppoſe that water is formed.

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Decompoſition of water.

But the experiments above related, concluſive as they appear, are not the only ones by which this important fact has been aſcertained. Meſſrs Van Trooſtwyk and Dieman, aſſiſted by Mr Cuthbertſon, filled a ſmall glaſs tube, $\frac{1}{8}$th of an inch in diameter and 12 inches long, with diſtilled water. One end of this tube was ſealed hermetically; but, at the ſame time, a ſmall gold wire had been paſſed through it. Another wire paſſed thro' the open end of the tube, and could be fixed at greater or ſmaller diſtances from the firſt wire. By means of theſe wires, they made a great number of electrical exploſions paſs through the water. Bubbles of air appeared at every exploſion, and collected at the top of the tube. When electric ſparks were paſſed through this air, it exploded and diſappeared almoſt completely. It muſt therefore have conſiſted of a mixture of oxygen and hydrogen gas, and this gas muſt have been formed by the decompoſition of the water: for they had taken care to deprive the water before hand of all its air, and they uſed every precaution to prevent the acceſs of atmoſpherical air; and, beſides, the quantity of gas produced did not diminiſh, but rather increaſed, by continuing to operate a number of times upon the ſame water, which could not have been the caſe had it been merely air diſſolved in water: nor would atmoſpherical air have exploded and left only a very ſmall reſiduum, not more than $\frac{1}{80}$th part. They had taken care alſo to prove that the electric ſpark did not contribute to form hydrogen gas; for on paſſing it through ſulphuric and nitric acids, the product was not hydrogen, but oxygen gas *.

* *Jour. de Phyſ.* xxxv. 369.

Theſe experiments have been ſince repeated by Dr Pearſon, aſſiſted by Mr Cuthbertſon. He produced, by means of electricity, quantities of gas from water, amounting to 56,5488 cubes of $\frac{1}{10}$th of an inch each; on nitrous gas being added to which, it ſuffered a diminution

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(D) Mr Berthollet had ſupplied Dr Prieſtley with the oxide. He had received two ounces of it from Mr Le Blanc, one of which he ſent to Dr Prieſtley, and the other he reſerved.

(E) Another favourite theory of La Metherie was, that gaſes themſelves are deſtitute of gravity, and that they owe their whole weight to the water with which they are combined: that during combuſtion the water of the two gaſes is depoſited; and that the gaſes themſelves eſcape through the veſſel and are loſt. He complains bitterly that this theory had never been noticed by his antagoniſts; as if it were neceſſary to refute a hypotheſis which is not ſupported by any proof whatever, and as if it had not been proved that oxygen increaſes the weight of metals, and conſequently poſſeſſes gravity.

(F) This, as has been formerly explained, was the original opinion of Dr Prieſtley; to which, though he does not explain himſelf fully, he evidently ſtill adheres. There is then no difference between his theory and this, except what relates to the decompoſition of the nitric acid.

nution of bulk, and nitrous acid appeared to have been formed: It muſt therefore have contained oxygen gas. When oxygen gas was added to the remainder, and an electric ſpark paſſed through it, a diminution took place preciſely as when oxygen and hydrogen gas are mixed: It muſt therefore have contained hydrogen. When an electric ſpark was paſſed through the gas thus produced from water, the gas diſappeared, being no doubt converted into water *.

Such are the proofs by which the compound nature of water is aſcertained; and we do not believe that any phyſical fact whatever can be produced which is ſupported by more complete evidence.

But what becomes of the caloric which was previouſly combined with theſe gaſes? It paſſes through the veſſel and is loſt, and its weight is too inconſiderable to make any ſenſible variation in the quantity of the product. If we were to judge from analogy, we would conclude, that the oxygen and hydrogen, while in the ſtate of gas, are probably ſomewhat lighter than after they are condenſed into water; but the difference, if it exiſts, can ſcarcely be ſenſible.

348 Combination and affinity of water.

Water is capable of combining with a vaſt number of ſubſtances: all bodies, indeed, which are ſoluble in water form a chemical union with it.

Its affinity for other bodies is doubtleſs various, tho' we have no method of aſcertaining this difference, except in thoſe bodies which have no affinity, or but a very ſmall affinity, for each other; and it is only in a few even of theſe that this difference can be aſcertained. If muriat of barytes be poured into lime-water, the lime is precipitated, owing, no doubt, to the ſuperior affinity of the muriat for water. Several very curious inſtances of the affinity of different ſalts for water have been mentioned by Mr Quatremere Dijonval. When the ſolutions of nitrat of lime and nitrat of magneſia in water are mixed together, the nitrat of magneſia is precipitated. Muriat of magneſia is alſo precipitated by muriat of lime, and ſulphat of magneſia by ſulphat of lime: ſo that it would ſeem that the ſalts which have magneſia for their baſis, have a leſs affinity for water than thoſe whoſe baſis is lime †.

Water has the property of diſſolving oxygen gas. If a quantity of common air be confined for ſome time above water, the whole of the oxygen is abſorbed, and nothing but the azotic gas remains. This fact was firſt obſerved by Mr Scheele.

CHAP. II. *Of* ALCOHOL.

349 Diſcovery of alcohol.

WINE has been known from the earlieſt ages. The Scriptures inform us, that Noah planted a vineyard and drank wine; and the heathen writers are unanimous in aſcribing the invention of this liquor to their earlieſt kings and heroes. Beer, too, ſeems to have been diſcovered at a very remote period. It was in common uſe in Egypt in the time of Herodotus ‡. Tacitus informs us, that it was the drink of the Germans §. Whether the ancients had any method of procuring ardent ſpirits from theſe or any other liquors, does not appear. The Greeks and Romans ſeem to have been ignorant of ardent ſpirits altogether, at leaſt we can diſcover no traces of any ſuch liquor in their writings. But among the northern nations of Europe, intoxicating liquors were in uſe from the earlieſt ages. Whether theſe liquors reſembled the beer of the Germans, we do not know. It is certain, at leaſt, that the method of procuring ardent ſpirits by diſtillation was known in the dark ages; and it is more than probable that it was practiſed in the north of Europe much earlier. They are mentioned expreſsly by Thaddæus, Villanovanus, and Lully *.

350 Method of procuring it.

Ardent ſpirits, ſuch as brandy, for inſtance, rum, and whiſky, conſiſt almoſt entirely of three ingredients, water, *alcohol* or *ſpirit of wine*, to which they owe their ſtrength, and a ſmall quantity of a peculiar oil, to which they owe their flavour.

The alcohol may be ſeparated from the water by the following proceſs. Into the whiſky or other ardent ſpirit a quantity of potaſs is to be put, which has juſt immediately before been expoſed for about half an hour in a crucible to a red heat, in order to deprive it of moiſture. Potaſs in this ſtate has a ſtrong attraction for water; it accordingly combines with the water of the ſpirit, and the ſolution of potaſs thus formed ſinks to the bottom of the veſſel, and the alcohol, which is lighter, ſwims over it, and may eaſily be decanted off; or, what is perhaps better, the ſolution of potaſs may be drawn off from below it by means of a ſtop-cock placed at the bottom of the veſſel. It is impoſſible to fix the quantity of potaſs which ought to be uſed, becauſe that muſt depend entirely on the ſtrength of the ſpirit; but it is of no conſequence though the potaſs employed be a little more than enough. The alcohol thus obtained contains a little potaſs diſſolved, which may be ſeparated by diſtilling it in a water bath with a very ſmall heat. The alcohol paſſes over, and leaves the potaſs behind. It is proper not to diſtil to dryneſs. This proceſs is firſt mentioned by Lully. Alcohol may be obtained in the ſame manner from wine and from beer; which liquids owe their ſtrength entirely to the quantity of that ſubſtance which they contain.

351 Its properties.

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

It is exceedingly fluid, and has never been frozen, though it has been expoſed to a cold ſo great that the thermomer ſtood at —69° †.

Its ſpecific gravity when pure is about 0,800.

It is exceedingly volatile, boiling at the temperature of 176°; in which heat it aſſumes the form of an elaſtic fluid, capable of reſiſting the preſſure of the atmoſphere, but which condenſes again into alcohol when that temperature is reduced. In a vacuum it boils at 56°, and exhibits the ſame phenomena: ſo that were it not for the preſſure of the atmoſphere, alcohol would always exiſt in the form of an elaſtic fluid, as tranſparent and inviſible as common air. This ſubject was firſt examined with attention by Mr Lavoiſier ‡. The fact, however, had been known long before.

Alcohol has a ſtrong affinity for water, and is miſcible with it in all proportions. The ſpecific gravity of all the different mixtures, in every proportion, and in all the different degrees of temperature, from 32° to 100°, has been lately aſcertained with great accuracy by Sir Charles Blagden and Mr Gilpin. But as a very full account of theſe intereſting experiments has been given in the Encyclopædia in the article SPIRITUOUS *Liquors*, we do not think ourſelves at liberty to repeat it here.

If alcohol be ſet on fire, it burns all away with a blue flame without leaving any reſiduum. Boerhaave obſerved,

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* Nicholſon's Journal, i. 242.

† Journ. de Phyſ. xvi.

‡ Lib. ii. n. 77.

§ De Mor. Germ. ch. xxiii.

* Berg. 4th. art ii. 4.

† At Hudſon's Bay.

‡ Journ. de Phyſ. 1785.

obſerved, that when the vapour which eſcapes during this combuſtion is collected in proper veſſels, it is found to conſiſt of nothing but water. Junker had made the ſame remark: and Dr Black ſuſpected, from his own obſervations, that the quantity of water obtained, if properly collected, exceeded the weight of the alcohol conſumed. This obſervation was confirmed by Lavoiſier; who found that the water produced during the combuſtion of alcohol exceeded the alcohol conſumed by about $\frac{1}{7}$th part[*].

352 Opinions oncerning ts compo- ition.

Different opinions were entertained by chemiſts about the nature of alcohol. Stahl thought that it was compoſed of a very light oil, united by means of an acid to a quantity of water. According to Junker, it was compoſed of phlogiſton, combined with water by means of an acid. Cartheuſer, on the other hand, affirmed, that it contained no acid, and that it was nothing elſe than pure phlogiſton and water. But theſe hypotheſes were mere aſſertions ſupported by no proof whatever. Lavoiſier was the firſt who attempted to analyſe it.

353 Lavoiſier's analyſis.

He ſet fire to a quantity of alcohol in cloſe veſſels, by means of the following apparatus: BCDE (fig. 6.) is a veſſel of marble filled with mercury. A is a ſtrong glaſs veſſel placed over it, filled with common air, and capable of containing about 15 pints (French). Into this veſſel is put the lamp R filled with alcohol, the weight of which has been exactly determined. On the wick of the lamp is put a ſmall particle of phoſphorus. The mercury is drawn up by ſuction to the height IH. This glaſs communicates by means of the pipe LK with another glaſs veſſel S filled with oxygen gas, and placed over a veſſel of water T. This communication may be ſhut up at pleaſure by means of the ſtop-cock M.

Things being thus diſpoſed, a crooked red-hot iron wire is thruſt up through the mercury, and made to touch the phoſphorus. This inſtantly kindles the wick, and the alcohol burns. As ſoon as the flame begins to grow dim, the ſtop-cock is turned, and a communication opened between the veſſels S and A; a quantity of oxygen gas ruſhes in, and reſtores the brightneſs of the flame. By repeating this occaſionally, the alcohol may be kept burning for ſome time. It goes out, however, at laſt, notwithſtanding the admiſſion of oxygen gas.

The reſult of this experiment, which Mr Lavoiſier repeated a great number of times, was as follows:

The quantity of alcohol conſumed amounted to 76,7083 grains troy.

The oxygen gas conſumed amounted to 266,82 cubic inches, and weighed 90,506 grains troy.

The whole weight of the ſubſtances conſumed, therefore, amounted to 167,2143 grains.

After the combuſtion, there were found in the glaſs veſſel 115,41 cubic inches of carbonic acid gas, the weight of which was 78,1192 grains troy. There was likewiſe found a conſiderable quantity of water in the veſſel, but it was not poſſible to collect and weigh it. Mr Lavoiſier, however, eſtimated its weight at 89,0951 grains; as he concluded, with reaſon, that the whole of the ſubſtances employed were ſtill in the veſſel. Now the whole contents of the veſſel conſiſted of carbonic acid gas and water; therefore the carbonic acid gas and water together muſt be equal to the oxygen gas and alcohol which had been conſumed.

But 78,1192 grains of carbonic acid gas contain, according to Mr Lavoiſier's calculation[†], 55,279 grains of oxygen: 90,506 grains, however, of oxygen gas had diſappeared; therefore 35,227 grains muſt have been employed in forming water.

35,227 grains of oxygen gas require, in order to form water, 6,038 grains of hydrogen gas; and the quantity of water formed by this combination is 41,265 grains. But there were found 89,095 grains of water in the glaſs veſſel; therefore 47,83 grains of water muſt have exiſted ready formed in the alcohol.

It follows from all theſe data, that the 76,7083 grains of alcohol, conſumed during the combuſtion, were compoſed of

22,840 Carbon,
6,038 Hydrogen,
47,830 Water.
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76,7[*]

Such were the conſequences which Mr Lavoiſier drew from his analyſis. He acknowledged, however, that there were two ſources of uncertainty, which rendered his concluſions not altogether to be depended upon. The firſt was, that he had no method of determining the quantity of alcohol conſumed, except by the difference of weight in the lamp before and after combuſtion; and that therefore a quantity might have evaporated without combuſtion, which, however, would be taken into the ſum of the alcohol conſumed. But this error could not have been great; for if a conſiderable quantity of alcohol had exiſted in the ſtate of vapour in the veſſel, an exploſion would certainly have taken place. The other ſource of error was, that the quantity of water was not known by actual weight, but by calculation.

354 Ingredients of alcohol.

To this we may add, that Mr Lavoiſier was not warranted to conclude from his experiment, that the water found in the veſſel, which had not been formed by the oxygen gas uſed, had exiſted in the alcohol in the ſtate of water: he was intitled to conclude from his data, that the ingredients of that water exiſted in the alcohol before combuſtion; but not that they were actually combined in the ſtate of water, becauſe that combination might have taken place, and in all probability did partly take place, during the combuſtion. It follows, therefore, from Mr Lavoiſier's experiments, that alcohol, ſuppoſing he uſed it perfectly pure, which is not probable, is compoſed of

0,2988 parts carbon,
0,1840 parts hydrogen,
0,5172 parts oxygen.
―――――
1,0000

But it gives us no information whatever of the manner in which theſe ingredients are combined. That alcohol contains oxygen, has been proved by a very ingenious ſet of experiments performed by Meſſrs Fourcroy and Vauquelin. When equal parts of alcohol and ſulphuric acid are mixed together, a quantity of caloric is diſengaged, ſufficient to elevate the temperature of the mixture to 190°. Bubbles of air are emitted, the liquor becomes turbid, aſſumes an opal colour, and at the end of a few days a deep red. When examined, the ſulphuric acid is found to have ſuffered no change; but the alcohol is decompoſed, partly converted into water and partly into ether, a ſubſtance which we ſhall deſcribe immediately. Now, it is evident that the alcohol could not have been converted into water unleſs it had contained oxygen[*].

When equal parts of ſulphuric acid and alcohol are mixed together and heat applied, the mixture boils at 208°,

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[*] Mem. Par. 1781. 493.

[†] Mem. r. 1781.

[*] Mem. Par. 1784.

[*] Nicholſon's Journal, i. 391.

208°, and a liquid equal to half the weight of the alcohol comes over into the receiver. This liquid is *ether*.

355 Ether.

Ether is obſcurely hinted at in ſome of the older chemical authors, but little attention was paid to it till a paper appeared in the Philoſophical Tranſactions for 1730, written by a German, who called himſelf *Frobenius* (G), containing a number of experiments on it. In this paper it firſt received the name of *ether*.

356 Its properties.

Ether is limpid and colourleſs, of a very fragrant ſmell, and a hot pungent taſte. Its ſpecific gravity is 0,7394. It is exceedingly volatile, boiling in the open air at 98°, and in a vacuum at —20°. Were it not therefore for the preſſure of the atmoſphere, it would always exiſt in a gaſeous ſtate. Ether unites with water in the proportion of ten parts of the latter to one of the former*. It is exceedingly inflammable, and, when kindled in the ſtate of vapour, burns with rapidity, or rather explodes, if it be mixed with oxygen gas.

357 Theory of its formation.

Chemiſts entertained various opinions reſpecting the nature of ether. Macquer ſuppoſed that it was merely alcohol deprived by the acid of all its water. But it was generally believed that the acid entered partly into its compoſition. Since the nature of acids has become better known, a great number of philoſophers have ſuppoſed that ether is merely alcohol combined with a quantity of oxygen furniſhed by the acid. The real compoſition of this ſingular ſubſtance has been lately aſcertained by the experiments of Fourcroy and Vauquelin.

" A combination (ſay they) of two parts of ſulphuric acid and one part of alcohol elevates the temperature to 201°, becomes immediately of a deep red colour, which changes to black a few days afterwards, and emits a ſmell perceptibly ethereal.

" When we carefully obſerve what happens in the combination of equal parts of alcohol and concentrated ſulphuric acid expoſed to the action of caloric in a proper apparatus, the following phenomena are ſeen :

" 1. When the temperature is elevated to 208°, the fluid boils, and emits a vapour which becomes condenſed by cold into a colourleſs, light, and odorant liquor, which from its properties has received the name of *ether*. If the operation be properly conducted, no permanent gas is diſengaged until about half the alcohol has paſſed over in the form of ether. Until this period there paſſes abſolutely nothing but ether and a ſmall portion of water, without mixture of ſulphurous or of carbonic acid.

" 2. If the receiver be changed as ſoon as the ſulphurous acid manifeſts itſelf, it is obſerved that no more ether is formed, but the ſweet oil of wine, water, and acetous acid, without the diſengagement hitherto of a ſingle bubble of carbonic acid gas. When the ſulphuric acid conſtitutes about four-fifths of the maſs which remains in the retort, an inflammable gas is diſengaged, which has the ſmell of ether, and burns with a white oily flame. This is what the Dutch chemiſts have called *carbonated hydrogen gas*, or *olefiant gas*, becauſe when mixed with the oxy-muriatic acid it forms oil. At this period the temperature of the fluid contained in the retort is elevated to 230° or 234°.

" 3. When the ſweet oil of wine ceaſes to flow, if the receiver be again changed, it is found that nothing more paſſes but ſulphurous acid, water, carbonic acid gas; and that the reſiduum in the retort is a black maſs, conſiſting for the moſt part of ſulphuric acid thickened by carbon.

" The ſeries of phenomena here expoſed will juſtify the following general inductions :

" 1. A ſmall quantity of ether is formed ſpontaneouſly, and without the aſſiſtance of heat, by the combination of two parts of concentrated ſulphuric acid and one part of alcohol.

" 2. As ſoon as ether is formed, there is a production of water at the ſame time ; and while the firſt of theſe compoſitions takes place, the ſulphuric acid undergoes no change in its intimate nature.

" 3. As ſoon as the ſulphurous acid appears, no more ether is formed, or at leaſt very little ; but then there paſſes the ſweet oil of wine, together with water and acetous acid.

" 4. The ſweet oil of wine having ceaſed to come over, nothing further is obtained but the ſulphurous and carbonic acids, and at laſt ſulphur, if the diſtillation be carried to dryneſs.

" The operation of ether is therefore naturally divided into three periods : the firſt, in which a ſmall quantity of ether and water are formed without the aſſiſtance of heat ; the ſecond, in which the whole of the ether which can be obtained is diſengaged without the accompaniment of ſulphurous acid; and the third, in which the ſweet oil of wine, the acetous acid, the ſulphurous acid, and the carbonic acid, are afforded. The three ſtages have no circumſtance common to all, but the continual formation of water, which takes place during the whole of the operation.

" The ether which is formed without the aſſiſtance of caloric, and the carbon which is ſeparated without decompoſition of the ſulphuric acid, prove that this acid acts on alcohol in a manner totally different from what has hitherto been ſuppoſed. It cannot, in fact, be affirmed, that the acid is altered by the carbon, becauſe daily experience ſhews that no ſenſible attraction takes place between theſe two bodies in the cold; neither can it be affected by the hydrogen ; for in that caſe ſulphurous acid would have been formed, of which it is known that no trace is exhibited during this firſt period. We muſt therefore have recourſe to another ſpecies of action, namely, the powerful attraction exerciſed by the ſulphuric acid upon water. It is this which determines the union of the principles which exiſt in the alcohol, and with which the concentrated acid is in contact : but this action is very limited if the acid be ſmall in quantity ; for an equation of affinity is ſoon eſtabliſhed, the effect of which is to maintain the mixture in a ſtate of repoſe.

" Since it is proved that ether is formed in the cold by the mixture of any quantities of alcohol and ſulphuric acid, it is evident that a maſs of alcohol might be completely changed into ether and vegetable acid by uſing a ſufficient abundance of ſulphuric acid. It is equally evident that the ſulphuric acid would not by this means undergo any other change than that of being diluted with a certain quantity of water. This obſervation proves that alcohol contains oxygen, becauſe water cannot exiſt without this principle, which muſt be afforded by the alcohol only, ſince the ſulphuric acid ſuffers no decompoſition.

" We muſt not, however, imagine, from theſe facts, that ether is alcohol minus oxygen and hydrogen. Its properties alone would contradict this ; for a quantity of carbon proportionally greater than that of the hydrogen

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* Count de Lauraguais.

(G) The name was ſuppoſed to have been feigned.

drogen is at the ſame time ſeparated. It may, in fact, be conceived that the oxygen, which in this caſe combines with the hydrogen to form water, not only ſaturated that hydrogen in the alcohol, but likewiſe the carbon. So that, inſtead of conſidering ether as alcohol minus hydrogen and oxygen, we muſt, by keeping an account of the precipitated carbon and the ſmall quantity of hydrogen contained in the water which is formed, regard it as alcohol plus hydrogen and oxygen.

"The foregoing are the effects produced by a combination of alcohol and ſulphuric acid, ſpontaneouſly produced without foreign heat. Let us, in the next place, obſerve how this combination is effected when caloric is added. The phenomena are then very different, tho' ſome of the reſults are the ſame.

"In the firſt place, we muſt obſerve, that a combination of ſulphuric acid and alcohol in equal parts does not boil at leſs than 207 degrees of temperature, while that of alcohol alone boils at 176. Now ſince ebullition does not take place till the higher temperature, it is clear that the alcohol is retained by the affinity of the ſulphuric acid, which fixes it more conſiderably. Let us alſo conſider that organic bodies, or their immediate products, expoſed to a lively briſk heat, without the poſſibility of eſcaping ſpeedily enough from its action, ſuffer a partial or total decompoſition, according to the degree of temperature. Alcohol undergoes this laſt alteration when paſſed through an ignited tube of porcelain. By this ſudden decompoſition it is converted into water, carbonic acid, and carbon. The reaſon, therefore, why alcohol is not decompoſed when it is ſubmitted alone to heat in the ordinary apparatus for diſtillation, is, that the temperature at which it riſes in vapours is not capable of effecting the ſeparation of its principles; but when it is fixed by the ſulphuric acid or any other body, the elevated temperature it undergoes, without the poſſibility of diſengagement from its combination, is ſufficient to effect a commencement of decompoſition, in which ether and water are formed, and carbon is depoſited. Nothing more therefore happens to the alcohol in theſe circumſtances than what takes place in the diſtillation of every other vegetable matter in which water, oil, acid, and coal, are afforded.

"Hence it may be conceived that the nature of the products of the decompoſition of alcohol muſt vary according to the different degrees of heat; and this explains why at a certain period no more ether is formed but the ſweet oil of wine and acetous acid. In fact, when the greateſt quantity of the alcohol has been changed into ether, the mixture becomes more denſe, and the heat which it acquires previous to ebullition is more conſiderable. The affinity of the acid for alcohol being increaſed, the principles of this acid become ſeparated; ſo that, on the one hand, its oxygen ſeizes the hydrogen, and forms much water, which is gradually volatilized; while, on the other, the ether retaining a greater quantity of carbon, with which at that temperature it can riſe, affords the ſweet oil of wine. This laſt ought therefore to be conſidered as an ether containing an extraordinary portion of carbon, which gives it more denſity, leſs volatility, and a lemon yellow colour.

"During the formation of the ſweet oil of wine, the quantity of carbon which is precipitated is no longer in the ſame proportion as during the formation of ether.

"What we have here ſtated concerning the manner in which ether is formed by the ſimultaneous action of the ſulphuric acid and heat, appears ſo conformable to truth, that nearly the ſame effects may be produced by a cauſtic fixed alkali. In this caſe alſo a kind of ether and a ſweet oil of wine are volatilized, and coal is precipitated. It is therefore only by fixing the alcohol that the ſulphuric acid permits the caloric to operate a ſort of decompoſition. It may alſo be urged as a proof of this aſſertion, that the ſulphuric acid, which has ſerved to make ether as far as the period at which the ſweet oil of wine begins to appear, is capable of ſaturating the ſame quantity of alkali as before its mixture with the alcohol *".

Ether may alſo be obtained by means of ſeveral other acids. The different liquids thus formed are diſtinguiſhed by prefixing the name of the acid uſed in the proceſs. Thus the ether above deſcribed is called *ſulphuric ether;* that obtained by means of nitric acid, *nitric ether,* and ſo on. There are ſeveral minute ſhades of difference between theſe various ethers, which have not yet been properly inquired into.

358 Subſtances ſoluble in alcohol.

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

I. *Subſtances diſſolved in large Quantities.*

Names of the Subſtances.	Temperature.	240 parts of alcohol diſſolve
Nitrat of cobalt -	54,5°	240parts
copper -	54,5	240
alumina -	54,5	240
magneſia -	180,5	694
Muriat of zinc -	54,5	240
alumina -	54,5	240
magneſia -	180,5	1313
iron - -	180,5	240
copper - -	180,5	240
Acetite of lead - -	113	
copper †		
Benzoic acid - - -	135,5	
Sulphat of magneſia		
Nitrat of zinc decompoſed		
iron decompoſed		
biſmuth decompoſed		

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* Nicholſon's Journ. i. 391.

† Withering, Phil. Tranſ. lxxii. 336.

II. *Subſtances diſſolved in ſmall Quantities.*

Names of the Subſtances.	240 parts of alcohol at the boiling temperature diſſolve
Muriat of lime	240 parts
Nitrat of ammonia	214
Oxy-muriat of mercury	212
Succinic acid	177
Acetite of ſoda	112
Nitrat of ſilver	100
Refined ſugar	59
Boracic acid	48
Nitrat of ſoda	23
Acetite of copper	18
Muriat of ammonia	17
Arſeniat of potaſs	9
Acidulated oxalat of potaſs	7
Nitrat of potaſs	5
Muriat of potaſs	5
Arſeniat of ſoda	4
Barytes	
Strontites	
White oxide of arſenic	3
Tartrat of potaſs	1
Phoſphorus	
Nitrat of lead [*]	
lime [*]	
Muriat of mercury [†]	
Carbonat of ammonia [*]	

III. *Subſtances inſoluble with Alcohol.*

Sugar of milk,
Borax,
Tartar,
Alum,
Sulphat of ammonia,
  lime,
  barytes [‡],
  iron (green),
  copper,
  ſilver,
  mercury,
  zinc,
  potaſs,
Sulphat of ſoda,
  magneſia,
Sulphite of ſoda,
Tartrite of ſoda and potaſs,
Phoſphoric acid,
Nitrat of lead,
  mercury,
Muriat of lead,
  ſilver [§],
Common ſalt,
Carbonat of potaſs,
  ſoda.

Theſe have been chiefly borrowed from tables which Mr de Morveau publiſhed in the *Journal de Phyſique* July 1785, and which were drawn up for the moſt part from the experiments deſcribed in Wenzel's Treatiſe on Affinities.

359 Its affinities.

The affinities of alcohol are very imperfectly known. Thoſe ſtated by Bergman are as follows:

Water,
Ether,
Volatile oil,
Sulphurets of alkalies.

Chap. III. *Of* Oils.

360 Diſcovery of oil.

Oil, which is of ſuch extenſive utility in the arts, was known at a very remote period. It is mentioned in Geneſis, and during the time of Abraham was even uſed in lamps [*]. The olive was very early cultivated, and oil extracted from it in Egypt. Cecrops brought it from Sais, a town in Lower Egypt, where it had been cultivated from time immemorial, and taught the Athenians to extract oil from it. In this manner the uſe of oil became known in Europe [†]. But the Greeks ſeem to have been ignorant of the method of procuring light by means of lamps till after the ſiege of Troy [‡]; at leaſt Homer never mentions them, and conſtantly deſcribes his heroes as lighted by torches of wood.

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

361 Fixed oils.

I. The fixed oils, called alſo *fat* or *expreſſed* oils, are numerous, and are obtained, partly from animals and partly from vegetables, by ſimple expreſſion. As inſtances, we ſhall mention whale oil or train oil, obtained from the blubber of the whale; olive oil, obtained from the fruit of the olive; lintſeed oil and almond oil, obtained from lintſeed and almond kernels. Fixed oils may alſo be obtained from poppy ſeeds, hemp ſeeds, beech maſt, and many other vegetable ſubſtances.

All theſe oils differ from each other in ſeveral particulars, but they alſo poſſeſs many particulars in common. Whether the oily principle in all the fixed oils is the ſame, and whether they owe their differences to accidental ingredients, is not yet completely aſcertained, as no proper analyſis has hitherto been made; but it is exceedingly probable, as all the oils hitherto tried have been found to yield the ſame products. In the preſent ſtate of our knowledge, it would be uſeleſs to give a particular deſcription of all the fixed oils, as the differences between them have not even been accurately aſcertained. We ſhall content ourſelves, therefore, with giving the characters which diſtinguiſh fixed oils in general, and an analyſis of one oil, by way of ſpecimen.

362 Their properties.

Fixed oils are inſoluble in alcohol, which diſtinguiſhes them from volatile oils. They are alſo inſoluble in water.

They have an unctuous feel, are tranſparent while fluid, are deſtitute of ſmell, and have a mild inſipid kind of taſte.

They are all ſuſceptible of becoming ſolid by expoſure to a ſufficient degree of cold. Olive oil and almond oil freeze at 10½ degrees [‡].

They are capable of being converted into vapour by heat; but require for that purpoſe a temperature conſiderably ſuperior to that of boiling water. Olive oil boils at 600°, and moſt of the fixed oils hitherto tried require nearly the ſame degree of heat.

When in the ſtate of vapour they take fire on the approach of an ignited body, and burn with a yellowiſh white flame. It is upon this principle that candles and lamps burn. The tallow or oil is firſt converted into the ſtate of vapour in the wick; it then takes fire, and ſupplies a ſufficient quantity of heat to convert more oil into vapour; and this proceſs goes on while any oil remains. The wick is neceſſary to preſent a ſufficiently ſmall quantity of oil at once for the heat to act upon. If the heat were ſufficiently great to keep the whole oil at the temperature of 600°, no wick would be neceſſary, as is obvious from oil catching fire ſpontaneouſly when it has been raiſed to that temperature.

363 Analyſis of olive oil.

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

The

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[*] Withering, Phil. Tranſ. lxxii. 336.

[†] Macquer, ibid.

[‡] Witbering, Ibid.

[§] Macquer, ibid.

[*] Gen. xv. 17.

[†] Herodot. lib. ii. 59. and 62.

[‡] Chaptal's Chemiſtry, Engliſh Tranſl. iii. 43.

The quantity of oil conſumed amounted to 15,79 grains troy.

The quantity of oxygen gas amounted to 50,86 gr. troy. The whole amount therefore of the ſubſtances conſumed during the combuſtion is 66,65 grains troy.

The carbonic acid obtained amounted to 44,50 gr. There was alſo a conſiderable quantity of water, the weight of which could not be accurately aſcertained: but as the whole of the ſubſtances conſumed were converted into carbonic acid gas and water, it is evident that if the weight of the carbonic acid be ſubtracted from the weight of theſe ſubſtances, there muſt remain preciſely the weight of the water. Mr Lavoiſier accordingly concluded, by calculation, that the weight of the water was 22,15 grains. Now the quantity of oxygen in 44,50 grains of carbonic acid gas is 32,04 grains, and the oxygen in 22,15 grains of water is 18,82 grains; both of which taken together amount to 50,86 grains, preciſely the weight of the oxygen gas employed. There does not appear therefore to be any oxygen in olive oil.

The quantity of carbon in 44,50 grains of carbonic acid gas is 12,47 grains; and the quantity of hydrogen in 22,15 grains of water is 3,32 grains; both of which, when taken together, amount to 15,79 grains, which is the weight of the oil conſumed.

It follows, therefore, from this analyſis, that 15,79 grains of olive oil are compoſed of

12,47 Carbon,
3,32 Hydrogen.

Olive oil therefore is compoſed of about

79 Carbon,
21 Hydrogen.
100*

In what manner theſe ſubſtances are combined, cannot be learned from this analyſis. Whether they combine directly, and ſaturate each other in that proportion, as is moſt probable -or whether the hydrogen is combined previouſly with a part of the carbon, and that compound combining with a certain quantity of carbon, forms oil, is altogether uncertain. Yet theſe queſtions are of the utmoſt importance; and till the method of ſolving them be diſcovered, we never can acquire any preciſe ideas about the conſtituent parts of a great number of ſubſtances, which, though formed ultimately of the ſame ingredients, differ very much in their properties from one another; as wax and oil; alcohol, ſugar, and ether.

364
Rancidity.

When fixed oils are expoſed to the atmoſphere, they become thick, acquire a brown colour, and a peculiarly unpleaſant ſmell: they are then ſaid to be *rancid.* When oil is poured upon water, ſo as to form a thin layer on its ſurface, and is in that manner expoſed to the atmoſphere, theſe changes are produced much ſooner, the oil becomes thicker, and aſſumes an appearance very much reſembling wax. Berthollet, who firſt examined theſe phenomena with attention, aſcribed them to the action of light: but Sennebier obſerved, that no ſuch change was produced on the oil though ever ſo long expoſed to the light, provided atmoſpherical air was excluded; but that it took place on the admiſſion of oxygen gas, whether the oil was expoſed to the light or not *. It cannot be doubted, then, that it is owing to the combination of oxygen. All ſubſtances that are capable of ſupplying that principle, the metallic oxides for inſtance, and ſeveral of the acids, produce the ſame effect upon oils; and it is a known fact, that oil is capable of reducing many of the metallic oxides to the metallic ſtate, and conſequently that it has a ſtronger affinity for oxygen.

Mr Chaptal has ſuppoſed that oils become rancid merely becauſe they contain a quantity of mucilage, with which the oxygen combines; and that when oxygen combines with fixed oils, it produces a different effect, converting them into what is called *drying oils.*

It is certain that oils contain a quantity of mucilage; but ſome change is evidently produced on the oils themſelves by rancidity; for no agitation in water is capable of reſtoring them to their former ſtate, although water deprives them of their mucilage.

365
Drying oils.

Drying oils, ſo called becauſe they are capable of *drying* completely when ſpread out, a property which renders them uſeful in painting, ſeem, as Sennebier obſerves, to be completely deprived of mucilage; for, in order to render an oil drying, it muſt be boiled, which evaporates or decompoſes all the mucilage: they ſeem alſo to loſe part of their hydrogen †.

366
Fixed oils diſſolve ſulphur.

Fixed oils are capable of diſſolving ſulphur at their boiling temperature. The ſolution is very fetid, owing to a partial decompoſition of the oil. Hydrogen gas flies off, having a quantity of ſulphur diſſolved in it. When the ſolution cools, the ſulphur cryſtallizes.

367
And phoſphorus.

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

Fixed oils are capable of combining with many of the metallic oxides. The compounds are called *metallic ſoaps.* Several of the oxides are decompoſed by being boiled in oils.

Fixed oils combine alſo with the alkaline earths and with alumina. The compounds are called *earthy ſoaps.*

368
Their affinities.

The affinities of the oils are as follows:

Lime,
Barytes,
Fixed alkalies,
Magneſia,
Ammonia,
Oxide of mercury,
Other metallic oxides (H),
Alumina.

Nitric acid,
Muriatic,
Sulphurous,
Sulphuric,
Acetous,
Sulphur,
Phoſphorus (I).

369
Volatile oils.

II. Volatile oils, called alſo *eſſential oils,* are all obtained from vegetables. They have a ſtrong aromatic ſmell, and a pungent acrid taſte. They are ſo volatile that they may be diſtilled by the heat of boiling water. They are ſoluble in alcohol, but not in water. They evaporate on the application of heat, without leaving any ſtain behind them, which is not the caſe with the fixed oils. By this teſt, accordingly, it is eaſy to diſcover whether they have been adulterated with any of the fixed oils. Let a drop of the volatile oil fall upon a ſheet of writing paper, and then apply a gentle heat

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* Mem. Par. 1784. and Jour. de Phyſ. for 1787, July.

* Ann. de Chim. xl. 3).

† Berthollet.

(H) Their order not well aſcertained.

(I) The firſt column was aſcertained by Berthollet. The laſt is to be conſidered as unconnected with the firſt. On account of the affinity of theſe two claſſes of bodies for each other, it has not been poſſible to diſcover which of them has the greateſt affinity for oil.

heat to it. If it evaporates without leaving any ſtain upon the paper, the oil is pure; but if it leaves a ſtain, it has been contaminated with ſome fixed oil or other.

Volatile oils are very numerous, and differ from one another, in fluidity and weight, in their freezing point, and in ſeveral other particulars. Little attention has been paid to the greateſt part of them, becauſe few of them have been found of any uſe. The principal quality for which they are valued is their odour. Some of them are obtained by expreſſion, as oil of bergamot, lemons, oranges; others by diſtillation, as oil of peppermint, thyme, lavender, &c. It would be uſeleſs, even if it were poſſible, to give a particular deſcription of all the volatile oils.

370 Their properties. They are more inflammable than the fixed oils; a quality which they owe to their volatility. As far as experiments have hitherto been made, they ſeem to conſiſt of carbon and hydrogen; but nothing is known concerning the proportions of theſe ingredients. They thicken when expoſed to the air, probably by combining with oxygen, and form *reſins* (K).

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

They diſſolve ſulphur, and form what have been called *balſams of ſulphur*.

They are capable of combining with moſt of the ſubſtances that unite with fixed oils. Their affinities, which certainly differ from thoſe of fixed oils, have not yet been properly aſcertained.

Chap. IV. *Of* Alkalies.

371 Properties of alkalies. Substances poſſeſſed of the following properties are called *alkalies*:

1. Incombuſtible.
2. Capable of converting vegetable blues to a green.
3. A hot cauſtic taſte.
4. Very ſoluble in water, even when combined with carbonic acid.

There are three alkalies, *potaſs*, *ſoda*, and *ammonia*. The two firſt are called *fixed* alkalies, becauſe a very violent heat is neceſſary to volatilize them; the laſt is called *volatile* alkali, becauſe it very eaſily aſſumes a gaſeous form, and is conſequently diſſipated by a very moderate degree of heat.

Sect. I. *Of Potaſs*.

372 Method of procuring potaſs. If a ſufficient quantity of wood be burnt to aſhes, and theſe aſhes be afterwards waſhed repeatedly with water till it comes off free from any taſte, and if this liquid be filtrated and evaporated to dryneſs, the ſubſtance which remains behind is *potaſs*; not, however, in a ſtate of purity, for it is contaminated with ſeveral other ſubſtances; but ſufficiently pure to exhibit many of its properties. In this ſtate, it occurs in commerce under the name of *potaſh*. It may be purified conſiderably, by putting it in a crucible, keeping it red hot for ſome time; then diſſolving it in water, filtrating it, and evaporating it again to dryneſs. By the following method it may be obtained nearly pure: Mix together equal quantities of nitre and carbon, and put them by little and little into a red hot crucible. They burn with a vivid flame, and leave behind them a quantity of potaſs. This is to be diſſolved in water, filtrated, and evaporated to dryneſs. Or potaſs may be obtained by burning tartar wrapt up in brown paper and placed in a crucible (M).

The potaſs procured by theſe laſt proceſſes is exceedingly white; it is not, however, quite pure; for it is combined with a ſubſtance which blunts all its properties conſiderably. This ſubſtance is carbonic acid gas; from which it may be ſeparated by diſſolving it, and mixing with it an equal quantity of lime made into a paſte with water. The lime has a greater affinity for carbonic acid gas, and therefore combines with it; and the pure potaſs remains diſſolved in the water, and may be ſeparated from the lime by filtrating the mixture This proceſs, however, muſt be performed in cloſe veſſels; for there is a little carbonic acid gas in the atmoſphere, which would again combine with the potaſs if it were allowed to ſtand expoſed to the air.

It is then to be evaporated till a thick pellicle appears on its ſurface, and afterwards allowed to cool; and all the cryſtals which have formed are to be ſeparated, for they conſiſt of foreign ſalts. The evaporation is then to be continued in an iron pot; and, during the proceſs, the pellicle which forms on the ſurface is to be carefully taken off with an iron ſkimmer. When no more pellicle appears, and when the matter ceaſes to boil, it is to be taken off the fire, and muſt be conſtantly agitated while cooling with an iron ſpatula. It is then to be diſſolved in double its own weight of cold water. This ſolution is to be filtered and evaporated in a glaſs retort till it begin to depoſite regular cryſtals. If the maſs conſolidates ever ſo little by cooling, a ſmall quantity of water is to be added, and it muſt be heated again. When a ſufficient number of cryſtals have been formed, the liquor which ſwims over them, and which has aſſumed a very brown colour, muſt be decanted off, and kept in a well-cloſed bottle till the brown matter has ſubſided, and then it may be evaporated as before, and more cryſtals obtained. The cryſtals may then be diſſolved in pure water. By this proceſs, which was invented by Mr Lowitz of Peterſburgh *, potaſs may be obtained in a ſtate of the greateſt purity. The ſhape of its cryſtals is very different, according to the way in which they have been produced. When allowed to form in the cold, they are octahedrons in groups, and contain 0,43 of water: When formed by evaporation

* Nicholſon's i. 164.

(K) Reſins are concrete vegetable juices; the diſtinguiſhing property of which is inſolubility in water and ſolubility in alcohol. *Common reſin*, or *roſin*, from which they derive their name, is one of them; and ſealing wax conſiſts almoſt entirely of another.

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

(M) That potaſs was known to the ancient Gauls and Germans, cannot be doubted, as they were the inventors of ſoap, which, Pliny informs us, they compoſed of aſhes and tallow. Theſe aſhes (for he mentions the aſhes of the beech tree particularly) were nothing elſe but potaſs; not, however, in a ſtate of purity. *Plinii*, lib. xviii. c. 51. The κονια, too, mentioned by Ariſtophanes and Plato, appears to have been a ley made of the ſame kind of aſhes.

tion on the fire, they aſſume the figure of very thin tranſparent blades of extraordinary magnitude, which, by an aſſemblage of lines croſſing each other in prodigious numbers, preſent an aggregate of cells or cavities, commonly ſo very cloſe, that the veſſel may be inverted without loſing one drop of the liquid which it contains†.

Pure potaſs is ſo exceedingly corroſive, that when applied to any part of the body, it deſtroys it almoſt inſtantaneouſly. On account of this property, it has been called *cauſtic*, and is often uſed by ſurgeons under the name of the *potential cautery*, to open abſceſſes, and deſtroy uſeleſs or hurtful excreſcences.

373
Black's diſcovery of the cauſe of its cauſticity.

As potaſs is never obtained at firſt in a ſtate of purity, but always combined with carbonic acid, it was long before chemiſts underſtood to what the changes produced upon it by lime were owing. According to ſome, it was deprived of a quantity of mucilage, in which it had formerly been enveloped; while, according to others, it was rendered more active by being more comminuted. At laſt, in 1756, Dr Black publiſhed the celebrated experiments which we have ſo often mentioned; in which he proved, by the moſt ingenious and ſatisfactory analyſis, that the *potaſs* which the world had conſidered as a ſimple ſubſtance, was really a compound, conſiſting of potaſs and carbonic acid; that lime deprived it of this acid; and that it became more active by becoming more ſimple.

374
Meyer's theory.

While Dr Black was thus occupied in Scotland, Mr Meyer was employed in Germany in the ſame reſearches; from which, however, he drew very different concluſions. His Eſſays on Lime appeared in 1764. Pouring into lime-water a ſolution of potaſs (*carbonat of potaſs*), he obtained a precipitate, which he found not to differ from limeſtone. The alkali had therefore deprived the lime of its cauſticity and its active properties; and theſe very properties it had itſelf acquired. From which he concluded, that the cauſticity of lime was owing to a particular acid with which it had combined during its calcination. The alkali deprived the lime of this acid, and therefore had a ſtronger affinity for it. To this acid he gave the name of *acidum pingue* or *cauſticum*. It was, according to him, a ſubtile elaſtic mixt, analogous to ſulphur, approaching very nearly to the nature of fire, and actually compoſed of an acid principle and fire. It was expanſible, compreſſible, volatile, aſtringent, capable of penetrating all veſſels, and was the cauſe of cauſticity in lime, alkalies, and metals. This theory was exceedingly ingenious, and it was ſupported by a vaſt number of new and important facts. But notwithſtanding the reputation and acknowledged genius and merit of its author, it never gained many followers; becauſe the true theory of cauſticity, which had been already publiſhed by Dr Black, ſoon became known on the continent; and, notwithſtanding ſome oppoſition at firſt, ſoon carried conviction into every unprejudiced mind. Even Mr Meyer himſelf readily acknowledged its truth and importance, though he did not at firſt, on that account, give up his own theory.

When potaſs is expoſed to the action of fire, it firſt becomes ſoft, and melts into a tranſparent liquid at the commencement of ignition.

When expoſed to the air, it attracts moiſture very faſt, and is ſoon converted into a liquid. It attracts, at the ſame time, carbonic acid gas, for which it has a very ſtrong affinity. It is impoſſible, then, to keep potaſs in a ſtate of purity, except in very cloſe veſſels.

375
Sulphuret of potaſs.

It unites readily with ſulphur, and forms *ſulphuret of potaſs*. This compound may be formed two ways; either by melting the ingredients together, or by boiling them in water, and then filtrating the ſolution. Sulphuret of potaſs when dry, in which ſtate it is obtained by the firſt proceſs, is of a brown colour. It is ſoluble in water, and very ſoon attracts moiſture.

While dry it produces no change upon the air of the atmoſphere, as Meſſrs Dieman, Van Trooſtwyck, Nieuwland, and Bondt, aſcertained by experiment *. But when moiſtened with water, it very ſoon abſorbs all the oxygen gas which happens to be in the veſſel in which it is encloſed, and leaves nothing but azotic gas. This fact was firſt obſerved by Scheele, and induced him to uſe ſulphuret of potaſs for an *eudiometer*, or inſtrument to meaſure the quantity of oxygen contained in any given portion of atmoſpheric air.

If ſulphuret of potaſs be allowed to remain moiſt, and in contact with the atmoſphere, it is gradually converted into ſulphat of potaſs by the ſulphur combining with oxygen, and forming ſulphuric acid. At the ſame time the ſulphuret emits a fetid ſmell, which is known to be the odour of ſulphurated hydrogen gas. The ſulphuret then decompoſes the water with which it is mixed. Very little ſulphurated hydrogen gas, however, is emitted, except an acid (the ſulphuric, for inſtance) be poured upon the mixture, and then it is given out very copiouſly. The reaſon of this is, that there is an affinity between the potaſs and this gas. Accordingly it is retained by the potaſs after it is formed. But as the acids have a much ſtronger affinity for potaſs, as ſoon as any of them is poured in the gas is obliged to ſeparate †.

If liquid ſulphuret of potaſs be kept in cloſe veſſels, it is not decompoſed except in part; becauſe as ſoon as the alkali is ſaturated with the ſulphurated hydrogen gas, the action of the ſulphur on the water is at an end ‡.

The explanation of the action of this ſulphuret on the atmoſphere, which the Dutch chemiſts above-mentioned give from theſe data, is as follows:

Sulphuret of potaſs decompoſes water; ſulphurated hydrogen gas is formed, and abſorbed by the alkali. This gas has a ſtrong affinity for oxygen, which it abſorbs from the atmoſphere: the hydrogen combines with this oxygen, and forms water; and the ſulphur is again precipitated, or rather left combined with the potaſs. Water is again decompoſed by the attraction of the ſulphur for oxygen; new ſulphurated hydrogen gas is again formed; again abſorbed; again attracts oxygen gas; and is again decompoſed. And this proceſs goes on till the whole of the ſulphur has combined with oxygen, and conſequently till the ſulphuret is converted into a ſulphat §.—The only part of this theory which requires confirmation, is the action of ſulphurated hydrogen gas on oxygen gas, and the conſequent formation of water. And this they have rendered not improbable, by ſhewing that ſulphurated hydrogen gas combined with alkali has the property of abſorbing oxygen gas from the atmoſphere ||.

376
Phoſphuret of potaſs.

Potaſs unites with phoſphorus by fuſion, and forms a phoſphuret of potaſs. Little is known concerning its properties, except that it produces phoſphurated hydrogen gas.

Potaſs ſeems alſo capable of combining with carbon.

Potaſs does not combine with the metals; but it unites with many of their oxides.

When

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* Nicholſon, i. 164.

* Ann. de Chim. xiv. 294.

† Ibid.

‡ Ibid.

§ Ibid.

|| Ibid. p. 305.

When a ſolution of potaſs is boiled upon ſilica recently procured, it diſſolves part of it. As the ſolution cools, it aſſumes the appearance of a jelly, even though previouſly diluted with 17 times its own weight of water *.

* Bergman, ii. 32.

377 Glaſs. When equal parts of ſilica and potaſs are melted together, they combine and form *glaſs*. A ſubſtance which, whether we conſider its hardneſs, beauty, and tranſparency, its amazing ductility, while hot, or the difficulty of decompoſing it, muſt be allowed to be one of the moſt uſeful compounds ever invented by man.

When the quantity of potaſs is double or triple that of the ſilica, the glaſs is ſoluble in water, and forms what is called *liquor ſilicum*.

Potaſs ſeems alſo capable of combining in the ſame manner with barytes, lime, magneſia, and alumina; but theſe combinations have never been examined with attention. Lime, however, is often added to the materials for making glaſs, and is ſuppoſed to increaſe its hardneſs and ſolidity.

The metallic oxides have the property of rendering glaſs more fuſible, and of communicating various colours to it; they accordingly very often make a part of its compoſition. The colours communicated by theſe oxides will appear from the following Table:

Metallic Oxides.	Colour communicated to Glaſs.
Oxide of gold and tin, -	Purple.
Silver, - - -	Yellow or golden.
Iron, - - -	Pale green.
Lead, - - -	Colourleſs.
Zinc, - - -	White.
Antimony, -	Green (N).
Arſenic, - -	White.
Cobalt, - - -	Blue.
Nickel, - - -	Blue (O).
Mangaueſe, -	Red.
Tungſten, - -	Colourleſs.
Molybdenum, -	Colourleſs.
Uranium, - -	Grey (opaque).
Titanium, - -	White (opaque).
Tellurium, - -	White.
Chromum, - -	Green.

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

379 Potaſs, whether a compound. Potaſs has never yet been decompoſed. Several chemiſts, indeed, have conjectured, that it was a compound of lime and azot; and ſome perſons have even endeavoured to prove this by experiment; but none of their proofs are at all ſatisfactory. We ought, therefore, in ſtrict propriety, to have aſſigned it a place in the firſt part of this article: but this would have ſeparated the alkalies from each other, and would have introduced a confuſion into the article, which would have more than counterbalanced the logical exactneſs of the arrangement. Beſides, we are certain, from a variety of facts, that all the alkalies are compounds: One of them has actually been decompounded; and the other two have been detected in the act of formation, though the ingredients which compoſe them have not hitherto been diſcovered.

Whether potaſs contains lime is a different queſtion. Were we to judge from analogy, we ſhould ſuppoſe, that the four alkaline earths, and the three alkalies, poſſeſs one common principle. They have a great number of common properties, and perhaps ought to be claſſed altogether under the name of *alkalies*.

That azot enters into the compoſition of all theſe bodies, as Fourcroy has conjectured, is far from improbable. One alkali, as we ſhall ſoon ſee, actually contains azot. But no concluſion can be drawn till future diſcoveries have lifted off the veil which at preſent obſtructs our view.

380 Its affinities. The affinities of potaſs are as follows:

Sulphuric acid,
Nitric,
Muriatic,
Sebacic,
Fluoric,
Phoſphoric,
Oxalic,
Tartarous,
Arſenic,
Succinic,
Citric,
Formic,
Lactic,
Benzoic,
Sulphurous,
Acetous,
Saccholactic,
Boracic,
Nitrous,
Carbonic,
Pruſſic,
Oil,
Sulphur,
Phoſphorus,
Water.

The place of the metallic oxides has not yet been aſcertained.

SECT. II. *Of Soda.*

SODA, called *mineral alkali*, becauſe it is found in the earth, was known to the ancients under the names of νιτρον and *nitrum* (P). It was long confounded with potaſs; and perhaps was never properly diſtinguiſhed from it till Du Hamel publiſhed a paper on the ſubject in 1736.

381 Properties of ſoda. Its properties, while pure, are preciſely the ſame with thoſe of potaſs, excepting only that its affinity for other bodies is not ſo ſtrong; it does not, therefore, require any particular deſcription. We ought to mention, however, that it differs from potaſs in one particular; potaſs attracts moiſture in the air, but ſoda parts with it, and when expoſed to the atmoſphere, ſoon crumbles down into a dry powder.

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

It

(N) If the glaſs be made with ſoda.

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

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

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

Some chemiſts have ſuppoſed that it is compoſed of magneſia and azot; but their proofs are inſufficient.

The order of its affinities is the ſame with that of potaſs.

Sect. III. *Of Ammonia.*

382 Diſcovery of ammonia.

Ammonia (q), volatile alkali, or *hartſhorn*, as it is called in commerce, is mentioned as early as the 15th century. Both Baſil Valentine and Raymond Lully deſcribed the methods of procuring it. Dr Black was the firſt who diſtinguiſhed pure ammonia from the carbonat of ammonia, or ammonia combined with carbonic acid; and Dr Prieſtley firſt diſcovered the method of obtaining it in a ſtate of complete purity.

To obtain pure ammonia, mix common ſal ammoniac with three parts of ſlacked lime; apply heat; and receive the product in a veſſel filled with mercury ſtanding in a baſon of mercury. A gas comes over, which is pure ammonia[*]. This gas is tranſparent like common air, and is not condenſed by cold.

383 Its properties.

Its ſpecific gravity is 0,000732. It is to common air as 600 to 1000[†].

It has a very ſtrong, but not unpleaſant ſmell. Animals cannot breathe it without death. When a lighted candle is let down into this gas, it goes out three or four times ſucceſſively; but at each time the flame is conſiderably enlarged by the addition of another flame of a pale yellow colour, and at laſt this flame deſcends from the top of the veſſel to the bottom[‡].

Water abſorbs this gas with avidity. It diſappears almoſt inſtantly on the introduction of a little water. From an experiment of Dr Prieſtley, it appears that water ſaturated with this gas is of the ſpecific gravity 1,1435[§].

This water acquires the ſmell of ammonia. It has a very ſtrong diſagreeable taſte, and converts vegetable colours to a green.

Ammonia in the ſtate of gas has no effect upon ſulphur or phoſphorus. Carbon abſorbs it; probably becauſe it contains water. Neither hydrogen nor azot produce any alteration on it[||].

Alcohol and ether abſorb it in conſiderable quantity[¶].

384 Its component parts.

Dr Prieſtley diſcovered, that when electric exploſions were made to paſs through this gas, its bulk was gradually augmented to thrice the ſpace which it formerly occupied. It was then moſtly converted into hydrogen gas. He diſcovered, too, that heat produced the very ſame effect[*]. Theſe experiments prove that hydrogen enters as an ingredient into the compoſition of ammonia.

Mr Scheele obſerved, that when ammonia was treated with the oxides of mangareſe, gold, or mercury, the oxides were reduced; the ammonia diſappeared; and nothing remained but a quantity of azotic gas. Theſe facts induced Bergman to conjecture, that ammonia was compoſed of hydrogen and azot: a conjecture which has been fully confirmed by the experiments of Berthollet.

This ingenious chemiſt obſerved, that if oxy-muriatic acid and ammonia be mixed, an efferveſcence takes place; azot is diſengaged, a quantity of water formed, and the oxy-muriatic acid is converted into common muriatic acid. Now the ſubſtances mixed were ammonia and oxy-muriatic acid, which is compoſed of oxygen and muriatic acid; the products were, muriatic acid, azot, and water, which is compoſed of oxygen and hydrogen. The oxygen of the water was furniſhed by the acid; the other products muſt have been furniſhed by the ammonia, which has diſappeared. Ammonia, therefore, muſt be compoſed of azot and hydrogen. Mr Berthollet proved, that ammonia was compoſed of theſe ingredients by a number of other experiments. For inſtance, if the oxide of copper be heated in contact with ammoniacal gas, it is reſtored to the metallic ſtate; the ammonia diſappears, a quantity of water is formed, and azotic gas is diſengaged. It follows from Mr Berthollet's experiments, that ammonia is compoſed of 121 parts of azot and 29 of hydrogen[*]. According to Dr Auſtin, it is compoſed of 121 parts of azot, and 32 of hydrogen[†].

385 Formation of ammonia.

After the compoſition of ammonia had been thus aſcertained, it became a queſtion of ſome conſequence, Whether it could be formed artificially? Dr Auſtin accordingly mixed hydrogen and azotic gas together in the proper proportions, and endeavoured to make them combine by the application of heat, by electricity, and by cold; but he found, that while theſe two ſubſtances were in a gaſeous ſtate, they could not be combined by any method which he could deviſe. It could not be doubted, however, that the combination often takes place when theſe bodies are preſented to each other in a different form. Dr Prieſtley[‡] and Mr Kirwan[||] had actually produced it, even before its compoſition was known. Accordingly he found, that when tin is moiſtened with nitric acid, and after being allowed to digeſt for a minute or two, a little potaſs or lime is added, ammonia is immediately exhaled[§]. In that caſe, the nitric acid and the water which it contains are decompoſed; the oxygen of each unites with the tin, and reduces it to the ſtate of an oxide; and at the ſame time the hydrogen of the water combines with the azot of the acid, and forms ammonia, which is driven off by the ſtronger affinity of the potaſs or lime. Dr Auſtin ſucceeded alſo in forming ammonia by ſeveral other methods. He introduced into a glaſs tube filled with mercury a little azotic gas, and then put into the gas ſome iron filings moiſtened with water. The iron decompoſes the water and combines with its oxygen; and the hydrogen meeting with azot at the moment of its admiſſion, combines with it, and forms ammonia. This experiment ſhews, that the gaſeous ſtate of the azot does not prevent its combination with hydrogen.

336 Sulphuret of ammonia.

Ammonia may be combined with ſulphur by mixing together two parts of muriat of ammonia (ammonia combined with muriatic acid), two parts of lime, and one part of ſulphur, and diſtilling; a yellow liquor is obtained, which contains ſulphuret of ammonia. It is capable of cryſtallizing.

The phoſphuret of ammonia is unknown.

Ammonia is capable of combining with ſeveral of the metallic oxides, particularly copper.

It combines with fixed oils, and forms *ſoap*.

The order of its affinities is preciſely the ſame with that of the fixed alkalies.

Chap.

[*] Prieſtley on Air, iii. 371.

[†] Kirwan on Phlog. p. 28.

[‡] Prieſtley, ii. 381.

[§] Ibid. p. 372.

[||] Ibid. p. 377.

[¶] Ibid.

[*] Ibid. 389.

[*] Mem. Par. 1785.

[†] Phil. Tranſ. 1788.

[‡] On Air, ii. 41.

[||] On Hepatic Air, § iii.

[§] Dr Auſtin.

(q) We have adopted this word, which is Dr Black's, becauſe we think it preferable to *ammoniac* or *ammoniaca*, the words propoſed and uſed by the French chemiſts.

CHAP. V. *Of* ACIDS.

387 Properties of acids. SUBSTANCES poſſeſſed of the following properties are denominated *acids*.

1. When applied to the tongue they excite that ſenſation which is called *ſour* or *acid*.

2. They change the blue colours of vegetables to a red. The vegetable blues employed for this purpoſe are generally tincture of litmus and ſyrup of violets or of radiſhes, which have obtained the name of *reagents* or *teſts*. If theſe colours have been previouſly converted to a *green* by alkalies, the acids reſtore them again.

3. They unite with water in almoſt any proportion.

4. They combine with all the alkalies, and moſt of the metallic oxides and earths, and form with them thoſe compounds which are called *neutral ſalts*.

It muſt be remarked, however, that every acid does not poſſeſs all theſe properties; but all of them poſſeſs a ſufficient number of them to diſtinguiſh them from other ſubſtances. And this is the only purpoſe which artificial definition is meant to anſwer.

388 Theories about the acid principle. Paracelſus believed that there was only one acid principle in nature, which communicated taſte and ſolubility to the bodies in which it was combined. Becher embraced the ſame opinion; and added to it, that this acid principle was a compound of earth and water, which he conſidered as two elements. Stahl adopted the theory of Becher, and endeavoured to prove, that his acid principle was ſulphuric acid; of which, according to him, all the other acids were mere compounds. But his proofs were only conjectures or vague experiments, from which nothing could be deduced. Nevertheleſs, his opinion, like every other which he advanced in chemiſtry, continued to have ſupporters for a long time, and was even countenanced by Macquer. At laſt its defects began to be perceived; Bergman and Scheele declared openly againſt it; and their diſcoveries, together with thoſe of the French chemiſts, notwithſtanding the ill-natured attempts of Monnet to ſupport it, demonſtrated the falſehood of both parts of the theory, by ſhewing that ſulphuric acid did not exiſt in the other acids, and that it was not compoſed of water and earth, but of ſulphur and oxygen.

The opinion, however, that acidity is owing to ſome principle common to all the ſalts, was not abandoned. Wallerius, Meyer, and Sage, had advanced different theories in ſucceſſion about the nature of this principle; but as they were founded rather on conjecture and analogy than direct proof, they obtained but few advocates.

389 Lavoiſier's theory. At laſt Mr Lavoiſier, by a number of ingenious and accurate experiments, proved, that ſeveral combuſtible ſubſtances when united with oxygen form acids; that a great number of acids contain oxygen; and that when this principle is ſeparated from them, they loſe their acid properties. He concluded, therefore, that the acidifying principle is oxygen, and that acids are nothing elſe but combuſtible ſubſtances combined with oxygen, and differing from one another according to the nature of the combuſtible baſe. This concluſion has been confirmed by every ſubſequent obſervation. All the acids hitherto analyſed contain oxygen, *one* perhaps excepted, *the Pruſſic acid*, which poſſeſſes properties ſo different from the reſt, that it might, without great impropriety, be placed in a diſtinct claſs. It is probable, therefore, that thoſe acids which it has not yet been poſſible to decompoſe conſiſt of oxygen combined with a combuſtible baſe: but till this analyſis has actually been accompliſhed, the theory of Mr Lavoiſier cannot be conſidered as completely demonſtrated (R).

390 Liſt of the acids. The acids at preſent known amount to about 39, moſt of which have been examined within theſe 30 years. Their names are as follows:

1. Sulphuric acid,
2. Sulphurous,
3. Nitric,
4. Nitrous,
5. Muriatic,
6. Oxy muriatic,
7. Phoſphoric,
8. Phoſphorous,
9. Boracic,
10. Fluoric,
11. Carbonic,
12. Acetic,
13. Acetous,
14. Oxalic,
15. Tartarous,
16. Citric,
17. Malic,
18. Lactic,
19. Saccholactic,
20. Gallic,
21. Benzoic,
22. Succinic,
23. Camphoric,
24. Suberic,
25. Laccic,
26. Pyromucous,
27. Pyrolignous,
28. Pyrotartarous,
29. Pruſſic,
30. Formic,
31. Sebacic,
32. Bombic,
33. Zoonic,
34. Arſenic,
35. Tungſtic,
36. Molybdic,
37. Chromic,
38. Platinic,
39. Stannic,

Theſe acids ſhall form the ſubject of the following ſections.

SECT. I. *Of Sulphuric Acid.*

SULPHUR combines with two different quantities of oxygen: with the ſmaller quantity it forms *ſulphurous acid*; with the larger *ſulphuric acid*. The laſt of theſe is the ſubject of the preſent ſection.

391 Diſcovery of ſulphuric acid. The ancients were acquainted with ſome of the compounds into which ſulphuric acid enters; *alum*, for inſtance, and *green vitriol*: but they appear to have been ignorant of the acid itſelf. It is firſt mentioned in the works of Baſil Valentine, which were publiſhed about the end of the 15th century.

It was for a long time obtained by diſtilling *green vitriol*, a ſalt compoſed of ſulphuric acid and green oxide of iron; hence it was called *oil of vitriol*, and afterwards *vitriolic acid*. Another method of obtaining it was by burning ſulphur under a glaſs bell; hence it was called alſo *oleum ſulphuris per campanam*. The French chemiſts in 1787, when they formed a new chemical nomenclature, gave it the name of *ſulphuric acid*.

392 Method of procuring it. At preſent it is generally procured by burning a mixture of ſulphur and nitre in chambers lined with lead. The theory of this proceſs requires no explanation. The nitre ſupplies a quantity of oxygen to the ſulphur,

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(R) This theory has been carried ſo far by ſome chemiſts, that they have conſidered it as a concluſive proof that oxygen did not enter into the compoſition of a body, if they could ſhew that the body was not an acid. Thus, according to them, *water* cannot contain oxygen, becauſe water is not an *acid*.—But ſurely no theory, however ingenious and ſatisfactory, can for a moment be put in competition with experiment. The ways of Nature are not as our ways, nor her thoughts as our thoughts.

ſulphur, and the air of the atmoſphere furniſhes the reſt. The acid thus obtained is not quite pure, containing a little potaſs, ſome lead, and perhaps alſo nitric and ſulphurous acids. Theſe acids may be driven off by applying for ſome time a gentle heat, and afterwards the ſulphuric acid itſelf may be diſtilled over pure.

393 Its component parts.

It appears from an experiment of Mr Berthollet, that ſulphuric acid contains 63,2 parts of ſulphur, and 36,8 of oxygen. He aſcertained, in the firſt place *, that nitre is totally decompoſed by being heated with $\frac{1}{5}$th of ſulphur. He then mixed together 288 grains of nitre and 72 of ſulphur; and after expoſing them to a ſufficient heat, he found 12 grains of ſulphur ſublimed, and 228 grains of ſulphat of potaſs †. But the ſum of the ingredients was 360 grains; conſequently 120 grains have been diſſipated. All this loſs muſt have been ſuffered by the acid of the nitre, for the heat was too ſmall to ſeparate any of the alkali. According to Mr Kirwan, 288 grains of nitre contain 132,96 of alkali, and 155,04 of acid. 155,04 — 120 = 35,04 = quantity of oxygen furniſhed by the nitre to convert 60 grains of ſulphur into acid.

394 Its properties.

Sulphuric acid is a liquid, ſomewhat of an oily conſiſtence, tranſparent and colourleſs as water, without any ſmell, and of a very ſtrong acid taſte. When applied to animal or vegetable ſubſtances, it very ſoon deſtroys their texture.

It always contains a quantity of water; part of which, however, may be driven off by the application of a moderate heat. This is called *concentrating the acid*. When as much concentrated as poſſible, its ſpecific gravity is 2,000.

It changes all vegetable blues to a red, except indigo.

According to Erxleben, it boils at 546°; according to Bergman, at 572°.

395 Its cryſtals.

When expoſed to a ſufficient degree of cold, it cryſtallizes or freezes; and after this has once taken place, it freezes again by the application of a much inferior cold. Moreveau froze it at — 4°; it aſſumed the appearance of frozen ſnow. After the proceſs began it went on in a cold not nearly ſo intenſe. The acid melted ſlowly at 27,5°; but it froze again at the ſame temperature, and took five days to melt in the temperature of 43° ‡. Chaptal, who manufactured this acid, once obſerved a large glaſs veſſel full of it cryſtallized at the temperature of 48°. Theſe cryſtals were in groups, and conſiſted of flat hexahedral priſms, terminated by a ſix-ſided pyramid. They felt hotter than the ſurrounding bodies, and melted on being handled §. Chaptal has obſerved, that ſulphuric acid, in order to cryſtallize, muſt not be too concentrated. This obſervation has been extended a good deal further by Mr Keir. He found, that ſulphuric acid, of the ſpecific gravity of 1,780, froze at 45°; but if it was either much more or much leſs concentrated, it required a much greater cold for congelation *.

396 Its affinity for water.

Sulphuric acid has a very ſtrong attraction for water. Neumann found, that when expoſed to the atmoſphere it attracted 6,25 times its own weight. Mr Gould found, that 180 grains of acid, when expoſed to the atmoſphere, attracted 68 grains of water the firſt day, 58 the ſecond, 39 the third, 23 the fourth, 18 the fifth, and at laſt only 5, 4, 3, 4, 3, &c. The 28th day, the augmentation was only half a grain †. The affinity therefore between ſulphuric acid and water, as is the caſe in general with other ſubſtances, becomes weaker the nearer they approach to ſaturation. He does not ſpecify the ſpecific gravity of his acid; but as it only attracted 3,166 times its own weight, it could not have been very concentrated.

When ſulphuric acid is mixed with water, a great quantity of caloric is evolved. A mixture of equal parts of theſe liquids cauſes a heat almoſt equal to that of boiling water. Lavoiſier and De la Place found, that when 2,625 lbs. troy of ſulphuric acid, of the ſpecific gravity 1,87058, was mixed with 1,969lbs. troy of water, as much caloric was evolved as melted 4,1226 pounds troy of ice, or as much caloric as the acid and water would have given out had they been heated without mixture to 155,9° ‡. This caloric is owing chiefly, if not ſolely, to the increaſe of denſity in the water; for when equal quantities of ſulphuric acid and water are mixed together, the ſpecific gravity is much greater than the mean; and it has been formerly ſhewn, that whenever bodies become denſer they give out caloric.

397 Strength of ſulphuric acid of various denſities.

Since there is ſuch a ſtrong affinity between ſulphuric acid and water, and ſince the denſity of the mixture is different from the mean denſity of the ingredients, it becomes a problem of the greateſt importance to determine how much of the ſtrongeſt ſulphuric acid that can be prepared exiſts in any given quantity of ſulphuric acid of inferior ſpecific gravity, and which conſequently conſiſts of a determined quantity of this ſtrong acid diluted with water.

This problem has been ſolved by Mr Kirwan §. He took ſulphuric acid of the ſpecific gravity 2,000, which is the ſtrongeſt that can be procured, for his ſtandard, and the point was to determine how much of this ſtandard acid exiſted in a given quantity of acid of inferior denſity.

He concluded, from a number of experiments with ſulphuric acid, of the ſpecific gravities 1,8846, 1,8689, 1,8042, 1,7500 (for he could not procure an acid of the ſpecific gravity 2,000 at the temperature of 60°, in which his experiments were performed), that when equal parts of ſtandard acid and water are mixed, the denſity is increaſed by $\frac{1}{75}$th part of the whole mixture. Then, by applying a formula given by Mr Poujet (s), he calculated, that the increaſe of denſity, on mixing

* Mem. Par. 1781, 232.

† Mem. Par. 1782, 603.

‡ Encyc. Method. Chim. i. 376.

§ Journ. de Phyſ. xxxi. 473.

* Phil. Tranſ. lxxvii. Part ii.

† Phil. Tranſ. 1684.

‡ Mem. Par. 1780.

§ Iriſh Tranſ. iv.

(s) Mr Poujet undertook the examination of the ſpecific gravity of alcohol mixed with different quantities of water. He took for his ſtandard alcohol whoſe ſpecific gravity was 0,8199, at the temperature of 65,75°. He then formed ten mixtures; the firſt containing nine meaſures of alcohol and one of water, the ſecond eight meaſures of alcohol and two of water, and ſo on, till the laſt contained only one meaſure of alcohol and nine of water. He took care that each of theſe meaſures ſhould contain equal bulks, which he aſcertained by weight, obſerving that a meaſure of water was to a meaſure of alcohol as 1 to 0,8199. Thus 10000 grains of water and 8199 of alcohol formed a mixture containing equal bulks of each. From the ſpecific gravity of each of theſe mixtures he diſcovered how much they had diminiſhed in bulk in conſequence of mixture, by the following method.

different quantities of ſtandard acid and water, was as in the following table:

Number of part of water.	Number of parts of ſtandard acid.	Augmentation of denſity.
5	95	0,0252
10	90	0,0479
15	85	0,0679
20	80	0,0856
25	75	0,0699
30	70	0,1119
35	65	0,1213
40	60	0,1279
45	55	0,1319
50	50	0,1333

The firſt 50 numbers of the following table were formed by adding theſe augmentations to the ſpecific gravity of the above mixture found by calculation, and taking the arithmetical mean for the intermediate quantities. The remaining numbers were formed from actual obſervation. He found by the firſt part of the table, that 100 parts of acid, of the ſpecific gravity 1,8472, contained 88,5 parts ſtandard, conſequently 400 grains of this acid contain 354 grains ſtandard. He took ſix portions of this acid, each containing 400 grains, and added to them as much water as made them contain reſpectively 48, 46, 44, 42, 40, 38 grains ſtandard. The quantity of water to be added in order to produce this effect, he found by the following method. Suppoſe $x =$ the quantity of water to be added to 400 parts of acid, that the mixture may contain 48 *per cent.* of ſtandard acid. Then $400 + x : 354 :: 100 : 48$, and conſequently $x = 337,5$. After finding the ſpecific gravity of theſe, the half of each was taken out, and as much water added; and thus the ſpecific gravities, correſponding to 24, 23, 22, 21, 20, 19, were found. Then ſix more portions, of 400 grains each, were taken, of the ſpecific gravity 1,8393, and the proper quantity of water added to make them contain 36, 34, 32, 30, 28, 26 *per cent.* of ſtandard. Their ſpecific gravities were found, the half of them taken out, and as much water added; and thus the ſpecific gravity of 18, 17, 16, 15, 14, and 13 found. Care was taken, after every addition of water, to allow the ingredient ſufficient time to unite.

The laſt 11 numbers were only found by analogy; obſerving the ſeries of decrement of the four laſt numbers before them.

TABLE

Calling A the real ſpecific gravity of any of the mixtures; B its ſpecific gravity found by calculation, ſuppoſing no diminution of bulk; n the number of meaſures compoſing the whole maſs; $n - x$ the number to which it is reduced in conſequence of mutual penetration—it is evident, ſince the increaſe of denſity does not diminiſh the weight of the whole maſs, that $n\,\mathrm{B} = \overline{n - x} \times \mathrm{A}$. Therefore $x = \frac{\mathrm{A} - \mathrm{B}}{\mathrm{A}} \times n$, or (making $n = 1$) $= \frac{\mathrm{A} - \mathrm{B}}{\mathrm{A}}$. $\frac{\mathrm{A} - \mathrm{B}}{\mathrm{A}}$ is therefore the diminution of volume produced by the mixture.

The following table contains the reſult of Mr Poujet's experiments, calculated according to that formula; the whole volume or n being $= 1$.

Meaſures of		Diminution of the whole volume = 1 by experiment.	By calculation.
Water.	Alcohol.		
1	9	0,0109	0,0103
2	8	0,0187	0,0184
3	7	0,0242	0,0242
4	6	0,0268	0,0276
5	5	0,0288	
6	4	0,0266	0,0276
7	3	0,0207	0,0242
8	2	0,0123	0,0184
9	1	0,0044	0,0103

It is evident, from this table, that the diminution of the bulk of the mixture follows a regular progreſſion. It is greateſt when the meaſures of water and alcohol are equal, and diminiſhes as it approaches both ends of the ſeries. Mr Poujet accounts for this by conceiving the alcohol to be diſſolved in the water, which retains a part of it in its pores, or abſorbs it. The quantity abſorbed ought to be in the ratio of that of the ſolvent and of the body diſſolved, and each meaſure of water will retain a quantity of alcohol proportional to the number of meaſures of alcohol in the mixture. Thus in a mixture formed of nine meaſures of alcohol and one of water, the water will contain a quantity of alcohol $= 9$; in one of eight meaſures of alcohol and two of water, the water will contain a quantity of alcohol $= 8$. Therefore the diminution of bulk in each mixture is in a ratio compounded of the meaſures of alcohol and water which form it; in the above table, as 1×9, 2×8, 3×7, 4×6, &c. And in general, taking the diminution of bulk when the meaſures of both liquids are equal for a conſtant quantity, and calling it c, calling the number of meaſures n, the number of meaſures of alcohol x, the increaſe of denſity

Table *of the Quantity of Standard Sulphuric Acid, Specific Gravity* 2,000 *in Sulphuric Acid of inferior Denſity, Temperature* 60°.

100 parts, at the ſpecific gravity	Contain of ſtandard acid	100 parts, at the ſpecific gravity	Contain of ſtandard acid	100 parts, at the ſpecific gravity	Contain of ſtandard acid
2,000	100	1,6217	67	1,2847	34
1,9859	99	1,6122	66	1,2757	33
1,9719	98	1,6027	65	1,2668	32
1,9579	97	1,5932	64	1,2589	31
1,9439	96	1,5840	63	1,2510	30
1,9299	95	1,5748	62	1,2415	29
1,9168	94	1,5656	61	1,2320	28
1,9041	93	1,5564	60	1,2210	27
1,8914	92	1,5473	59	1,2101	26
1,8787	91	1,5385	58	1,2009	25
1,8660	90	1,5292	57	1,1918	24
1,8542	89	1,5202	56	1,1836	23
1,8424	88	1,5112	55	1,1746	22
1,8306	87	1,5022	54	1,1678	21
1,8188	86	1,4933	53	1,1614	20
1,8070	85	1,4844	52	1,1531	19
1,7959	84	1,4755	51	1,1398	18
1,7849	83	1,4666	50	1,1309	17
1,7738	82	1,4427	49	1,1208	16
1,7629	81	1,4189	48	1,1129	15
1,7519	80	1,4099	47	1,1011	14
1,7416	79	1,4010	46	1,0955	13
1,7312	78	1,3875	45	1,0896	12
1,7208	77	1,3741	44	1,0833	11
1,7104	76	1,3663	43	1,0780	10
1,7000	75	1,3586	42	1,0725	9
1,6899	74	1,3473	41	1,0666	8
1,6800	73	1,3360	40	1,0610	7
1,6701	72	1,3254	39	1,0555	6
1,6602	71	1,3149	38	1,0492	5
1,6503	70	1,3102	37	1,0450	4
1,6407	69	1,3056	36	1,0396	3
1,6312	68	1,2951	35	1,0343	2

398 Quantity of real acid in ſtrong ſulphuric acid.

But we have no reaſon to ſuppoſe that ſulphuric acid, at the denſity 2,000, is free from all mixture of water; ſo far from that, we know for certain that it contains a conſiderable proportion; for when it is combined with other bodies, barytes, for inſtance, or potaſs, there is a conſiderable quantity of water which remains behind, and does not enter into the combination. Now, is it poſſible to determine what would be the denſity of ſulphuric acid, ſuppoſing it to be deprived of all water, or at leaſt of all water except what is neceſſary for its exiſtence as an acid? or to determine, how much real acid exiſts in a given quantity of ſtandard acid?

Homberg firſt attempted to anſwer this queſtion. It was afterwards undertaken by Bergman, and Wenzel, and Wiegleb. They do not inform us of the quantity of water contained in a given weight of acid, but they put it in our power to find it, by informing us how much real acid is neceſſary to ſaturate a given quantity of potaſs. Their reſpective experiments give the following numbers:

	Homb.	Berg.	Wenzel.	Wiegleb.
100 parts of potaſs require	38,3	78,5	82,63	101,92.

Homberg uſed carbonat of potaſs, and did not take into conſideration the carbonic acid driven off by the ſulphuric. When this is taken in, his number ſhould be 54 inſtead of 38,3.

Now to diſcover the quantity of real acid in any ſulphuric acid mixture, we have only to find out how much potaſs it would require for ſaturation. The differences between the above reſults are ſo great, that there was reaſon to ſuſpect their accuracy. Mr Kirwan therefore attempted to aſcertain the denſity of pure ſulphuric acid by another method, and he rated it at 4,226. As this method has been already deſcribed in the article Chemistry, *Encycl.* we cannot enter upon it here. At any rate, it would be unneceſſary, as many of the principles upon which Mr Kirwan went were erroneous, as Mr Morveau* and Mr Keir† have ſufficiently ſhewn; and Mr Kirwan, with his uſual candour, has accordingly abandoned it, and adopted another method which is not liable to the ſame exceptions. He diſſolved 1523,5 grains

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* *Encyc. Method.* art. *Affinité.*

† *Keir's Dictionary*, art. *Acid.*

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denſity or diminution of bulk z; we ſhall have $c : z :: \frac{n}{2} \times \frac{n}{2} : \overline{n - x}, \times x$ and $z = \frac{4c}{n^2} \times \overline{nx - x^2}$, or (making $n = 1) = 4cx^2$.

The diminution of bulk, calculated according to this formula, make the laſt column of the above table. They correſpond very well with experiment, while the meaſures of alcohol are more than thoſe of water, but not when the reverſe is the caſe. This Mr Poujet thinks is owing to the attraction which exiſts between the particles of water, and which, when the water is conſiderable compared with the alcohol, reſiſts the union of the water with the alcohol.

By the formula $z = \frac{4cnx - 4cx^2}{n^2}$, the quantity of alcohol of the ſtandard may be determined in any mixture where the alcohol exceeds the water.

Let the number of meaſures, or the whole maſs - - - $= 1$
The meaſures of alcohol - - - - - - - - $= x$
The diminution of bulk at equal meaſures - - - - $= c$
The diminution of bulk of a mixture containing x meaſures of alcohol - $= 4cx - 4cx^2$
The ſpecific gravity of water - - - - - $= a$
The ſpecific gravity of the alcohol - - - - - $= b$
The ſpecific gravity of the unknown mixture - - - $= y$

grains of pure carbonat of potaſs, dried in a red heat, in diſtilled water. The whole weighed 4570 grains. He took 360 grains of this mixture, which contained 120 grains of carbonat of potaſs, and ſaturated it with pure ſulphuric acid of the ſpecific gravity 1,565, which, according to the above table, contained 61 *per cent.* of ſtandard acid. The acid required for ſaturating the ſolution of potaſs amounted to 130 grains, and contained therefore 79 of ſtandard. The carbonic acid diſengaged was 34 grains, and conſequently the quantity of alkali was 120 — 34 = 86 grains. The ſolution being turbid, was diluted with 3238 grains of water. Its ſpecific gravity was then 1,013 at the temperature of 60°. The weight of the whole was 3694 grains. Forty-five grains of ſulphat of potaſs (potaſs combined with ſulphuric acid), diſſolved in 1017 grains of diſtilled water, have the ſame ſpecific gravity at the ſame temperature; from whence it follows, that the proportion of ſalt in each was equal. But in the laſt ſolution the quantity of ſalt was $\frac{1}{23,6}$ of the whole; therefore the quantity of ſalt in the firſt was $\frac{3694}{23,6} = 159,52$ grs. Now of this weight 86 grains were alkali; the remainder, therefore, which amounts to 70,52 grains, muſt be acid. But the quantity of ſtandard acid employed was 79 grains; of this there were $8\frac{1}{2}$ grains which did not enter into the combination, and which muſt have been pure water: 79 parts of ſtandard acid, therefore, contain at leaſt 8,5 parts of water, and conſequently 100 parts of ſtandard acid contain 10,75 parts of water. It only remains now to conſider how much water ſulphat of potaſs contains. Mr Kirwan thinks it contains none, becauſe it loſes no weight in any degree of heat below ignition, and even when expoſed to a red heat for half an hour it hardly loſes a grain. This is certainly ſufficient to prove, at leaſt, that it contains very little water; and conſequently we may conclude, with Mr Kirwan, that 100 parts of ſulphuric acid, of the ſpecific gravity 2,000, are compoſed pretty nearly of 89,25 of pure acid and 10,75 of water. This method uſed by Mr Kirwan is nearly the ſame with that propoſed by Mr Keir *.

It ſeems even poſſible to obtain ſulphuric acid free from all the water that may not be neceſſary to its acid ſtate. When it is procured by diſtillation from green vitriol, if the receiver be changed after the proceſs has gone on for ſome time, a quantity of acid is obtained in a ſolid form, or cryſtallized. This, as Morveau has ſhewn, is ſulphuric acid deprived of the water with which it is uſually combined. When this *glacial* acid, as it has been called, is expoſed to the air, it riſes in white fumes, and is ſoon diſſipated. This ſingular effect is produced by its violent attraction for the water which exiſts in atmoſpheric air. When thrown into water, it ſeizes it with violence; a great deal of caloric is evolved, ſufficient, if the quantity of water be not too great, to elevate the whole in vapours *.

399 Action of this acid on other bodies.

Sulphuric acid is capable of decompoſing alcohol and oils; and when aſſiſted by heat, it decompoſes alſo ſome of the metallic oxides which contain the greateſt quantity of oxygen; as red oxide of lead, black oxide of manganeſe. It decompoſes likewiſe all the ſulphurets and phoſphurets which have an alkaline or earthy baſis.

It oxidates iron, zinc, and manganeſe, in the cold. By the aſſiſtance of heat it oxidates ſilver, mercury, copper, antimony, biſmuth, arſenic, tin, and tellurium. At a boiling heat it oxidates lead, cobalt, nickel, molybdenum. It does not act upon gold, platinum, tungſten, nor titanium.

It unites readily with all the alkalies, the alkaline earths, alumina, and jargonia, and with moſt of the metallic oxides, and forms ſalts denominated *ſulphats*. Thus the combination of ſulphuric acid and ſoda is called *ſulphat of ſoda*; the compound of ſulphuric acid and lime, *ſulphat of lime*, and ſo on. It does not act upon ſilica nor adamanta.

400 Its affinities.

The affinities of ſulphuric acid are as follows †:

Barytes,
Strontites ‡,
Potaſs,
Soda,
Lime,
Magneſia,
Ammonia,
Alumina,
Jargonia § ?
Oxide of zinc,
—— iron,
—— manganeſe,
—— cobalt,
—— nickel,
—— lead,
—— tin,
—— copper,
—— biſmuth,

Oxide

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

* *Encyc. Method. Chim.* i. 590.

† See *Bergman* and *Lavoiſier.*

‡ *Dr Hope, Tranſ. Edin.* iv.

§ *Vauquelin, Ann. de Chim.* xxii. 208.

Then ſince the increaſe of denſity does not change the weight of the whole, $\overline{1-x} \times a + bx = \overline{1-4cx+4cx^2} \times y$.

$$\text{Hence } x = 0,5 - \frac{a-b}{8cy} + \sqrt{\frac{a-y}{4cy} + \left(\frac{a-b}{8cy} - 0,5\right)}$$

$$y = \frac{a - ax + bx}{1 - 4cx + 4cx^2}$$

And making $a = 1$, $b = 0,8199$, $c = 0,0288$

$$x = 0,5 - \frac{0,1801}{0,2304y} + \sqrt{\frac{1-y}{0,1152y} + \left(\frac{0,1801}{0,2304y} - 0,5\right)}$$

$$y = \frac{1 - 0,1801x}{1 - 0,1152x + 0,1152x^2}.$$

See *Iriſh Tranſ.* III.

Oxide of antimony,
—— arſenic,
—— mercury,
—— ſilver,
—— gold,
—— platinum,
Oil,
Water.

Sect. II. *Of Sulphurous Acid.*

401
Component parts of ſulphurous acid.

Sulphurous acid is compoſed of ſulphur and oxygen combined: the proportions have not been aſcertained; but the fact itſelf, and that the quantity of oxygen is leſs than what enters into ſulphuric acid, has been proved beyond the poſſibility of doubt. Neither can it be doubted, though the fact has not been attended to, that in this acid the ſulphur and oxygen mutually ſaturate each other; and that ſulphuric acid is not compoſed of ſulphur and oxygen, but of ſulphurous acid and oxygen. Phoſphorus is capable of decompoſing ſulphuric acid by the aſſiſtance of heat, of ſeizing a quantity of its oxygen, and converting it into ſulphurous acid; but upon ſulphurous acid it has no effect whatever *. The affinity of phoſphorus therefore for oxygen is leſs than that of ſulphur; yet it is capable of taking oxygen from ſulphuric acid. Is it not evident from this, that ſulphuric acid is compoſed of ſulphurous acid and oxygen? and that ſulphur has a ſtronger affinity for oxygen than ſulphurous acid has? For if both the acids were compoſed directly of ſulphur and oxygen, it would follow from experiment, that the affinity of phoſphorus for oxygen was both ſtronger and weaker than that of ſulphur; which would be abſurd.

402
Its diſcovery.

Sulphurous acid has been known ſince the time of Stahl. Scheele firſt diſcovered the method of obtaining it in quantities; and Dr Prieſtley firſt procured it in a ſtate of purity; for Scheele's acid was diſſolved in water.

403
Method of procuring it.

Stahl's method of procuring ſulphurous acid was to burn ſulphur at a low temperature, and expoſe to its flames cloth dipped in a ſolution of potaſs. By this method he obtained a combination of potaſs and ſulphurous acid; for at a low temperature ſulphur forms by combuſtion only ſulphurous acid. On this ſalt Scheele poured a quantity of tartarous acid, and then applied a gentle heat. The ſulphurous acid is in this manner diſplaced, becauſe its affinity for potaſs is not ſo ſtrong as that of tartarous acid; and it comes over into the receiver diſſolved in water. It is now commonly procured by mixing with ſulphuric acid oil, greaſe, metals, or any other ſubſtance that has a ſtronger affinity for oxygen than ſulphurous acid, and applying a heat ſufficient to diſtil over the ſulphurous acid as it forms. Mr Berthollet has found, that ſugar is the beſt ſubſtance to employ for this purpoſe.

Dr Prieſtley poured a little oil on ſulphuric acid, applied heat, and received the product in a glaſs jar filled with mercury. It was ſulphurous acid free from all ſuperfluous water, and in a gaſeous form.

404
Its properties,

In this ſtate it is colourleſs and inviſible like common air. It is incapable of maintaining combuſtion; nor can animals breathe it without death. It has a ſtrong and ſuffocating odour. It is this odour which burning ſulphur exhales. Its ſpecific gravity, according to Bergman, is 0,00246 *; according to Lavoiſier, 0,00251 †. Clouet and Mongé found, that by the application of extreme cold it is converted into a liquid.

Dr Prieſtley diſcovered, that when a ſtrong heat is applied to this acid in cloſe veſſels, a quantity of ſulphur is precipitated, and the acid is converted into ſulphuric ‡. Berthollet obtained the ſame reſult: but Fourcroy and Vauquelin could not ſucceed §.

Water abſorbs this acid with avidity. According to Dr Prieſtley, 1000 grains of water, at the temperature 54,5°, abſorb 39,6 grains of this acid. The ſpecific gravity of water ſaturated with ſulphurous acid is 1,040 ||. Water in the ſtate of ice abſorbs it very rapidly, and is inſtantly melted. Water ſaturated with this acid can be frozen without parting with any of it. When water, which has been ſaturated with this acid at the freezing temperature, is expoſed to the heat of 65,25°, it is filled with a vaſt number of bubbles, which continually increaſe and riſe to the ſurface. Theſe bubbles are a part of the acid ſeparating from it. It freezes a few degrees below 32 ¶.

Sulphuric acid abſorbs it at zero; but allows great part of it to eſcape at 32 *.

It reddens tincture of turnſol; but deſtroys the colour of ſyrup of violets.

It is decompoſed by hydrogen and carbon, and ſulphurated hydrogen gas, when aſſiſted by heat †.

Oxygen gas gradually converts it into ſulphuric acid; but this change does not take place unleſs water be preſent.

It does not ſeem capable of oxidating any of the metals except iron, zinc, and manganeſe.

When in the ſtate of gas it is abſorbed by oils and ether.

When glaſs tubes, filled with ſulphurous acid in the ſtate of gas, are expoſed to a ſtrong heat, a quantity of ſulphur precipitates, and the reſt of the acid is converted into the ſulphuric.

405
Its combinations,

It combines with the alkalies, alkaline earths, and alumina, and many of the metallic oxides, and forms neutral ſalts, known by the name of *ſulphites*.

406
And affinities.

Its affinities, as far as they have been inveſtigated, are as follows ‡:

Barytes,
Lime,
Potaſs,
Soda,
Magneſia,
Ammonia,
Alumina,
Jargonia * ?
Metallic oxides,
Water.

Sect. III. *Of Nitric Acid.*

There are three different ſubſtances compoſed of azot and oxygen, *nitric acid*, *nitrous acid*, and *nitrous gas*. The firſt contains moſt oxygen; the laſt contains leaſt.

407
Diſcovery of nitric acid.

Nitric acid ſeems to have been firſt obtained in a ſeparate ſtate by Raymond Lully, who was born at Majorca in 1235. He procured it by diſtilling a mixture of nitre and clay. Baſil Valentine, who lived in the 15th century, deſcribes the proceſs minutely, and calls the acid *water of nitre*. It was afterwards denominated

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* *Fourcroy* and *Vauquelin.*

* On *Elective Attraction*, § 43.

† *Chemiſtry, Appendix.*

‡ On *Air*, ii. 330.

§ *Nicholſon's Journal*, i. 513.

|| *Berthollet, Ann. de Chim.* ii. 50.

¶ *Fourcroy* and *Vauquelin, Nicholſon, ibid.*

* *Ibid.*

† *Ibid.*

‡ *Ibid.*

* *Vauquelin, Ann. de Chim.* xxii. 208.

ted *aqua fortis* and *ſpirit of nitre.* The name *nitric acid* was firſt given it in 1787 by the French chemiſts.

408
Method of procuring it.

Nitric acid is generally obtained in large manufactories by diſtilling a mixture of nitre (T) and clay; but the acid procured by this proceſs is weak and impure. Chemiſts generally prepare it by diſtilling three parts of nitre and one of ſulphuric acid in a glaſs retort. This method was firſt uſed by Glauber. When obtained in this manner it contains ſome nitrous acid, which may be expelled by the application of a very gentle heat *.

* *Scheele.*

Nitric acid is one of the moſt important inſtruments of analyſis which the chemiſt poſſeſſes; nor is it of inferior conſequence when conſidered in a political or commercial view, as it forms one of the moſt eſſential ingredients of gunpowder. Its nature and compoſition accordingly have long occupied the attention of philoſophers. We ſhall endeavour to trace the various ſteps by which its component parts were diſcovered.

400
Diſcovery of its component parts.

As nitre is often produced upon the ſurface of the earth, and never except in places which have a communication with atmoſpheric air, it was natural to ſuppoſe that air, or ſome part of the air, entered into the compoſition of nitric acid. Mayow having obſerved, that nitre and atmoſpherical air were both poſſeſſed of the property of giving a red colour to the blood, and that air was deprived of this property by combuſtion and reſpiration—concluded, that nitre *contained that part of the air which ſupported combuſtion, and was neceſſary for reſpiration.*

Dr Hales, by applying heat to nitric acid, and what he called *Walton mineral*, obtained a quantity of air poſſeſſed of ſingular properties. When atmoſpherical air was let into the jar which contained it, a reddiſh turbid fume appeared, a quantity of air was abſorbed, and the remainder became tranſparent again *. Dr Prieſtley diſcovered that this air could only be obtained from nitric (U) acid; and therefore called it *nitrous air.* He found that when this gas was mixed with oxygen gas, nitrous acid was reproduced. Here, then, we find, that oxygen is a part of the nitric acid, and conſequently that Mayow's affirmation is verified.

* *Veget. Statics,* ii. 284.

Dr Prieſtley, however, explained this fact in a different manner. According to him, nitrous gas is compoſed of nitrous acid and phlogiſton. When oxygen is added, it ſeparates this phlogiſton, and the acid of courſe is precipitated. This hypotheſis was adopted by Macquer and Fontana; and theſe three philoſophers endeavoured to ſupport it with their uſual ingenuity. But there was one difficulty which they were unable to ſurmount. When the two gaſes are mixed in proper proportions, almoſt the whole aſſumes the form of nitric acid; and the ſmall reſiduum ($\frac{1}{13}$th part), in all probability, or rather certainly, depends on ſome accidental impurity in the oxygen gas. What then becomes of the oxygen and phlogiſton? Dr Prieſtley ſuppoſed that they formed carbonic acid gas: but Mr Cavendiſh proved, that when proper precautions are taken, no ſuch acid appears †.

† *Phil. Tranſ.* 1784.

Dr Prieſtley had procured his nitrous gas by diſſolving metals in nitric acid; during the ſolution of which a great deal of nitrous gas eſcapes. He ſuppoſed that nitrous gas contained phlogiſton, becauſe the metal was oxidated (and conſequently, according to the then received theory, muſt have loſt phlogiſton) during its formation. Mr Lavoiſier proved that this ſuppoſition was ill-founded by the following celebrated experiment *: To 945 grains of nitric acid (ſpecific gravity 1,316) he added 1104 grains of mercury. During the ſolution 273,234 cubic inches of nitrous gas were produced. He then diſtilled the ſalt (oxide of mercury) which had been formed to dryneſs. As ſoon as it became red hot it emitted oxygen gas, and continued to do ſo till almoſt the whole of the mercury was revived: The quantity of oxygen emitted was 287,742 cubic inches. All that had happened, therefore, during the ſolution of the mercury, was the ſeparation of the acid into two parts; nitrous gas, which flew off, and oxygen, which united with the metal (X).

* *Mem. Par.* 1776, p. 673.

Mr Lavoiſier concluded, therefore, that the whole of the nitrous gas was derived from the nitric acid; that nitric acid is compoſed of oxygen and nitrous gas; and that the proportions are nearly 64 parts by weight of nitrous gas, and 36 of oxygen gas.

But there was one difficulty which Mr Lavoiſier acknowledged he could not remove. The quantity of oxygen obtained by decompoſing nitric acid was often much greater than what was neceſſary to ſaturate the nitrous gas. Mr De Morveau attempted to account for this; but without ſucceſs†. Nitrous gas itſelf was evidently a compound; but the difficulty was to diſcover the ingredients. Mr Lavoiſier concluded, from an experiment made by decompoſing nitre by means of charcoal, that it contained azot: and ſeveral of Dr Prieſtley's experiments led to the ſame reſult. But what was the other ingredient?

† *Encyc. Method. Chim. Acide Nitrique.*

Mr Cavendiſh had obſerved, while he was making experiments on the compoſition of water, that ſome nitric acid was formed during the combuſtion of oxygen and hydrogen gas, and that its quantity was increaſed by adding a little azot to the two gaſes before the exploſion. Hence he concluded that the formation of the acid was owing to the accidental preſence of azotic gas. To verify this conjecture, he paſſed an electrical ſhock through a quantity of common air encloſed in a glaſs tube: the air was diminiſhed, and ſome nitric acid formed. He repeated the experiment, by mixing together oxygen and azotic gas; and found that when they bore a certain proportion to each other, they were totally convertible into nitric acid. In one experiment, the proportion of azot to oxygen (in bulk) was as 416 to 914; in another, as 1920 to 4860 ‡.

‡ *Phil. Tranſ.* 1783.

Theſe experiments were immediately repeated by Meſſrs Van Marum and Van Trooſtwyk, and with nearly the ſame reſult.

The moſt convenient method of performing them is the following: Take a glaſs tube, the diameter of which

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(T) Nitre is compoſed of nitric acid and potaſs.

(U) Or nitrous acid: for at the period of Dr Prieſtley's diſcovery (1772) they were not accurately diſtinguiſhed.

(X) We have already mentioned, in a preceding note, that this experiment was firſt made by Mr Bayen. See Part I. chap. iii. of this Article.

which is about the ſixth part of an inch, through the cork that ſhuts one end of which let a ſmall metallic conductor paſs with a ball at each end. Fill this tube with mercury, and plunge its open end into a baſon of mercury: then put into it a mixture of 0,13 of azotic and 0,87 of oxygen gas, till it occupies three inches of the tube; and introduce a ſolution of potaſs till it fill half an inch more. Then, by means of the conductor, make electrical exploſions (from a very powerful machine) to paſs through the tube till the air is as much diminiſhed as poſſible. Part of the potaſs will be found converted into nitre. Mr Cavendiſh actually ſaturated the potaſs with this acid. Mr Van Marum did not, though a good deal more gas had diſappeared than in the experiments of Mr Cavendiſh. This difference evidently depends on the quantity of potaſs contained in a given weight of the ſolution. The ſolution which Mr Van Marum uſed was no doubt ſtronger than that which Mr Cavendiſh employed.

Dr Prieſtley had obſerved, ſeveral years before theſe experiments were made, that atmoſpherical air was diminiſhed by the electric ſpark, and that during the diminution the infuſion of turnſol became red; but he concluded merely that he had precipitated the acid of the air. Landriani, who thought, on the contrary, that carbonic acid gas was formed, enounced the alteration of lime-water by it as a proof of his opinion. It was to refute this notion that Mr Cavendiſh undertook his experiments. He has ſince that time repeated them with the ſame ſucceſs *.

It cannot be doubted, then, that nitric acid is compoſed of azot and oxygen; for the objections of Dr Prieſtley have been conſidered while we were treating of water. Conſequently nitrous gas muſt alſo be compoſed of the ſame ingredients. According to Lavoiſier, nitric acid is compoſed of four parts, by weight, of oxygen and one part of azot.

410 Its properties.

Nitric acid is liquid, colourleſs, and tranſparent; but the affinity between its component parts is ſo weak, that the action of light is ſufficient to drive off a part of its oxygen in the form of gas; and thus, by converting it partly into nitrous acid, to make it aſſume a yellow colour. Its taſte is exceedingly acid and peculiar. It is very corroſive, and tinges the ſkin of a yellow colour, which does not diſappear till the epidermis comes off.

It has a ſtrong affinity for water, and has never yet been obtained except mixed with that liquid. When concentrated, it attracts moiſture from the atmoſphere, but not ſo powerfully as ſulphuric acid. It alſo produces heat when mixed with water, owing evidently to the concentration of the water.

411 Its ſtrength at different ſpecific gravities.

The ſpecific gravity of the ſtrongeſt nitric acid that can be procured is, according to Rouelle, 1,583; but at the temperature of 60°, Mr Kirwan could not procure it ſtronger than 1,5543.

Taking this acid for the ſtandard, Mr Kirwan has calculated how much of it exiſts in nitric acid of inferior denſity. His determination may be ſeen in the following Table, which was formed preciſely in the ſame manner as that formerly given of the ſtrength of ſulphuric acid.

100 parts, at the ſpecific gravity	Contain of ſtandard acid	100 parts, at the ſpecific gravity	Contain of ſtandard acid	100 parts, at the ſpecific gravity	Contain of ſtandard acid
1,5543	100	1,4018	70	1,2586	44
1,5295	95	1,3975	69	1,2525	43
1,5183	94	1,3925	68	1,2464	42
1,5070	93	1,3875	67	1,2419	41
1,4957	92	1,3825	66	1,2374	40
1,4844	91	1,3775	65	1,2291	39
1,4731	90	1,3721	64	1,2209	38
1,4719	89	1,3671	63	1,2180	37
1,4707	88	1,3621	62	1,2152	36
1,4695	87	1,3571	61	1,2033	35
1,4683	86	1,3521	60	1,2015	34
1,4671	85	1,3468	59	1,1963	33
1,4640	84	1,3417	58	1,1911	32
1,4611	83	1,3366	57	1,1845	31
1,4582	82	1,3315	56	1,1779	30
1,4553	81	1,3264	55	1,1704	29
1,4524	80	1,3212	54	1,1639	28
1,4471	79	1,3160	53	1,1581	27
1,4422	78	1,3108	52	1,1524	26
1,4373	77	1,3056	51	1,1421	25
1,4324	76	1,3004	50	1,1319	24
1,4275	75	1,2911	49	1,1284	23
1,4222	74	1,2812	48	1,1241	22
1,4171	73	1,2795	47	1,1165	21
1,4120	72	1,2779	46	1,1111	20
1,4069	71	1,2687	45	1,1040	19

Now, how much water does nitric acid contain, the denſity of which is 1,5543?

412 Quantity of real acid contained in concentrated nitric acid.

Mr Kirwan dried a quantity of cryſtallized carbonat of ſoda in a red heat, and diſſolved it in water, in ſuch a proportion, that 367 grains of the ſolution contained 50,05 of alkali. He ſaturated 367 grains of this ſolution with 147 grains of nitric acid, the ſpecific gravity of which was 1,2754, and which, therefore, by the preceding table, contained 45,7 *per cent.* of acid ſtandard. The carbonic acid driven off amounted to 14 grains. On adding 939 grains of water, the ſpecific gravity of the ſolution, at the temperature of 58,5°, was 1,0401. By comparing this with a ſolution of nitrat of ſoda, of the ſame denſity, preciſely in the manner deſcribed formerly under ſulphuric acid, he found, that the ſalt contained in it amounted to $\frac{1}{16,901}$ of the whole. There was an exceſs of acid of about two grains. The weight of the whole was 1439 grains: The quantity of ſalt, conſequently, was $\frac{1439}{16,901} = 85,142$ grains. The quantity of alkali was $50,05 - 14 = 36,05$. The quantity of ſtandard acid employed was 66,7. The whole of which amounted to 102,75 grains; but as only 85,142 grains entered into the compoſition of the ſalt, the remaining 17,608 muſt have been pure water mixed with the nitric acid. But if 66,7 of ſtandard acid contain 17,608 of water, 100 parts of the ſame acid muſt contain 26,38 *.

One hundred parts of ſtandard nitric acid, therefore, is compoſed of 73,62 parts of pure nitric acid and 26,38 of water. But as Mr Kirwan has not proved that nitrat of ſoda contains no water, perhaps the proportion of

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* *Phil. Tranſ.* 1788.

* *Iriſh Tranſ.* iv.

of water may be greater. He has rendered it probable, however, that nitrat of ſoda contains very little water.

413 Its action on other bodies,

Nitric acid is decompoſed by a great variety of ſubſtances. When poured upon oils, it ſets them on fire. This is occaſioned by a decompoſition both of the acid and oil. The oxygen of the acid combines with the carbon and with the hydrogen of the oils, and at the ſame time lets go a quantity of caloric. Hence we ſee that the oxygen which enters into the compoſition of the nitric acid ſtill contains a great deal of caloric; a fact which is confirmed by a great number of other phenomena. The combuſtion of oils by this acid was firſt taken notice of by Borrichius and Slare; but it is probable that Homberg communicated it to Slare. In order to ſet fire to the fixed oils, it muſt be mixed with ſome ſulphuric acid; the reaſon of which ſeems to be, that theſe oils contain *water*, which muſt be previouſly removed. The ſulphuric acid combines with this water, and allows the nitric acid, or rather the oil and nitric acid together, to act. The drying oils do not require any ſulphuric acid: they have been boiled, and conſequently deprived of all moiſture. It ſets fire alſo to charcoal, provided it be perfectly dry. This fact was firſt obſerved by Prouſt, and afterwards confirmed by the Dijon academicians. It ſets fire alſo to zinc, biſmuth, and tin, if it be poured on them in fuſion, and to filings of iron, if they be perfectly dry *. In all theſe caſes the acid is decompoſed. Sulphurated hydrogen gas alſo takes fire, and burns with a ſtrong flame by means of this acid †.

It is capable of oxidating all the metals except gold, platinum (x), and titanium. It appears, from the experiments of Scheffer, Bergman, Sage, and Tillet, that nitric acid is capable of diſſolving (and conſequently of oxidating) a very minute quantity even of gold.

414 Its combinations,

Nitric acid combines with alkalies, alkaline earths, alumina, and jargonia, and with the oxides of metals, and forms compounds which are called *nitrats*. It does not act upon ſilica nor adamanta.

415 And affinities.

The order of its affinities is as follows:

Barytes,
Potaſs,
Soda,
Strontites ‡,
Lime,
Magneſia,
Ammonia,
Alumina,
Jargonia § ?
Metallic oxides, in the ſame order as for ſulphuric acid.
Water.

SECT. IV. *Of Nitrous Acid.*

416 Component parts of nitrous acid.

If oxygen gas be mixed with nitrous gas, a quantity of red fumes appear, which are readily abſorbed by water. Theſe red fumes are *nitrous acid*.

If a glaſs veſſel containing nitric acid be inverted into another veſſel containing the ſame acid, and expoſed to the light, the inverted glaſs will become partly full of oxygen gas, and at the ſame time part of the nitric acid is converted into nitrous acid *. It follows, from this experiment, that nitrous acid contains leſs oxygen than nitric acid. Lavoiſier has calculated, that it contains ſomewhat leſs than three parts of oxygen to one of azot.

417 Its properties.

Nitrous acid is of a brown or red colour, exceedingly volatile, and emitting a very ſuffocating and ſcarcely tolerable odour. When to this acid, concentrated, a fourth part by weight of water is added, the colour is changed from red to a fine green; and when equal parts of water are added, it becomes blue †. Dr Prieſtley obſerved, that water impregnated with this acid in the ſtate of vapour became firſt blue, then green, and laſtly yellow. A green nitrous acid became orange-coloured while hot, and retained a yellow tinge when cold. A blue acid became yellow on being heated in a tube hermetically ſealed. An orange-coloured acid, by long keeping, became green, and afterwards of a deep blue; and when expoſed to air, reſumed its original colour. Theſe colours ſeem to depend upon the concentration of the acid.

Dr Prieſtley found that water abſorbed great quantities of this acid in the ſtate of vapour; and that when ſaturated, its bulk was increaſed one-third.

In the ſtate of vapour, it is abſorbed rapidly by oils. Whale oil, by abſorbing it, became green, thick, and heavier It gradually decompoſed the acid, retained the oxygen, and emitted the azot in the ſtate of gas ‡.

It is abſorbed by ſulphuric acid, but ſeemingly without producing any change; for when water is poured into the mixture, the heat produced expels it in the uſual form of red fumes §. The only ſingular circumſtance attending this impregnation is, that it diſpoſes the ſulphuric acid to cryſtallize ‖. This fact, firſt obſerved by Dr Prieſtley in 1777 (y), was afterwards confirmed by Mr Cornette.

Nitrous acid appears capable of combining with moſt of the bodies with which nitric acid unites. The ſalts which it forms are called *nitrites*.

Its affinities have never been accurately examined. Bergman ſuppoſes them the ſame with thoſe of nitric acid.

Of

* *Prouſt, Dijon Academicians,* and *Cornette.*

† *Tromſdorff.*

‡ *Dr Hope.*

§ *Vauquelin, Ann. de Chim.* xxii. 208.

* *Scheele, Crell's Annals* 1780.

† *Bergman.*

‡ *Prieſtley*, iii. 111.

§ *Ibid.* p. 144.

‖ *Ibid.* p. 156.

(x) Nitre, however, acts upon platinum, as Mr Tennant has proved. *Phil. Tranſ.* 1797. Morveau had made the ſame obſervation in the *Elemens de Chimie de l'Academie de Dijon.*

(y) Bernhardt, however, relates, in 1765, that once, when he was diſtilling a mixture of ten pounds of nitre with an equal quantity of calcined vitriol, which he had put into a retort, to which was fitted an adapter between the retort and the receiver, which contained a quantity of water—he obſerved a conſiderable quantity of a white cryſtalline ſalt formed in the adapter, while the liquid acid paſſed as uſual into the receiver. This ſalt was very volatile, ſmoked ſtrongly when it was expoſed to the air, and exhaled a red vapour; it burnt, to a black coal, wood, feathers, or linen, as ſulphuric acid does; and where a piece of it fell, it evaporated in form of a blood red vapour, till the whole of it diſappeared. Half an ounce of theſe cryſtals diſſolved in water with ſpurting and hiſſing, like that of a red-hot iron dipped in water, and formed a green nitrous acid. Some of this ſalt being put into a bottle, which was not well ſtopped, entirely vaniſhed. Theſe cryſtals were evidently the ſame with Dr Prieſtley's. See *Keir's Dictionary.*

Of Nitrous Gas.

418 Diſcovery of nitrous gas.

NITROUS gas was firſt obtained by Dr Hales, but its properties were diſcovered by Dr Prieſtley. It may be procured by diſſolving metals in nitric or nitrous acid, and catching the product by means of a pneumatic apparatus.

As nitrous acid is formed by combining nitrous gas and oxygen, it is evident that nitrous gas contains leſs oxygen than nitrous acid. According to Lavoiſier, it is compoſed of two parts of oxygen and one of azot.

419 Its properties.

Nitrous gas is elaſtic, and inviſible like common air. It extinguiſhes light, and inſtantly kills all thoſe animals that are obliged to breathe it. Its ſpecific gravity, according to Mr Kirwan, is 0,001458 *.

Dr Prieſtley found that water was capable of abſorbing about one-tenth of nitrous gas, and that by the abſorption it acquired an aſtringent taſte †. Water parts with all the nitrous gas it has imbibed on being frozen ‡.

Neither phoſphorus nor ſulphur ſeem capable of decompoſing nitrous gas.

Mr Linck, profeſſor at Roſtoc, found, that three parts of nitrous gas and two of hydrogen gas, obtained by ſulphuric acid and iron, are ſcarcely, or not at all, diminiſhed when expoſed to day-light over water. Common air is not more dminiſhed by this admixture kept a long time: but the mixture itſelf of theſe two gaſes is diminiſhed by the addition of new portions of nitrous gas. Mr Linck concludes, from this obſervation, that part of the oxygen of the nitrous gas combined with the hydrogen and formed water, and that the remaining oxygen and azot formed a mixture ſimilar to the air of the atmoſphere. Mr Vauquelin had previouſly made the ſame obſervation. The affinity of hydrogen, therefore, for oxygen is greater than that of azot §.

Oils imbibe nitrous gas with avidity, and decompoſe it.

Nitric acid abſorbs a vaſt quantity of it, and is by that means converted into nitrous acid.—Sulphuric acid alſo abſorbs it.

420 The eudiometer.

The moſt important property of nitrous gas is that of combining inſtantly with oxygen gas, and forming nitrous acid, which is inſtantly abſorbed by water. This property induced Dr Prieſtley to uſe nitrous gas as a teſt of the purity of common air. He mixed together equal bulks of theſe ſubſtances, and judged of the purity of the air by the diminution of bulk. The apparatus uſed for this purpoſe, which conſiſts of a graduated tube, has been called a *eudiometer*. This eudiometer has been greatly improved by Fontana, but it is ſtill liable to uncertainty in its application. Perhaps the beſt eudiometer is ſulphuret of potaſs, which, as Morveau has diſcovered, abſorbs, on the application of heat, the whole oxygen in a given bulk of air almoſt inſtantaneouſly.

Dr Prieſtley found that nitrous gas was decompoſed by paſſing electric exploſions through it.

Let us now conſider in what manner oxygen and azot are combined in the three ſubſtances which have been juſt deſcribed.

421 Manner in which azot and oxygen are combined.

It can hardly be conceived that azot is capable of combining with three different proportions of oxygen, and of being ſaturated with each: it is ſurely much more probable, that in nitrous gas the oxygen and azot ſaturate each other directly and completely; that nitrous acid is compoſed of nitrous gas and oxygen, and nitric acid of nitrous acid and oxygen. And this ſuppoſition is confirmed by conſidering that the ſtrength of affinity by which the oxygen is retained in each of theſe ſubſtances is very different. Some ſubſtances, as light, are capable of decompoſing nitric acid, by ſeizing ſome of its oxygen, and of converting it into nitrous acid; but they have no effect whatever upon nitrous acid or nitrous gas. Others, as biſmuth, copper, phoſphorus, and ſulphur, are capable of decompoſing both nitric and nitrous acids, but are incapable of altering nitrous gas: And others, again, as carbon, zinc, and iron, are capable of decompoſing all the three. Every body which is capable of decompoſing nitrous acid is capable alſo of decompoſing nitric acid; and every body that decompoſes nitrous gas is capable alſo of decompoſing the other two. But the reverſe of this is not true. The affinity of oxygen, then, for azot, nitrous gas, and nitrous acid, is different: oxygen has a ſtronger affinity for azot than it has for nitrous gas, and a ſtronger affinity for nitrous gas than for nitrous acid. But if all theſe bodies were direct combinations of azot and oxygen, how could this difference of affinity take place? Is it reaſonable to ſuppoſe that a ſubſtance has a ſtronger affinity for one proportion of any other body than for another proportion? or that, if ſuch a difference exiſted, the ſtrongeſt affinity ſhould not always prevail? Mix together nitric acid and nitrous gas in proper proportions, and the whole mixture is converted into nitrous acid: but mix nitrous and nitric acids together, and no change whatever is produced. In the firſt caſe, is it not evident that the affinity of nitrous gas for oxygen is greater than that of nitrous acid; that therefore it decompoſes the nitric acid, deprives it of oxygen, and leaves it in the ſtate of nitrous acid? But, in the ſecond caſe, no change can take place, becauſe nitric acid is compoſed of nitrous acid and oxygen; and it would be abſurd to ſuppoſe, that *nitrous acid* has a ſtronger affinity for oxygen than *nitrous acid* has. But were azot and oxygen capable of uniting in various proportions, why ſhould not a mixture of nitric and nitrous acids, or of nitrous gas and nitrous acid, form new ſubſtances? And why are the only ſubſtances which appear in decompoſitions nitrous acid and nitrous gas? Surely theſe reaſons are ſufficient to ſhew us, that theſe bodies are combined in the following manner:

Azot and Oxygen } form nitrous gas;
Nitrous gas and oxygen } form nitrous acid;
Nitrous acid and oxygen } form nitric acid.

Perhaps there may be even more links in the chain than we are aware of. The dephlogiſticated nitrous air of Dr Prieſtley, which Dieman and Van Trooſtwyck have lately proved to be compoſed of 37 parts of oxygen and 63 of azot, and of which little more is known than that it ſupports flame, is noxious to animals, abſorbed by water, and only obtained by means of ſubſtances capable of decompoſing nitrous gas—perhaps this *air* is compoſed directly of oxygen and azot, nitrous gas of this air and oxygen, and ſo on. There may be even links ſtill farther back than that.

SECT. V. *Of Muriatic Acid.*

422 Diſcovery of muriatic acid.

MURIATIC acid appears to have been known to Baſil Valentine; but Glauber was the firſt who extracted it

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* *On Phlogiſton*, p. 28.

† *Prieſtley*, i. 365.

‡ *Ibid.* p. 407.

§ *Nicholſon's Jour.* ii. 72.

from common ſalt by means of ſulphuric acid. Common ſalt is compoſed of muriatic acid and ſoda, for which laſt ſubſtance ſulphuric acid has a ſtronger affinity. This acid was firſt called *ſpirit of ſalt*, afterwards *marine acid*, and now, pretty generally, *muriatic acid* *.

* From *muria.*

It is ſometimes prepared by mixing one part of common ſalt with ſeven or eight parts of clay, and diſtilling the mixture. The clay, in this inſtance, is ſuppoſed to act chiefly by means of the ſulphuric acid which it always contains (z): But this ſubject ſtill requires farther elucidation. By theſe proceſſes, muriatic acid is obtained diſſolved in water. Dr Prieſtley diſcovered, that by applying heat to this ſolution, and receiving the product in veſſels filled with mercury, a gas was procured; which gas is muriatic acid in a ſtate of purity.

423
Its properties.

Muriatic acid gas is inviſible and elaſtic, like common air. It deſtroys life and extinguiſhes flame. A candle, juſt before it goes out in it, burns with a beautiful green, or rather light blue flame; and the ſame flame appears when it is firſt lighted again †.

† *Prieſtley*, ii. 293.

The ſpecific gravity of muriatic acid in the ſtate of gas is, according to Mr Kirwan ‡, 0,002315, which is nearly double that of common air.

‡ *Iriſh Tranſ.* iv.

Water abſorbs this gas with avidity. Ten grains of water are capable of abſorbing ten grains of the gas. The ſolution thus obtained occupies the ſpace of 13,3 grains of water nearly. Hence its ſpecific gravity is 1,500, and the denſity of the pure muriatic acid in it is 3,03 § (A).

§ *Kirwan, Iriſh Tranſ.* vol. iv.

As muriatic acid can only be uſed conveniently when diſſolved in water, it is of much conſequence to know how much pure acid is contained in a given quantity of liquid muriatic acid of any particular denſity.

424
Quantity of it contained in acids of various denſities.

Now the ſpecific gravity of the pureſt muriatic acid that can eaſily be procured and preſerved, is 1,196; it would be needleſs, therefore, to examine the purity of any muriatic acid of ſuperior denſity. Mr Kirwan calculated that muriatic acid, of the denſity 1,196, contains $\frac{49}{100}$ parts of acid of the denſity 1,500, which he took for the ſtandard; then, by means of experiments, he formed the following Table:

100 parts, at the ſpecific gravity	Contain of ſtandard acid	100 parts, at the ſpecific gravity	Contain of ſtandard acid	100 parts, at the ſpecific gravity	Contain of ſtandard acid
1,196	49	1,147	37	1,1036	26
1,191	48	1,1414	36	1,0984	25
1,187	47	1,1396	35	1,0942	24
1,183	46	1,1358	34	1,0910	23
1,179	45	1,1320	33	1,0868	22
1,175	44	1,1282	32	1,0826	21
1,171	43	1,1244	31	1,0784	20
1,167	42	1,1206	30	1,0742	19
1,163	41	1,1168	29	1,0630	16
1,159	40	1,1120	28	1,0345	10
1,155	39	1,1078	27	1,0169	5
1,151	38				

Muriatic acid (for this ſolution of the acid in water is always called by that name) is generally of a pale yellow colour, owing, as Dr Prieſtley ſuppoſed, to ſome earthy matter diſſolved in it; but much more probably to its having abſorbed a quantity of oxygen, for which it has a ſtrong affinity. Indeed, that this is the cauſe appears evidently from Dr Prieſtley's own obſervations; for it was deſtroyed only by thoſe bodies which had a ſtronger affinity for oxygen. It is very volatile, as might be expected, conſtantly emitting white fumes of a peculiar and unpleaſant odour.

425
Its action on other bodies.

Muriatic acid is capable, by the aſſiſtance of heat, of oxidating the following metals: Iron, tin, lead, zinc, biſmuth, cobalt, nickel, mangaeſe, antimony, arſenic. Several of theſe, as iron, for inſtance, it oxidates even without the aſſiſtance of heat.

At a boiling heat, it oxidates ſilver and copper. It has no action on gold, platinum, mercury, tungſten, molybdenum, tellurium, titanium. Its action on uranium has not been tried.

In the ſtate of gas, it appears to decompoſe alcohol and oils by its affinity for water *.

* *Prieſtley*, ii. 281.

It is capable of diſſolving a little ſulphat and fluat † of lime, and arſeniat of mercury.

† See ſect. ix.

It combines with the alkalies, alkaline earths, alumina, and jargonia, and with moſt of the metallic oxides, and forms neutral ſalts, known by the name of *muriats*.

426
Deſtroys putrid miaſmata.

Morveau firſt ſhewed, that this acid, in the ſtate of gas, neutralized putrid miaſmata, and by that means deſtroyed their bad effects. In 1773, the cathedral of Dijon was ſo infected by putrid exhalations, that it was deſerted, after ſeveral unſucceſsful attempts to purify it. Application was made to Mr Morveau to ſee whether he knew any method of deſtroying theſe exhalations. He poured two pounds of ſulphuric acid on ſix pounds of common ſalt, contained in a glaſs capſule, which had been placed on a few live coals in the middle of the church. He withdrew precipitately, and ſhut all the doors. The muriatic acid gas ſoon filled the whole cathedral, and could even be perceived at the door. After 12 hours, the doors were thrown open, and a current of air made to paſs through to remove the gas. This deſtroyed completely every putrid odour ‡.

‡ *Jour. de Phyſ.* i. 436.

427
Its affinities.

The affinities of muriatic acid are as follow:

Barytes,
Potaſs,
Soda,
Strontites §,
Lime,
Magneſia,
Ammonia,
Alumina,
Jargonia ‖,
Metallic oxides as in ſulphuric acid,
Water.

§ *Dr Hope.*

‖ *Vauquelin, Ann. de Chim.* xxii. 208.

SECT. VI. *Of Oxy-muriatic Acid.*

428
Diſcovery and preparation of oxy-muriatic acid.

PUT into a glaſs retort one part of the black oxide of mangaeſe and three parts of muriatic acid; place it in a ſand-bath in ſuch a manner that the liquor which riſes up into the neck of the retort may fall back again into

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(z) Morveau has ſhewn, that even alumina contains ſulphuric acid, provided a precipitation, on adding muriat of barytes, be a ſufficient teſt.

(A) For let D = the denſity of a mixture; *m* the weight of the denſer ingredient; *d* its denſity; *l* the weight of an into the veſſel; and apply a ſmall receiver, with a little water in it, luted to the retort merely by a fillet of brown paper. In about a quarter of an hour the receiver will appear filled with a yellow-coloured gas; it is then to be removed, and others applied ſucceſſively till the operation be finiſhed.

This gas is oxy-muriatic acid, firſt diſcovered by Scheele, while he was making experiments on mangaueſe, and called by him *dephlogiſticated muriatic acid*, becauſe he thought it muriatic acid deprived of phlogiſton. The French chemiſts called it *oxygenated muriatic acid*, which Dr Pearſon contracted into *oxy-muriatic acid*; and this laſt name we have adopted, becauſe it is ſhorter and equally diſtinct.

429
Its compoſition.

The true theory of the formation and compoſition of this acid, which was firſt given by Berthollet, will appear from the following facts: The *black* oxide of manganeſe is, during the proceſs, converted into *white* oxide, and muſt therefore have given out a quantity of oxygen. When oxy-muriatic acid diſſolved in water is preſented to the light in a veſſel half empty, oxygen gas is diſengaged and floats above, and the acid is converted into common muriatic acid: Conſequently oxy-muriatic acid is compoſed of muriatic acid and oxygen. Black oxide of mangaueſe is compoſed of white oxide and oxygen; muriatic acid has a ſtronger affinity for oxygen than the white oxide; during the diſtillation the black oxide is decompoſed, the oxygen combines with muriatic acid, and the product is oxy-muriatic acid gas.

430
Its properties.

Oxy-muriatic acid gas is of a yellow colour. It ſupports flame, but cannot be breathed without proving noxious. The death of the ingenious and induſtrious Pelletier, to whom we have ſo often referred, was occaſioned by his attempting to reſpire it. A conſumption was the conſequence of this attempt, which, in a ſhort time, proved fatal.

It does not unite readily with water. Scheele found, that after ſtanding 12 hours over water, $\frac{4}{5}$ths of the gas were abſorbed: the remainder was common air, which no doubt had been contained in the veſſel before the operation. Berthollet ſurrounded ſeveral bottles containing it with ice: as ſoon as the water in theſe bottles was ſaturated, the gas became concrete, and ſunk to the bottom of the veſſels; but the ſmalleſt heat made it riſe in bubbles, and endeavour to eſcape in the form of gas*. Weſtrum obſerved that it became ſolid when expoſed in large veſſels to the temperature of 40°; and that then it exhibited a kind of cryſtallization†. The ſpecific gravity of water ſaturated with this gas, at the temperature of 43°, is 1,003*. Water impregnated with it has not an acid, but an auſtere taſte†, unlike that of other acids.

It renders vegetable colours *white*, and not red, as other acids do; and the colour thus deſtroyed can neither be reſtored by acids nor alkalies. It has the ſame effects on yellow wax. If the quantity of vegetable colours to which it is applied be ſufficiently great, it is found reduced to the ſtate of common muriatic acid. Hence it is evident, that it deſtroys theſe colours by communicating oxygen. This property has rendered oxy-muriatic acid a very important article in bleaching.

Nitrous gas, hydrogen, ſulphur, ſulphurous acid, and phoſphorus, decompoſe this acid, by depriving it of its oxygen, and leaving the muriatic acid in a ſeparate ſtate. Phoſphorus, however, does not produce this effect ſo readily, except when aſſiſted by heat*.

431
Nitro-muriatic acid.

When muriatic acid is mixed with nitric acid, the compound has preciſely the ſmell and the qualities of oxy-muriatic. It can ſcarcely be doubted, therefore, that as far as it acts as an acid, different from the muriatic and the nitric, it is nothing elſe but oxy-muriatic acid.

This mixture of the two acids was formerly called *aqua regia*; but at preſent it is called by the French chemiſts *nitro-muriatic acid*. It is firſt mentioned by Iſaac the Hollander, and ſeems to have been known before the muriatic acid itſelf. It was prepared by pouring nitric acid on common ſalt. The nitric acid decompoſes the ſalt, and part of it unites with the muriatic acid thus ſet at liberty.

432
Its action on other bodies.

Oxy-muriatic acid oxidates all the metals (except, perhaps, titanium) without the aſſiſtance of heat.

It decompoſes red ſulphuret of mercury, or cinnabar, which neither ſulphuric nor nitric acid is able to accompliſh§.

All the ſubſtances placed before muriatic acid in the table of the affinities of oxygen, are capable of decompoſing this acid. Many of them, when plunged into it while in the ſtate of gas, actually take fire. Weſtrum obſerved, for inſtance, that when pieces of wood were plunged into this gas, they took fire; that arſenic burned with a blue and green flame; biſmuth, with a lively bluiſh flame; nickel, with a white flame, bordering on yellow; cobalt, with a white flame, approaching to blue; zinc, with a lively white flame; tin, with a feeble bluiſh flame; lead, with a ſparkling white flame; copper and iron, with a red flame: that powdered charcoal took fire in it at the temperature of 90°, and that ammonia produced with it a loud detonation‖.

* *Journ. de Phyſ.* 1785.

† *Journ. de Phyſique*, xxxvii. 382.

* *Berthollet, Journ. de Phyſ.* 1785.

† *Scheele.*

* *Morveau, Encyc. Method. Chimie*, i. 25.

§ *Bergman.*

‖ *Journ. de Phyſique*, xxxvii. 385.

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an equal bulk of water; and m', d', and l', the ſame elements of the rarer: Then $D = \frac{m + m'}{l + l'}$. In the above caſe, $m + m' = 20$, and $l + l' = 13{,}3$. Then $D = \frac{20}{13{,}3} = 1{,}5$. Now to find the ſpecific gravity of the condenſed muriatic acid gas, we have from the above equation $l = \frac{m + m' - l'D}{D} = \frac{5}{1{,}5} = 3{,}3$; and $d = \frac{m}{l} = \frac{10}{3{,}3} = 3{,}03$. *See Iriſh Tranſactions*, vol. iv.

This calculation, however, is formed upon the ſuppoſition that the water ſuffers no condenſation at all—a ſuppoſition certainly contradicted by every analogy, and which, as Mr Keir has ſhewn, the experiments mentioned in Mr Kirwan's firſt paper are inſufficient to prove.

With alkalies, earths, and metallic oxides, it is capable of combining and forming neutral ſalts, which have been called *oxy-mariats*.

433 Its affinities.

The affinities of this acid, according to Lavoiſier, are as follows:

Alumina,
Jargonia * ?
Ammonia,
Oxide of antimony,
——— ſilver,
——— arſenic,
Barytes,
Strontites?
Oxide of biſmuth,
Lime,
Oxide of cobalt,
——— copper,
——— tin,
——— iron,
Magneſia (B),
Oxide of mangane ſe,
——— mercury,
——— molybdenum,
——— nickel,
——— gold,
——— platinum,
——— lead,
Potaſs,
Soda,
Oxide of tungſten,
——— zinc (C).

434 Of the component parts of muriatic acid.

The component parts of muriatic acid are ſtill imperfectly known. Dr Girtanner pretended, about the year 1790, that he had decompoſed it; and that it conſiſted of hydrogen combined with a greater proportion of oxygen than enters into the compoſition of water. He paſſed electrical exploſions through muriatic acid, and obtained a quantity of oxygen and hydrogen gas. But a repetition of theſe experiments ſhewed, that the gaſes were owing, not to the decompoſition of the acid, but to that of the water with which the acid was combined.

The experiments of Mr Lambe (D) have lately opened a new and unexpected path, which ſeems to lead directly to the diſcovery of the component parts of this acid. He found, that when iron was acted upon by ſulphurated hydrogen gas, a ſubſtance was produced which poſſeſſed all the properties of oxy-muriat of iron (oxy-muriatic acid combined with iron). The ſulphurated hydrogen gas which he uſed was obtained from ſulphuret of iron, formed by fuſing equal parts of iron and flowers of ſulphur; and it was extricated by diluted ſulphuric acid. In a ſolution of this gas in diſtilled water, he digeſted iron filings, previouſly purified by repeated waſhings with diſtilled water. The bottle was filled with the ſolution, and corked. The iron was preſently acted upon; numerous bubbles aroſe, which drove the cork out of the bottle; they were ſtrongly inflammable, and probably, therefore, pure hydrogen gas. The liquor gradually loſt its odour of ſulphurated hydrogen gas, and after ſome days ſmelled very much like ſtagnant rain-water. As the bubbles ceaſed to be produced, it recovered its tranſparency. On evaporating a ſmall quantity of this ſolution in a watch-glaſs to dryneſs, a bitter deliqueſcent ſalt was left behind. On this ſalt a little ſulphuric acid was dropped, and paper moiſtened with ammonia was held over the glaſs; white vapours were immediately formed over the glaſs; and conſequently ſome volatile acid was ſeparated by the ſulphuric acid. Mr Lambe evaporated about eight ounce meaſures of the ſame liquor, and, as before, dropped a little ſulphuric acid on the reſiduum; a ſtrong efferveſcence was excited, very pungent acid fumes aroſe, which, from their ſmell, were readily known to be muriatic. The ſame truth was eſtabliſhed beyond a doubt, by holding a bit of paper moiſtened with water, which made the vapours viſible in the form of a grey ſmoke; a diſtinguiſhing characteriſtic, as Bergman has obſerved, of the muriatic acid.—When mangane ſe and mercury were diſſolved in ſulphurated hydrogen gas, the ſalts formed gave the ſame unequivocal marks of the preſence of muriatic acid *.

Shall we conclude from theſe facts, that the baſis of muriatic acid is ſulphurated hydrogen; that muriatic acid is ſulphurated hydrogen combined with oxygen; that this combination takes place during the ſolution of the iron; and that the eſcape of hydrogen is owing to the decompoſition of the water?

SECT. VII. *Phoſphoric Acid.*

435 Diſcovery of phoſphorus.

PHOSPHORUS is capable of forming combinations with two different quantities of oxygen; with the larger it forms phoſphoric; and with the ſmaller phoſphorous acid.

Phoſphoric acid was unknown till after the diſcovery of phoſphorus. Boyle is perhaps the firſt perſon who mentions it: he diſcovered it by allowing phoſphorus to burn ſlowly in common air. But Margraf was the firſt perſon who examined its properties, and diſcovered it to be a peculiar acid.

It may be procured by expoſing phoſphorus to a moderate heat: the phoſphorus takes fire, combines with oxygen, and is converted into an acid.

436 Method of preparing it.

It may alſo be prepared by expoſing phoſphorus during ſome weeks to the ordinary temperature of the atmoſphere, even in winter; when the phoſphorus undergoes a ſlow combuſtion, and is gradually changed into a liquid acid. For this purpoſe, it is uſual to put ſmall pieces of phoſphorus on the inclined ſide of a glaſs funnel, through which the liquor which is formed drops into the bottle placed to receive it. From one ounce of phoſphorus about three ounces of acid liquor may be thus prepared, called *phoſphoric acid by deliqueſcence.*

Scheele has contrived another mode of obtaining the phoſphoric

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* *Vauquelin, Ann de Chim.* xxii. 208.

* *Lambe, ibid.*

(B) According to Trommſdorf, oxy-muriatic acid is incapable of combining with magneſia. *Ann. de Chim.* xxii. 218.

(C) This is the order of the affinities of nitro-muriatic acid. Many facts (ſome of which ſhall appear afterwards) concur to prove that the affinities of the oxy-muriatic acid are the ſame, and indeed that they are the ſame acids.

(D) Analyſis of the waters of two mineral ſprings at Leminton Priors. *Mancheſter Memoirs*, vol. V. part 1ſt.

phoſphoric acid from phoſphorus without combuſtion, by the mere action of the nitric acid on phoſphorus *. Mr Lavoiſier has repeated and deſcribed this proceſs †. He put two pounds of nitric acid, the ſpecific gravity of which was 1,29895, into a retort, the contents of which were equal to ſix or ſeven French pints, and to which a balloon was fitted. Having placed this retort in a ſand-bath, and brought the heat of the acid contained in it to $133\frac{1}{3}$ deg. he added ſucceſſively ſmall quantities of phoſphorus, about 10 or 12 grains at a time, until he had diſſolved $2\frac{3}{4}$ oz. At firſt the effervеſcence was great, but at laſt he was obliged to apply heat to effect the ſolution. The operation laſted 17 or 18 hours. A good deal of nitrous acid had paſſed into the receiver. He then poured the contents of the retort into a ſmaller retort, and evaporated by means of a ſtronger heat, until the phoſphoric acid began to diſtil in white vapours. The remaining acid was ſo thick that he could not pour it out of the retort, and therefore could not aſcertain its quantity; but he ſuppoſes it might be 8 or 9 ounces, in which he thinks there were about $2\frac{1}{2}$ ounces of phoſphorus; the remaining $\frac{1}{4}$ ounce being ſuppoſed to have evaporated. The quantity of oxygen imbibed he reckons at $3\frac{1}{2}$ ounces, and the quantity of water at about 2 ounces.

Lavoiſier computes that phoſphoric acid contains 100 parts of phoſphorus and 154 of oxygen.

437 Its properties.

The colour of this acid is white; it has no ſmell, has an acid taſte; but is not corroſive (E).

It is exceedingly fixed. When expoſed to the fire in a matraſs with a long neck, it loſes at firſt the greater part of its water; then an odour of garlic is felt, owing to ſome phoſphorus, from which it is exceedingly difficult to clear it entirely; there is likewiſe a ſmall quantity of the acid volatilized along with the water. The liquor then becomes thick and milky: ſmall luminous decrepitations take place from time to time, and they continue for ſome time after the veſſel is taken from the fire. If the matter be then put into a crucible, and placed among burning coals, it firſt boils violently, and gives out a vapour which tinges flame green, and is at laſt converted to a white tranſparent glaſs, inſoluble in water.

The ſpecific gravity of this acid in a ſtate of dryneſs is 2,687 ‡, that of phoſphoric acid by deliqueſcence 1,417 §. It is capable of cryſtallizing; its cryſtals are quadrangular priſms terminated by quadrangular pyramids.

Phoſphoric acid obtained by deliqueſcence, when mixed with an equal quantity of diſtilled water, acquired ſo little *heat* as to raiſe the thermometer only one degree, as Mr Sage obſerved.

Mr Lavoiſier raiſed Reaümur's thermometer from 8° to 14° or 15° by mixing phoſphoric acid boiled to the conſiſtence of a ſyrup, with an equal quantity of water; and from 8° to 32° or 33° when the acid was as thick as turpentine ‖.

438 Its action on other bodies.

Phoſphoric acid is capable of oxidating iron, tin, lead, zinc, antimony, biſmuth, mangaueſe. When fuſed with ſeveral of theſe metals, as tin, lead, iron, and zinc, it is converted into phoſphorus; a proof that they have a ſtronger affinity for oxygen.

It does not act upon gold, platinum, ſilver, copper, mercury, arſenic, cobalt, nickel. It appears, however, to have ſome action on gold in the *dry way*, as it is called; for when fuſed with gold-leaf it aſſumes a purple colour; a proof that the gold has been oxidated.

It is capable of combining with alkalies, alkaline earths, alumina, and metallic oxides; and of forming ſalts known by the name of *phoſphats*.

Phoſphoric acid, by the aſſiſtance of heat, is capable of decompoſing glaſs.

439 Its affinities.

Its affinities are as follows:

Lime,
Barytes,
Strontites*,
Magneſia,
Potaſs,
Soda,
Ammonia,
Alumina,
Jargonia †,
Metallic oxides as in ſulphuric acid,
Water.

440 Phoſphorous acid.

The Phosphorous Acid is formed when phoſphorus is expoſed to a ſlow ſpontaneous combuſtion at the temperature of the atmoſphere; but it gradually abſorbs more oxygen, and is converted into phoſphoric acid.

Concerning phoſphorous acid nothing of any conſequence is at preſent known, except that it contains leſs oxygen than phoſphoric acid.

Sect. VIII. *Boracic Acid.*

441 Borax.

The word *borax* firſt occurs in the works of Geber, an Arabian chemiſt of the 10th century. It is a name given to a ſpecies of white ſalt much uſed by various artiſts. Its uſe in ſoldering metals appears to have been known to Agricola.

Borax is found mixed with other ſubſtances in Thibet. It ſeems to exiſt in ſome lands adjacent to lakes, from which it is extracted by water, and depoſited in thoſe lakes; whence in ſummer, when the water is ſhallow, it is extracted and carried off in large lumps. Sometimes the water in theſe lakes is admitted into reſervoirs, at the bottom of which, when the water is exhaled by the ſummer's heat, this ſalt is found.—Hence it is carried to the Eaſt Indies, where it is in ſome meaſure purified and cryſtallized: in this ſtate it comes to Europe, and is called *tincal*. In other parts of Thibet, it ſeems, by accounts received from China, they dig it out of the ground at the depth of about two yards, where they find it in ſmall cryſtalline maſſes, called by the Chineſe *mi poun*, *boui poun*, and *pin poun*; and the earth or ore is called *pounxa* ‡.

442 Diſcovery of boracic acid.

Though borax has been in common uſe for nearly three centuries, it was only in 1702 that Homberg, by diſtilling a mixture of borax and green vitriol, diſcovered the *boracic acid*. He called it *narcotic* or *ſedative ſalt*, from a notion of his, that it poſſeſſed the properties indicated by theſe names In his opinion, it was merely a product of the vitriol which he had uſed; but Lemery the Younger ſoon after diſcovered, that it could likewiſe be obtained from borax by means of the nitric and muriatic acids. Geoffroi afterwards diſcovered, that

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* *On Fire*, § lxxvii.

† *Mem. Acad.* 1780.

‡ *Bergman.*

§ *Morveau.*

‖ *Keir's Dictionary.*

* *Hope, Tranſ. Edin.* iv.

† *Vauquelin, Ann. de Chim.* xxii. 208.

‡ *Kirwan's Mineralogy*, ii. 37.

(E) We have obſerved, however, that when very much concentrated it deſtroyed the texture of vegetable ſubſtances, paper for inſtance, very completely.

that borax contained ſoda: and at laſt Baron proved, by a number of experiments, that borax was compoſed of boracic acid and ſoda; that it might be reproduced by combining theſe two ſubſtances—and that therefore the boracic acid was not formed during the decompoſition of borax, as former chemiſts had imagined, but was a peculiar ſubſtance which pre-exiſted in that ſalt.

443 Attempts to prove that it does not exiſt in borax;

This concluſion has been called in queſtion by Mr Cadet *, who affirmed that it was compoſed of *ſoda, the vitrifiable earth of copper, another unknown metal, and muriatic acid.* But this aſſertion has never been confirmed by a ſingle proof; Mr Cadet has only proved that boracic acid ſometimes contains copper; and Beaumé's experiments are ſufficient to convince us that this metal is merely accidentally preſent, and that it is probably derived from the veſſels employed in cryſtallizing borax: That boracic acid generally contains a little of the acid employed to ſeparate it from the ſoda, with which it is combined in borax: And that crude borax contains a quantity of earth imperfectly ſaturated with boracic acid:—All which may be very true; but they are altogether inſufficient to prove that boracic acid is not a peculiar ſubſtance, ſince it diſplays properties different from every other body.

444 And to prove that it is phoſphoric acid.

Meſſrs Exſchaquet and Struve have endeavoured, on the other hand, to prove that the phoſphoric and boracic acids are the ſame. But their experiments merely ſhew that theſe acids reſemble one another in ſeveral particulars; and though they add conſiderably to our knowledge of the properties of the phoſphoric acid, they are quite inadequate to eſtabliſh the principle which theſe chemiſts had in view; ſince it is not ſufficient to prove the identity of the two acids, to ſhew us a reſemblance in a few particulars, while they differ in many others. Boracic acid muſt therefore be conſidered as a diſtinct ſubſtance, the component parts of which are entirely unknown.

445 Method of procuring it.

The eaſieſt method of procuring boracic acid is the following one: Diſſolve borax in hot water, and filter the ſolution; then add ſulphuric acid, by little and little, till the liquor be rather more than ſaturated. Lay it aſide to cool, and a great number of ſmall, ſhining, laminated cryſtals will form. Theſe are the boracic acid. They are to be waſhed with cold water, and drained upon brown paper.

446 Its properties.

This acid has a ſouriſh taſte at firſt, then makes a bitteriſh cooling impreſſion, and at laſt leaves an agreeable ſweetneſs. Its cryſtals have ſome reſemblance to ſpermaceti, and it has the ſame kind of feel.

It changes vegetable blues to red; it has no ſmell; but when ſulphuric acid is poured on it, a tranſient odour of muſk is produced *. The air produces no change on it.

According to Reuſs, it is ſoluble in 20 parts of cold water, eight parts of warm water, and 2,5 of boiling water. According to Wenzel, 960 grains of boiling water diſſolve 434 of this acid. According to Morveau, one pound of boiling water diſſolves only 183 grains.

It is exceedingly fixed when not combined with water. When expoſed to a violent fire it is converted into a white tranſparent glaſs; which, however, is ſoluble in water, and produces the acid again by evaporation.

Boracic acid is alſo ſoluble in alcohol; and alcohol containing it burns with a green flame.

Its ſpecific gravity is 1,479 ‡.

Paper dipped into a ſolution of boracic acid burns with a green flame.

Though mixed with fine powder of charcoal, it is nevertheleſs capable of vitrification; and with ſoot it melts into a black bitumen-like maſs, which is, however, ſoluble in water, and cannot be eaſily calcined to aſhes, but ſublimes in part *.

With the aſſiſtance of a diſtilling heat it diſſolves in oils, eſpecially in mineral oils; and with theſe it yields fluid and ſolid products, which give a green colour to ſpirit of wine.

When boracic acid is rubbed with phoſphorus, it does not prevent its inflammation; but an earthy yellow matter is left behind †.

447 Its action on other bodies.

It is hardly capable of oxidating or diſſolving any of the metals except iron and zinc, and perhaps copper.

Boracic acid combines with alkalies, alkaline earths, and alumina, and moſt of the metallic oxides, and forms compounds, which are called *borats*.

448 Its affinities.

Its affinities are as follows:

Lime,
Barytes,
Strontites ‡,
Magneſia,
Potaſs,
Soda,
Ammonia,
Oxide of zinc,
——— iron,
——— lead,
——— tin,
——— cobalt,
——— copper,
——— nickel,
——— mercury,
Alumina,
Jargonia §,
Water,
Alcohol.

Sect. IX. *Fluoric Acid.*

449 Diſcovery of fluoric acid.

The mineral called *fluor* or *fuſible ſpar*, was not properly diſtinguiſhed from other ſpars till Margraf publiſhed a diſſertation on it in the Berlin Tranſactions for 1768. He firſt proved that it contained no ſulphuric acid, as had been formerly ſuppoſed; he then attempted to decompoſe it, by mixing together equal quantities of this mineral and ſulphuric acid, and diſtilling them. By this method he obtained a *white ſublimate*, which he ſuppoſed to be the fluor itſelf volatilized by the acid. He obſerved, with aſtoniſhment, that the glaſs retort was corroded, and even pierced with holes. Nothing more was known concerning fluor till Scheele publiſhed his experiments three years after; by which he proved that it was compoſed chiefly of lime and a particular acid, which has been called *fluoric acid*.

450 Method of obtaining it.

To obtain it, put eight ounces of finely powdered fluor into a retort, and pour on it an equal quantity of ſulphuric acid, and lute to the retort, as exactly as poſſible, a receiver containing eight ounces of water. Vapours immediately appear and darken the inſide of the veſſel: Theſe are the acid in the ſtate of gas. The diſtillation is to be conducted with a very moderate heat, not only to allow the gas to condenſe, but alſo to prevent the fluor itſelf from ſubliming. After the proceſs,

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* *Journ. de Phyſ.* 1782.

* *Reuſs De Sale Sedat.* 1778.

‡ *Kirwan's Miner.* ii. 4.

* *Keir's Dictionary.*

† *Ibid.*

‡ *Dr Hope, Tranſ. Edin.* iv.

§ *Vauquelin, Ann. de Chim.* xxii. 208.

ceſs, a cruſt of white earth is found in the receiver, which has all the properties of ſilica.

Scheele ſuppoſed that the ſilica produced was formed of fluoric acid and water, and Bergman adopted the ſame opinion. But Wiegleb and Buccholz ſhewed, that the quantity of ſilica was exactly equal to what the retort loſt in weight; and Meyer completed the proof that it was derived from the glaſs, by the following experiment: He put into each of three equal cylindrical tin veſſels a mixture of three oz. of ſulphuric acid and one oz. of fluor, which had been pulverized in a mortar of metal. Into the firſt he put one oz. of pounded glaſs; into the ſecond, the ſame quantity of quartz in powder; and into the third, nothing. Above each of the veſſels he hung a ſponge moiſtened with water; and having covered them, he expoſed them to a moderate heat. The ſponge in the firſt cylinder was covered with the cruſt in half an hour; the ſponge in the ſecond in two hours; but no cruſt was formed in the third, though it was expoſed ſeveral days. In conſequence of this deciſive experiment, Bergman gave up his opinion, and wrote an account of Meyer's experiment to Morveau, who was employed in tranſlating his works, to enable him to correct the miſtake in his notes.

451 Attempts to diſprove its exiſtence. Soon after the diſcovery of this acid, difficulties and doubts concerning its exiſtence as a peculiar acid were ſtarted by ſome French chemiſts, diſguiſed under the name of Boulanger, and afterwards by Mr Achard and Mr Monnet. To remove theſe objections, Mr Scheele inſtituted and publiſhed a new ſet of experiments; which not only completely eſtabliſhed the peculiar nature of the fluoric acid, but once more diſplayed the unrivalled abilities of the illuſtrious diſcoverer. Theſe important particulars we paſs over thus ſlightly, becauſe they have been partly treated of already in the article CHEMISTRY, *Encycl.* 452 Refuted by Scheele, One experiment, however, we cannot omit, becauſe it is ſufficient of itſelf to deſtroy almoſt all the objections of his antagoniſts, which conſiſted in attempting to prove, that the fluoric acid was merely a modification of the acid employed to extract it. We ſhall give it in Mr Sheele's own words.

"I melted together (ſays he) in a crucible two ounces of finely pulverized fluor ſpar with four ounces of potaſs. As ſoon as they were melted, I poured out the maſs, rubbed it, when it was become cold, to a powder, and extracted the alkali from it again by lixiviation with water. I evaporated the lixivium to dryneſs; and threw away the remaining undiſſolved powder (which was only one of the component parts of the fluor, and which diſſolved readily, and with effervescence, in acids) from its ſolution, in which it may be precipitated by ſulphuric acid in the form of ſelenite (ſulphat of lime). Upon a little of the dried alkali, put into a ſmall retort, I poured ſome ſulphuric acid, fitted to it a receiver containing ſome water; and even before the retort was become hot, I obſerved this water to be covered over with a pellicle of ſiliceous earth: a certain proof that the alkali had extracted the acid from the fluor during its expoſure to the fire with it. Should Mr Achard, agreeably to the opinion which he has adopted, conclude from this experiment, that the alkali ſeparated the volatile earth from the fluor (F); ſtill he muſt certainly allow this earth of his to be of an acid nature, ſince the alkali is capable of diſengaging it from the calcareous earth.—The remaining portion of the dried alkali I diſſolved again in water, and ſaturated the ſuperfluous alkali with pure nitric acid. After expelling from this ſaturated ſolution, by means of heat, the carbonic acid gas, which in ſuch caſes is always retained in the liquor, I dropped ſome of it into lime-water; whereupon I obtained a white precipitate, which was a regenerated fluor. I now diſſolved ſome oxide of lead in vinegar, and continued to add to the ley, which had been ſaturated with nitric acid, as much of this ſolution as was requiſite, till all precipitation ceaſed. Thus I transferred the fluor acid from the alkali to the oxide of lead. After waſhing the precipitate in cold water, and drying it, I dropped upon a ſmall quantity of it a few drops of ſulphuric acid; a frothing up immediately enſued, accompanied with an extrication of fluor acid vapours. But perhaps, in this caſe, the volatile earth of fluor unites with the ſulphuric acid, and converts this fixed, or almoſt fixed acid into acid gas. I can eaſily make allowance to Dr Prieſtley for being inclined to draw ſuch a concluſion, ſince this celebrated philoſopher does not pretend to be a chemiſt (G). Being deſirous of ſeeing whether heat alone was capable of expelling this acid from the oxide of lead, I put a little of this fluorated oxide into a ſmall retort, the receiver to which contained ſome water. The oxide was melted; but I could not perceive any acid. The bottom of the retort was moreover quite corroded and diſſolved, ſo that the whole ran into the fire. Thus the oxide of lead retains this acid in the fire, and will not part with it, unleſs the oxide is combined with ſome other ſubſtance. I therefore rubbed the remainder of my fluorated oxide of lead with an equal quantity of charcoal powder, and diſtilled the mixture in an open fire in a ſmall glaſs retort, to which was adapted a receiver containing ſome water. As ſoon as the reduction of the oxide of lead took place, the neck of the retort became incruſted with a white ſublimate, and a ſiliceous pellicle appeared upon the water. The ſublimate had a ſour taſte, becauſe the ſiliceous earth of which it conſiſts is penetrated with fluoric acid; and the acid water in the receiver let fall, on the addition of volatile alkali, a ſiliceous earth *."

Sorry are we to add, that ſince the death of this admirable man, to uſe the words of Mr Kirwan †, a man as eminent in the chemical as Newton in the mathematical branch of natural philoſophy, Mr Monnet ‡ has thought proper to renew his attacks in a ſtyle of haughtineſs and acrimony that inſpires infinite diſguſt. The falacy of his reaſoning is ſufficiently expoſed by Mr Leonhardi, in the 6th volume of his late learned edition of Macquer's Dictionary. 453 And Leonhardi.

* *Crell's Journal*, i. 221. Eng. Tranſl.
† *Mineralogy*, i. 226.
‡ *Journ. de Phyſ.* xxx. 253.

454 Its properties. Fluoric acid may be obtained in the form of gas, by applying a moderate heat to ſulphuric acid and fluor ſpar, and receiving the product over mercury.

This gas is the acid in a ſtate of purity. It is inviſible and elaſtic like air; it does not maintain combuſtion,

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(F) Mr Achard affirmed that fluor was compoſed of a peculiar volatile earth.

(G) Dr Prieſtley at firſt advanced this hypotheſis, but he afterwards gave it up.

tion, nor can animals breathe it without death. It has a pungent ſmell, not unlike that of muriatic acid.

It is heavier than common air. It corrodes the ſkin almoſt inſtantly. It combines rapidly with water; and if it has been obtained by means of glaſs veſſels, it depoſites at the ſame time a quantity of ſilica.

Water impregnated with this gas does not freeze at a higher temperature than 23° *.

455 Its action on other bodies.

In the ſtate of gas this acid does not act upon nitrous gas nor ſulphur Alcohol and ether abſorb it, but it does not alter their qualities †.

It is capable of oxidating iron, zinc, copper, and arſenic.

It does not act upon gold, platinum, ſilver, mercury, lead ? tin, antimony, cobalt.

It combines with alkalies, alkaline earths, and alumina, and metallic oxides, and forms compounds denominated *fluats*.

It is capable, as we have ſeen, of diſſolving ſilica, which is inſoluble in every other acid; accordingly it corrodes glaſs. This property has induced ſeveral ingenious men to attempt, by means of it, to engrave, or rather etch, upon glaſs.

456 Its affinities.

The affinities of fluoric acid are as follows:

Lime,
Barytes,
Strontites ‡,
Magneſia,
Potaſs,
Soda,
Ammonia,
Oxide of zinc,
——— manganeſe §,
——— iron,
——— lead,
——— tin,
——— cobalt,
——— copper,
——— nickel,
——— arſenic,
——— biſmuth,
——— mercury,
——— ſilver,
——— gold,
——— platinum,
Alumina,
Jargonia || ?
Water,
Silica,
Alcohol.

SECT. X. *Of Carbonic Acid.*

CARBONIC acid is compoſed of carbon and oxygen. According to Lavoiſier's experiments, the proportions are 28 parts of carbon and 72 of oxygen. Mr Prouſt informs us that there is alſo a *carbonous acid* (H); but with this acid we are not at preſent acquainted, and cannot therefore deſcribe it.

457 Diſcovery of carbonic acid.

Paracelſus and Van Helmont were acquainted with the fact, that air is extricated from ſolid bodies during certain proceſſes, and the latter gave to air thus produced the name of *gas*. Boyle called theſe kinds of air *artificial airs*, and ſuſpected that they might be different from the air of the atmoſphere. Hales aſcertained the quantity of air that could be extricated from a great variety of bodies, and ſhewed that it formed an eſſential part of their compoſition. Dr Black proved, that the ſubſtances then called *lime*, *magneſia*, and *alkalies*, are compounds, conſiſting of a *peculiar ſpecies of air*, and pure lime, magneſia, and alkali. To this ſpecies of air he gave the name of *fixed air*, becauſe it exiſted in theſe bodies in a fixed ſtate. This air or gas was afterwards inveſtigated by Dr Prieſtley, and a great number of its properties aſcertained. From theſe properties Mr Keir * firſt concluded that it was an acid; and this opinion was ſoon confirmed by the experiments of Bergman, Fontana, &c. Dr Prieſtley at firſt ſuſpected that this acid entered as an element into the compoſition of atmoſpherical air; and Bergman adopting the ſame opinion, gave it the name of *aerial acid*. Mr Bewdly called it *mephitic acid*, becauſe it could not be reſpired without occaſioning death; and this name was alſo adopted by Morveau. Mr Keir called it *calcareous acid;* and at laſt Mr Lavoiſier, after diſcovering its compoſition, gave it the name of *carbonic acid gas*.

458 Theories about its compoſition.

The opinions of chemiſts concerning the *compoſition* of carbonic acid have undergone as many revolutions as its name. Dr Prieſtley and Bergman ſeem at firſt to have conſidered it as an element; and ſeveral celebrated chemiſts maintained that it was the acidifying principle. Afterwards it was diſcovered that it was a compound, and that oxygen gas was one of its component parts. Upon this diſcovery the prevalent opinion of chemiſts was, that it conſiſted of oxygen and phlogiſton; and when hydrogen and phlogiſton came (according to Mr Kirwan's theory) to ſignify the ſame thing, it was of courſe maintained that carbonic acid was compoſed of oxygen and hydrogen: and though Mr Lavoiſier demonſtrated that it was formed by the combination of carbon and oxygen, this did not prevent the old theory from being maintained; becauſe carbon was itſelf conſidered as a compound, into which a very great quantity of hydrogen entered. But after Mr Lavoiſier had demonſtrated that the weight of the carbonic acid produced was preciſely equal to the carbon and oxygen employed; after Mr Cavendiſh had diſcovered that oxygen and hydrogen when combined did not form carbonic acid, but water—it was no longer poſſible to heſitate that this acid was compoſed of carbon and oxygen. Accordingly all farther diſpute about it ſeems now at an end. At any rate, as we have already examined the objections that have been made to this concluſion, it would be improper to enter upon them here.

459 Its analyſis.

If any thing was ſtill wanting to put this concluſion beyond the reach of doubt, it was to *decompound* carbonic acid, and thus to exhibit its component parts by analyſis as well as ſyntheſis. This has been actually done by the ingenious Mr Tennant. Into a tube of glaſs he introduced a bit of phoſphorus and ſome

* Prieſtley, ii 362.

† Ibid.

‡ Dr Hope.

§ Lavoiſier.

|| Vauquelin, Ann. de Chim. xxii. 208.

* Keir's Macquer, art. Air.

(H) When there are two acids having the ſame baſe, but containing different quantities of oxygen, they are diſtinguiſhed by their termination. The name of that which contains moſt oxygen ends in *ic*, the other in *ous*. Thus ſulphuric and ſulphurous acids, nitric and nitrous, phoſphoric and phoſphorous, carbonic and carbonous.

ſome carbonat of lime. He then ſealed the tube hermetically, and applied heat. Phoſphat of lime was formed, and a quantity of carbon depoſited. Now phoſphat of lime is compoſed of phoſphoric acid and lime; and phoſphoric acid is compoſed of phoſphorus and oxygen. The ſubſtances introduced into the tube were phoſphorus, lime, and carbonic acid; and the ſubſtances found in it were phoſphorus, lime, oxygen, and carbon. The carbonic acid, therefore, muſt have been decompoſed, and it muſt have conſiſted of oxygen and carbon. This experiment was repeated by Dr Pearſon, who aſcertained that the weight of the oxygen and carbon were together equal to that of the carbonic acid which had been introduced; and in order to ſhew that it was the carbonic acid which had been decompoſed, he introduced pure lime and phoſphorus; and inſtead of obtaining phoſphat of lime and carbon, he got nothing but phoſphuret of lime. Theſe experiments were alſo confirmed by Meſſrs Fourcroy, Vauquelin, Sylveſtre, and Broigniart (I) *.

* *Ann. de Chim.* xiii. 312.

Carbonic acid may be obtained by pouring ſulphuric acid upon chalk, and receiving the product in a pneumatic apparatus.

460 Its properties,

It is inviſible and elaſtic like common air. It extinguiſhes a candle, and is unfit for reſpiration. It has no ſmell.

Its ſpecific gravity is 0,0018 †; but this varies according to its dryneſs or moiſture.

† *Bergman*, i. 9.

It reddens the tincture of turnſole, but no other vegetable colour ‡.

‡ *Ibid.*

Atmoſpheric air contains about $\frac{1}{100}$ part of this gas (K).

Water abſorbs it by agitation, or by allowing it to remain long in contact with it. At the temperature of 41° water abſorbs its own bulk of this gas. The ſpecific gravity of water ſaturated with it is 1,0015. This water, at the temperature of 35°, has little taſte; but if it be left a few hours in the temperature of 88°, it aſſumes an agreeable acidity, and a ſparkling appearance §.

§ *Ibid.*

Ice abſorbs no carbonic acid; and if water containing it be frozen, the whole ſeparates in the act of freezing ‖.

‖ *Prieſtley*, i. 120.

This gas alſo ſeparates from water at the boiling temperature ¶.

¶ *Ibid.*

Alcohol and oil of turpentine abſorb double their weight of this gas; olive oil its own bulk. Ether mixes with it in the ſtate of gas *.

* *Bergman*, *ibid.*

Phoſphorus ſuffers no change in this gas except it contains a mixture of oxygen gas †. It has an affinity for common air. Bergman left a bottle of it uncorked, and found that in a few days it contained nothing but common air. Common air, indeed, has ſo ſtrong an affinity for this gas, that it attracts it from water, as Mr Welter has obſerved ‡.

† *Brugnatelli, Nicholſon's Journal*, i. 446.

‡ *Ann. de Chim.* iii. 91.

It is abſorbed by red hot charcoal, as Morozzo and La Metherie have ſhewn.

461 Compounds,

It is capable of combining with alkalies, alkaline earths, and alumina, and ſeveral metallic oxides, and of forming compounds known by the name of *carbonats*. It has no affinity for jargonia, according to Klaproth *; but, according to Vauquelin, it has †.

* *Journ. de Phyſ.* xxxvi. 186.

† *Ann. de Chim.* xxii. 204.

462 And affinities.

Its affinities, as arranged by Bergman, are as follows:

Barytes,
Lime,
Strontites ‡,
Potaſs,
Soda,
Magneſia,
Alumina,
Metallic oxides as in *ſulphuric acid*,
Oxygen gas §,
Water,
Alcohol.

‡ *Dr Hope.*

§ *Mr Welter.*

SECT. XI. *Of Acetous Acid.*

Acetous acid or vinegar was known many ages before the diſcovery of any other acid, thoſe only excepted which exiſt ready formed in vegetables. It is mentioned by Moſes, and indeed ſeems to have been in common uſe among the Iſraelites and other eaſtern nations at a very early period.

The methods of procuring, purifying, and concentrating this acid, have been already given in the articles CHEMISTRY, FERMENTATION, and VINEGAR, *Encycl.* and cannot therefore be repeated in this place.

It has been aſcertained beyond a doubt, that this acid is compoſed of carbon, hydrogen, and oxygen; but neither the manner in which theſe ſubſtances are combined, nor their proportions, have been accurately aſcertained.

463 Lowitz's method of obtaining pure acetous acid.

Acetous acid, as commonly prepared, is very fluid, has a pleaſant ſmell, and an acid taſte. It reddens vegetable colours. In this ſtate it is mixed with a great proportion of water; but Mr Lowitz of Peterſburg has diſcovered that it may be obtained in a ſolid cryſtallized form. Of this curious and inſtructive proceſs we ſhall tranſcribe his own account ‖.

‖ *Crell's Journal*, i. 242. Eng. Tranſl.

" I have long been accuſtomed (ſays he) to prepare concentrated vinegar by congelation in the following manner: I freeze a whole barrel of vinegar as much as poſſible, then diſtil the remaining unfrozen vinegar in a water-bath; by which means I at firſt eſpecially collect the ſpirituous ethereal part; the vinegar, which next comes over, I freeze again as much as poſſible, and afterwards purify it, by diſtilling it again with three or four pounds of charcoal powder. Thus I never fail to get a very pure, ſweet-ſmelling, highly concentrated vinegar; the agreeable odour of which, however, may be

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(I) Count Muſſin-Puſchin having boiled a ſolution of carbonat of potaſs on purified phoſphorus, obtained carbon. This he conſidered as an inſtance of the decompoſition of carbonic acid, and as a confirmation of the experiments related in the text. See *Ann. de Chim.* xxv. 105.

(K) At leaſt near the ſurface of the earth. Lamanon, Mongez, and the other unfortunate philoſophers who accompanied La Perouſe in his laſt voyage, have rendered it not improbable that at great heights the quantity of this gas is much ſmaller. They could detect none in the atmoſphere at the ſummit of the Peak of Teneriffe. See ***Lamanon's Memoir at the end of La Perouſe's Voyage.***

ſtill improved by the addition of a proper quantity of the ethereal liquor collected at the beginning of the firſt diſtillation, but which muſt be previouſly dephlegmated by two or three rectifications.

“ After the diſtillation in the water-bath was over, that no vinegar might be loſt, I uſed to move the retort, with the charcoal powder which remained in it, to a ſand-bath; and thus I obtained, by means of a ſtrong fire, a few ounces more of a remarkably concentrated vinegar, which was of a yellow colour.

“ Having collected about ten ounces of this concentrated vinegar, I expoſed it laſt winter in the month of December to a cold equal to —22°; in which ſituation it ſhot into cryſtals from every part. I let what remained fluid drop away from the cryſtals into a baſon placed underneath, firſt in the cold air, and afterwards at the window within doors. There remained in the bottle ſnow-white finely foliated cryſtals, cloſely accumulated one upon the other, and which I at firſt took to be nothing but ice: on placing them upon the warm ſtove, they diſſolved into a fluid which was perfectly as limpid as water, had an uncommonly ſtrong, highly pungent, and almoſt ſuffocating acetous ſmell, and in the temperature of —37° immediately congealed into a ſolid white cryſtallized maſs, reſembling camphor.

“ After I had obſerved that vinegar in this ſtate is of ſuch an extraordinary ſtrength and purity as to he in its higheſt degree of perfection, I took all poſſible pains to find out a method of obtaining all the acetous acid in the ſtate of glacial vinegar.

“ To avoid circumlocution, I ſhall denote the ſtrength of each ſort of vinegar, which it was neceſſary for me to know in my experiments, by degrees, which I aſcertain in the following manner: *viz.* to one drachm of vinegar I add, drop by drop, a clear ſolution of equal parts of carbonat of potaſs and water, till all at once a cloudineſs or precipitation appears. Although, on the appearance of this ſign, the acid is already ſuperſaturated with the alkali, yet it ſeems to me to be a more accurate teſt for aſcertaining its ſtrength than the ceſſation of efferveſcence; for as the point of ſaturation approaches, the efferveſcence becomes ſo imperceptible, that it is almoſt impoſſible to determine with preciſion when it is really at an end. Now, every five drops of the alkaline ſolution, which I find it neceſſary to add to the vinegar till the precipitation takes place, I reckon as one degree. Thus, for example, if a determinate quantity of vinegar requires 25 drops for that effect, I denote its ſtrength by five degrees. This is about the ſtrength of good diſtilled vinegar.

“ I call that vinegar which, in conſequence of its concentration, is capable of cryſtallizing in a great degree of cold, *cryſtallizable vinegar;* the cryſtals of vinegar, ſeparated after the cryſtallization is completed from the remaining fluid portion, I call *glacial vinegar;* and, laſtly, to the fluid reſiduum I give the name of *mother-ley of vinegar.*

“ From a great number of experiments, I have found that vinegar muſt have at leaſt 24 degrees of concentration before it can be brought to cryſtallize by expoſure to the moſt intenſe cold. Vinegar muſt be of the ſtrength of 42 degrees at leaſt, in order to become glacial vinegar; *viz.* in this ſtate of concentration it has the property of cryſtallizing in a degree of cold not exceeding that in which water begins to freeze.

“ I have found that charcoal, on being diſtilled with vinegar in a water bath, poſſeſſes the ſingular and hitherto unknown property of imbibing a certain quantity of the acetous acid in a very concentrated ſtate, and of retaining it ſo ſtrongly, that the acid cannot be ſeparated from it again but by the application of a conſiderably greater degree of heat than that of boiling water. Upon this circumſtance is founded the new method which I have diſcovered of concentrating vinegar, ſo as to obtain all its acid in the pureſt ſtate, *viz.* that of a glacial vinegar.

“ Let a barrel of vinegar be concentrated by freezing in the manner above deſcribed, and let the concentrated vinegar thus obtained, free from all inflammable or ſpirituous parts, be put into two retorts: Add to each of them five pounds of good charcoal reduced to a fine powder, and ſubject them to diſtillation in a water-bath. When no more drops of vinegar come over, put the diſtilled liquor into two freſh retorts; and after adding five pounds of charcoal powder to each, proceed as before to the diſtillation in a water-bath. In the mean while, the two firſt retorts are to be placed in a ſand-bath, that, by means of a briſk fire, the cryſtallizable vinegar, which is retained in the apparently dry charcoal powder, may be expelled from it. The heat muſt be ſtrong enough to make the drops follow one another every two ſeconds; and when, in this degree of heat, 20 ſeconds intervene between each drop, the vinegar which has been collected muſt be removed; for what follows is hardly any thing elſe but mere water. In this manner about ſix ounces and a half of cryſtallizable vinegar, which is generally of the ſtrength of between 36 and 40 degrees, may be collected from each retort. As ſoon as the diſtillation by the water-bath in the two retorts is over, the diſtilled liquor is to be poured back again into the firſt retorts upon the charcoal powder, which remains in them, and which has been already uſed; and from each of theſe retorts the remaining cryſtallizable vinegar (which generally amounts to as much as the firſt quantity) is to be abſtracted by diſtillation in a ſand-bath. Theſe operations may be alternately repeated till all the acid of the vinegar which had been concentrated by freezing is converted into cryſtallizable vinegar; or until the diſtilled liquor, conſtantly becoming weaker and weaker at every repetition of the diſtillation, comes over at length in the ſtate of mere water, which, with the above mentioned quantity of charcoal powder, generally happens at the fourth or fifth diſtillation. Now, in order to obtain the greateſt part of the pure acid contained in the cryſtallizable vinegar in the form of glacial vinegar, it muſt be ſet to cryſtallize in a great degree of cold; and the mother-ley muſt be afterwards thoroughly drained from the glacial vinegar, by letting it drop from the cryſtals, firſt in the cold, and then in the room before the window. The mother-ley may be rendered further cryſtallizable by diſtilling it with a little charcoal powder; the weaker part, which comes over firſt, being put aſide. But if a perſon wiſhes to keep the cryſtallizable vinegar for other purpoſes, and without ſeparating any glacial vinegar from it, he muſt diſtil the whole of it again with charcoal powder in a ſand-bath.

“ I have found by accurate experiments, that, by means of this curious proceſs, ten pounds of vinegar, concentrated by freezing to the 90th degree, may be made

made to yield 38 ounces of cryſtallizable vinegar, from which 20 ounces of glacial vinegar may be obtained.

“ What conſtitutes the excellence of this method is, that the concentration and purification are effected by one and the ſame medium, viz. the charcoal powder; in conſequence of which, both intentions are fulfilled at the ſame time.

“ Laſt year, after much reflection, I was ſo happy as to find out another very effectual method of ſeparating the acetous acid from the other ſubſtances combined with it, ſo as to obtain it at once in the ſtate of a glacial vinegar of the greateſt poſſible ſtrength. The ſeparating medium which I thought of is ſulphat of potaſs ſuperſaturated with ſulphuric acid; a ſalt in which, conformably to my purpoſe, the ſulphuric acid exiſts in a perfectly dry and dephlegmated ſtate.

“ By means of this ſalt a highly concentrated glacial vinegar may be obtained in the following manner:

“ Let three parts of acetated ſoda, prepared with vinegar diſtilled over charcoal, and evaporated to perfect dryneſs, be melted in a ſtrong heat; then pour it out, and rub it to a very fine powder. Mix this powder very accurately with eight parts of ſuperſaturated ſulphat of potaſs that has been previouſly well dried, and in like manner reduced to a fine powder; put the whole into a retort, and diſtil with a gentle heat, in ſuch manner that, along with the drops, ſome vapours alſo may be perceived to come out of the neck of the retort; but by no means ſo that the receiver ſhall be filled with theſe vapours. Notwithſtanding the moderate heat, the vinegar comes over very faſt, and the quantity of glacial vinegar, of the ſtrength of 54 degrees, which is thus obtained, amounts to nearly two parts.”

464 Action of acetous acid on other bodies.

Acetous acid is capable of oxidating iron, zinc, lead, nickel, tin, copper.

It does not act upon gold, ſilver, platinum, mercury, biſmuth, cobalt, antimony, arſenic.

It combines with alkalies, alkaline earths, and alumina, and metallic oxides, and forms compounds known by the name of *acetites*.

465 Its affinities.

Its affinities are as follows:

Barytes,
Potaſs,
Soda,
Strontites?
Lime,
Magneſia,
Ammonia,
Oxide of zinc,
——— mangaueſe,
——— iron,
——— lead,
——— tin,
——— cobalt,
——— copper,
——— nickel,
——— arſenic,
——— biſmuth,
——— mercury,
——— antimony,
——— ſilver,
——— gold,
——— platinum,
Alumina *,
Jargonia †?
Water,
Alcohol,

Sect. XII. *Of Acetic Acid.*

If acetite of copper be diſtilled, an acid comes over of a more pungent ſmell than acetous acid, capable of cryſtallizing, and having a ſtronger affinity for other bodies than acetous acid. It is called *acetic acid*, and is ſuppoſed to contain a larger proportion of oxygen than acetous acid. This additional doſe it is ſuppoſed to receive from the oxide of copper, which during the proceſs is reduced to the metallic ſtate. It can hardly be doubted that the glacial vinegar of Lowitz, deſcribed in the preceding ſection, is really acetic acid, though it would perhaps be difficult to explain its formation. Its affinities are the ſame with thoſe of the acetous acid.

Sect. XIII. *Of Oxalic Acid.*

Sugar, a well-known ſubſtance extracted from the ſugar-cane, appears to have been uſed in the Eaſt at a very early period; but it made its way weſtward very ſlowly. As a medicine, it is mentioned by Dioſcorides; but it was not in common uſe in Europe till after the 14th century.

466 Compoſition of ſugar.

It has been proved that ſugar is compoſed of oxygen, carbon, and hydrogen. Lavoiſier concluded, from a long ſeries of delicate experiments, that it conſiſts of 8 parts of hydrogen, 64 of oxygen, and 28 of carbon.

467 Diſcovery of oxalic acid.

From ſugar, by a particular proceſs, an acid has been obtained called *oxalic acid*, becauſe it exiſts ready formed, as Scheele has proved, in the *oxalis acetoſella*, or wood ſorrel. At firſt, however, it was called the *acid of ſugar*, or the *ſaccharine acid*.

As the earlieſt and beſt account of the oxalic acid was publiſhed by Bergman, he was for a long time reckoned the diſcoverer of it; but Mr Ehrhart, one of Scheele's intimate friends, informs us, that the world is indebted for its knowledge of this acid to that illuſtrious chemiſt *, and Hermſtadt and Weſtrum aſſign the diſcovery to the ſame author †. The aſſertions of theſe gentlemen, who had the beſt opportunity of obtaining accurate information, are certainly ſufficient to eſtabliſh the fact, that Scheele was the real diſcoverer of oxalic acid.

468 Method of procuring it.

Bergman gives us the following proceſs for obtaining this acid. “ Put one ounce of white ſugar powdered into a tubulated retort, with three ounces of ſtrong nitric acid, the ſpecific gravity of which is to that of water as 1,567. When the ſolution is over, during which many fumes of the nitrous acid eſcape, let a receiver be fitted, and the liquor made to boil, by which abundance of nitrous gas is expelled. When the liquor in the retort acquires a reddiſh brown colour, add three ounces more of nitric acid, and continue the boiling till the fumes ceaſe, and the colour of the liquor vaniſhes. Then let the contents of the retort be emptied into a wide veſſel; and upon cooling, a cryſtallization will take place of ſlender, quadrilateral priſms, which are often affixed to each other at an angle of 45°. Theſe cryſtals, collected and dried on blotting paper, will be found to weigh 1½ dr. 19 gr. By boiling the remaining lixivium with two ounces of nitric acid in the retort, till the red fumes almoſt diſappear, and by repeating the cryſtallization as before, ½ dr. 13 gr. of ſolid acid will be obtained. If the proceſs be repeated

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* *Lavoiſier.*
† *Vauquelin, Ann. de Chim.* xxii. 208.

* *Elwart's Magazine for Apothecaries*, 1785, Part i. p. 54.
† *Keir's Dictionary.*

once more upon the reſiduum, which has now a glutinous conſiſtence, with the ſucceſſive additions of ſmall quantities of nitric acid, amounting in all to two ounces, a ſaline brown deliqueſcent maſs will be formed, weighing half a dram, of which about a half will be loſt by a farther purification. The cryſtals obtained thus at different times may be purified by ſolution and cryſtallization, and by digeſting the laſt lixivium with ſome nitric acid, and evaporation with the heat of the ſun."

By the ſame proceſs Bergman obtained it from gum arabic, alcohol, and honey: Scheele, Hermſtadt, Weſtrum, Hoffman, &c. from a great variety of other vegetable productions; and Berthollet from a great number of animal ſubſtances.

It is of great conſequence not to uſe too much nitric acid, otherwiſe the quantity of oxalic acid will be diminiſhed; and if a very great quantity of nitric acid be uſed, no oxalic acid will be obtained at all *. On the contrary, if too ſmall a quantity of nitric acid be uſed, the acid obtained will not be the oxalic, but the tartarous †. We think we have obſerved, that a conſiderably larger proportion of oxalic acid may be obtained by pouring nitric acid on ſugar, and allowing theſe ſubſtances to act upon each other while cold. When the proceſs is conducted in that manner, hardly any thing ſeparates but nitrous gas.

469
Its properties.

Oxalic acid is capable of cryſtallization, or rather it is generally obtained in that ſtate. Its cryſtals are quadrilateral priſms, the ends of which often terminate in ridges ‡.

They are ſoluble in their own weight of boiling water: water at the temperature of 65,7° diſſolves half its weight of them. The ſpecific gravity of the ſolution is 1,0593 ‖. One hundred parts of boiling alcohol diſſolve 56 parts of theſe cryſtals; but at a mean temperature only 40 parts §. They are not eaſily ſoluble in ether. Fixed and volatile oils diſſolve them, and they may be again obtained by gentle evaporation. Too violent a heat would ſublime the acid itſelf.

Oxalic acid has a very acrid taſte when it is concentrated, but a very agreeable acid taſte when ſufficiently diluted with water ¶.

It changes all vegetable blues except indigo to a red. One grain of cryſtallized acid, diſſolved in 1920 grains of water, reddens the blue paper with which ſugar loaves are wrapt: one grain of it, diſſolved in 3600 grains of water, reddens paper ſtained with turnſole *. According to Morveau, one part of the cryſtallized acid is ſufficient to communicate a ſenſible acidity to 2633 parts of water †.

Its fixity is ſuch, that none of it is ſublimed when water containing it in ſolution is raiſed to the boiling temperature.

When this cryſtallized acid is expoſed to heat in an open veſſel, there ariſes a ſmoke from it, which affects diſagreeably the noſe and lungs. The reſiduum is a powder of a much whiter colour than the acid had been. By this proceſs it loſes $\frac{3}{10}$ths of its weight; but ſoon recovers them again on expoſure to the air. When diſtilled, it firſt loſes its water of cryſtallization, then liquifies and becomes brown; a little phlegm paſſes over, a white ſaline cruſt ſublimes, ſome part of which paſſes into the receiver; but the greateſt part of the acid is deſtroyed, leaving in the retort a maſs $\frac{1}{50}$th of the whole, which has an empyreumatic ſmell, blackens ſulphuric acid, renders nitric acid yellow, and diſſolves in muriatic acid without alteration. That part of the acid which ſublimes is unaltered. When this acid is diſtilled a ſecond time, it gives out a white ſmoke, which, condenſing in the receiver, produces a colourleſs uncryſtallizable acid, and a dark coloured matter remains behind *. During all this diſtillation a vaſt quantity of elaſtic vapour makes its eſcape. From 279 grains of oxalic acid, Bergman obtained 109 cubic inches of gas, half of which was carbonic acid and half hydrogen. Fontana from an ounce of it obtained 430 cubic inches of gas, one-third of which was carbonic acid, the reſt hydrogen. From theſe facts, it is evident that oxalic acid is compoſed of oxygen, hydrogen, and carbon; but the proportions are ſtill unknown.

When nitric acid is frequently diſtilled off oxalic acid, acetous acid is produced †. The ſulphuric acid, when concentrated, ſeems to produce the ſame effect. Muriatic and acetous acids diſſolve oxalic acid, but without altering it ‡.

470
Its action on other bodies.

Oxalic acid is capable of oxidating lead, copper, iron, tin, biſmuth, nickel, cobalt, zinc, mangaueſe.

It does not act upon gold, ſilver, platinum, mercury, arſenic?

Oxalic acid combines with alkalies, alkaline earths, and alumina, and metallic oxides, and forms ſalts known by the name of *oxalats*.

471
Its affinities.

Its affinities, according to Bergman, are as follows:

Lime,
Barytes,
Strontites §,
Magneſia,
Potaſs,
Soda,
Ammonia,
Alumina,
Jargonia ‖ ?
Metallic oxides as in *ſulphuric acid*,
Water,
Alcohol.

SECT. XIV. *Of Tartarous Acid.*

472
Diſcovery of tartarous acid.

TARTAR, or *cream of tartar* as it is commonly called when pure, has occupied the attention of chemiſts for ſeveral centuries. Duhamel and Groſſe, and after them Margraf and Rouelle the Younger, proved that it was compoſed of an acid united to potaſs: but Scheele was the firſt who obtained this acid in a ſeparate ſtate. He communicated his proceſs for obtaining it to Retzius, who publiſhed it in the Stockholm Tranſactions for 1770. It conſiſted in boiling tartar with lime, and in decompoſing the tartrite of lime thus formed by means of ſulphuric acid.

473
Its properties.

This acid, by a gentle evaporation, yields cryſtals ſo irregular in their figure, that every chemiſt who has treated of this ſubject has given a different deſcription of them. According to Bergman, they generally conſiſt of divaricating lamellæ *; according to Van Packen, they aſſume ofteneſt the form of long pointed priſms †; Spielman and Corvinus ‡ obtained them in groups, ſome of them lance-ſhaped, others needle-formed, others pyramidal. Morveau obtained them needle-form §. They do not experience any change in the air;

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* *Bergman.*

† *Hermſtadt.*

‡ *Bergman,* i. 255.

‖ *Ibid.*

§ *Ibid.*

¶ *Ibid.*

* *Ibid.*

† *Encyc. Method* art. *Acide Saccharin.*

* *Bergman.*

† *Weſtrum.*

‡ *Bergman.*

§ *Dr Hope, Tranſ. Edin.* iv.

‖ *Vauquelin, Ann. de Chim.* xxii. 208.

* *Bergman,* iii. 308.

† *De Sale Eſſent. acidi Tartari.*

‡ *Analecta de Tartaro.*

§ *Encyc. Method. Chim.* i. 323.

heat decompoſes them. In the open fire they burn without leaving any other reſiduum than a coal, which generally contains a little lime [*]. In cloſe veſſels, the product is carbonic acid and hydrogen gas [†]. If the proper quantity of nitric acid be diſtilled off the cryſtals, they are converted into oxalic acid, and the nitric acid, as uſual, paſſes into the nitrous acid [‡]. Hence it is evident that tartarous acid alſo, like the four former, is compoſed of oxygen, hydrogen, and carbon; but the proportions are equally unaſcertained.

This acid, when in cryſtals, diſſolves readily in water. Bergman obtained a ſolution, the ſpecific gravity of which was 1,230 [§]. Morveau obſerved, however, that cryſtals formed ſpontaneouſly in a ſolution, the ſpecific gravity of which was 1,084.

474
Its action on other bodies.

It has a very ſharp acid taſte, and reddens vegetable blues.

Tartarous acid does not oxidate gold, ſilver, platinum, lead, biſmuth, nor tin, and hardly antimony and nickel.

It combines with alkalies, alkaline earths, and alumina, and metallic oxides, and forms ſalts known by the name of *tartrites*.

475
Its affinities.

The order of its affinities is the ſame as that given for oxalic acid; except that, according to Lavoiſier, the oxide of ſilver comes before that of mercury.

SECT. XV. *Of Citric Acid.*

476
Method of obtaining citric acid.

CHEMISTS have always conſidered the juice of oranges and lemons as a peculiar acid. This juice contains a quantity of mucilage and water, which render the acid impure, and ſubject to ſpontaneous decompoſition. Mr Georgius took the following method to ſeparate the mucilage. He filled a bottle entirely with lemon-juice, corked it, and placed it in a cellar: in four years the liquid was become as limpid as water, a quantity of mucilage had fallen to the bottom in the form of flakes, and a thick cruſt had formed under the cork. He expoſed this acid to a cold of 23°, which froze a great part of the water, and left behind a ſtrong and pretty pure acid [‖]. It was Scheele, however, that firſt pointed out a method of obtaining this acid perfectly pure. He ſaturated lemon-juice with lime, edulcorated the precipitate, which conſiſted of citric acid and lime, ſeparated the lime from it by diluted ſulphuric acid, cleared it from the ſulphat of lime by repeated filtrations and evaporation; then evaporated it to the conſiſtence of a ſyrup, and ſet it by in a cool place: a quantity of cryſtals formed, which were pure citric acid [¶]. It exiſts ready formed alſo in the juices of the following berries: *Vaccinium occicoccos, vaccinium vitis idæa, prunus padus, ſolanum dulcamara, roſa canina* [*], *cherries* [†].

Scheele adviſes the uſe of an exceſs of ſulphuric acid, in order to enſure the ſeparation of all the lime; but according to Dizé, this exceſs is neceſſary for another purpoſe [‡]. A quantity of mucilage ſtill adheres to the citric acid in its combination with lime, and ſulphuric acid is neceſſary to decompoſe this mucilage, which, as Fourcroy and Vauquelin have proved, it is capable of doing. His proof of the preſence of mucilage is, that when the ſolution of citric acid in water, which he had obtained, was ſufficiently concentrated by evaporation, it aſſumed a brown colour, and even became black towards the end of the evaporation. The cryſtals alſo were black. By repeated ſolutions and evaporations, this black matter was ſeparated, and found to be carbon. Hence he concluded that mucilage had been preſent; for mucilage is compoſed of carbon, hydrogen, and oxygen; ſulphuric acid cauſes the hydrogen and oxygen to combine and form water, and the carbon remains behind. It is not certain, however, as Mr Nicholſon remarks very juſtly [*], that the ſulphuric acid may not act upon the citric acid itſelf, and that the carbon may not proceed from the decompoſition of it; at leaſt the experiments of Mr Dizé are inſufficient to prove the contrary. In that caſe the ſmaller the exceſs of ſulphuric acid uſed the better.

477
Its properties.

The cryſtals of citric acid are rhomboidal priſms, the ſides of which are inclined to each other in angles of about 120 and 60 degrees, terminated at each end by four trapezoidal faces, which include the ſolid angles [†]. They are not altered by expoſure to the air.

An ounce of diſtilled water, at the temperature of the atmoſphere, diſſolves one ounce and two drams of cryſtallized citric acid; and during the ſolution the temperature is lowered 29,75°. Boiling water diſſolves twice its weight of this acid [‡].

Citric acid has a very acid taſte; it turns vegetable blues to a red.

478
Its action on other bodies.

It is capable of oxidating iron, zinc, tin. It does not act upon gold, ſilver, platinum, mercury, biſmuth, antimony, arſenic.

It combines with alkalies, alkaline earths, and alumina, and metallic oxides, and forms ſalts known by the name of *citrats*.

Fire decompoſes this acid, converting it into an acidulous phlegm, carbonic acid gas, and carbonated hydrogen gas. Its ſolution in water is alſo gradually decompoſed, if acceſs of air be permitted. It is evident, therefore, that this acid is alſo compoſed of oxygen, hydrogen, and carbon.

Scheele ſaid that he could not convert it into oxalic acid by means of nitric acid, as he had done ſeveral other acids; but Weſtrum affirms, that this converſion may be effected; and thinks that Scheele had probably failed from having uſed too large a quantity of nitric acid, by which he had proceeded beyond the converſion into oxalic acid, and had changed the citric acid into vinegar; and in ſupport of his opinion, he quotes his own experiments: from which it appeared that, by treating ſixty grains of citron acid with different quantities of nitric acid, his products were very different. Thus with 200 grains of nitric acid he got 30 grains of oxalic acid; with 300 grains of nitric acid he obtained only 15 grains of the oxalic acid; and with 600 grains of nitric acid no veſtige appeared of the oxalic acid. On diſtilling the products of theſe experiments, eſpecially of the laſt, he obtained vinegar mixed with nitric acid.

479
Its affinities.

The affinities of this acid are as follows [§]:

Lime (L),
Barytes,
Strontites [‖],
Magneſia,
Potaſs,
Soda,

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[*] Bergman, ibid and ii. 465.

[†] Spielman and Corvinus, ibid.

[‡] Hermſtadt and Weſtrum.

[§] Bergman, i. 250.

[‖] Stockholm Tranſ. 1774.

[¶] Scheele's Eſſays.

[*] Scheele, Crell's Annals, 1788.

[†] Weſtrum.

[‡] Nicholſon's Journal, ii. 43.

[*] Nicholſon, ibid.

[†] Dizé, ibid.

[‡] Id ibid.

[§] See Bergman and Lavoiſier.

[‖] Dr Hope, Tranſ. Edin. iv.

(L) Mr De Breſſey places barytes before lime.

Soda,
Ammonia,
Oxide of zinc,
——— manganeſe *,
——— iron,
——— lead,
——— cobalt,
——— copper,
——— arſenic,
——— mercury,
——— antimony †,
——— ſilver,
——— gold,
——— platinum,
Alumina ‡,
Jargonia § ?
Water,
Alcohol.

Sect. XVI. *Of Malic Acid.*

480 Diſcovery of malic acid.

Scheele diſcovered a peculiar acid in the juices of ſeveral fruits, which, becauſe it is found moſt abundantly in apples, has been called *malic acid.*

481 Method of obtaining it.

He obtained it by the following proceſs: Saturate the juice of apples with potaſs, and add to the ſolution acetite of lead till no more precipitation enſues. Waſh the precipitate carefully with a ſufficient quantity of water; then pour upon it diluted ſulphuric acid till the mixture has a perfectly acid taſte, without any of that ſweetneſs which is perceptible as long as any lead remains diſſolved in it; then ſeparate the ſulphat of lead, which has precipitated, by filtration, and there remains behind pure malic acid ‖.

This acid is contained in the berries of the *barberis vulgaris*, the *ſambucus nigra*, the *prunus ſpinoſa*, the *ſorbus aucuparia*, and the *prunus domeſtica* ¶.

If nitric acid be diſtilled with an equal quantity of ſugar, till the mixture aſſumes a brown colour (which is a ſign that all the nitric acid has been abſtracted from it), this ſubſtance will be found of an acid taſte; and after all the oxalic acid which may have been formed is ſeparated by lime-water, there remains another acid, which may be obtained by the following proceſs: Saturate it with lime, and filter the ſolution; then pour upon it a quantity of alcohol, and a coagulation takes place. This coagulum is the acid combined with lime. Separate it by filtration, and edulcorate it with freſh alcohol; then diſſolve it in diſtilled water, and pour in acetite of lead till no more precipitation enſues. The precipitate is the acid combined with lead, from which it may be ſeparated by diluted ſulphuric acid. It poſſeſſes all the properties of malic acid *. This acid, therefore, may be obtained from ſugar; and it may be converted into oxalic acid, by diſtilling off it the proper quantity of nitric acid †.

482 Its properties.

This acid bears a ſtrong reſemblance to the citric, but differs from it in the following particulars:

1. The citric acid ſhoots into fine cryſtals, but this acid does not cryſtallize.

2. The ſalt formed from the citric acid with lime is almoſt inſoluble in boiling water; whereas the ſalt made with malic acid and the ſame baſis is readily ſoluble by boiling water.

3. Malic acid precipitates mercury, lead, and ſilver, from the nitrous acid, and alſo the ſolution of gold when diluted with water; whereas citric acid does not alter any of theſe ſolutions.

3. Malic acid ſeems to have a leſs affinity than citric acid for lime; for when a ſolution of lime in the former acid is boiled one minute with a ſalt formed from volatile alkali and citric acid, a decompoſition takes place, and the latter acid combines with the lime and is precipitated.

483 Its combinations.

The malic acid combines with alkalies, alkaline earths, and alumina, and metallic oxides, and forms ſalts known by the name of *malats*.

Its affinities have not yet been aſcertained.

Sect. XVII. *Of Lactic Acid.*

If milk be kept for ſome time it becomes ſour. The acid which then appears in it was firſt examined by Scheele, and found by him to have peculiar properties. It is called *lactic* acid. In the whey of milk this acid is mixed with a little curd, ſome phoſphat of lime, ſugar of milk, and mucilage. All theſe muſt be ſeparated before the acid can be examined. Scheele accompliſhed this by the following proceſs:

484 Method of obtaining lactic acid.

Evaporate a quantity of ſour whey to an eighth part, and then filtrate it: this ſeparates the cheeſy part. Saturate the liquid with lime-water, and the phoſphat of lime precipitates. Filtrate again, and dilute the liquid with three times its own bulk of water; then let fall into it oxalic acid, drop by drop, to precipitate the lime which it has diſſolved from the lime-water: then add a very ſmall quantity of lime-water, to ſee whether too much oxalic acid has been added. If there has, oxalat of lime immediately precipitates. Evaporate the ſolution to the conſiſtence of honey, pour in a ſufficient quantity of alcohol, and filtrate again; the acid paſſes through diſſolved in the alcohol, but the ſugar of milk and every other ſubſtance remains behind. Add to the ſolution a ſmall quantity of water, and diſtil with a ſmall heat, the alcohol paſſes over, and leaves behind the lactic acid diſſolved in water *.

485 Its properties.

This acid is incapable of cryſtallizing: when evaporated to dryneſs, it deliqueſces again in the air †.

When diſtilled, water comes over firſt, then a weak acid reſembling the tartarous, then an empyreumatic oil mixed with more of the ſame acid, and laſtly carbonic acid and hydrogen gas—there remains behind a ſmall quantity of coal ‡.

486 Combinations,

The combinations which this acid forms with alkalies, earths, and metallic oxides, are called *lactats*.

487 And affinities.

Its affinities, according to Bergman, are as follows:

Barytes,
Potaſs,
Soda,
Ammonia,
Lime,
Magneſia,
Alumina,
Jargonia § ?
Metallic oxides as in *ſulphuric acid*,
Water,
Alcohol.

Sect. XVIII. *Of Saccholactic Acid.*

488 Sugar of milk.

If a quantity of freſh whey of milk be filtrated, and then evaporated by a gentle fire till it is of the conſiſtence of honey, and afterwards allowed to cool, a ſolid maſs

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* *Lavoiſier.*

† *Id.*

‡ *Id.*

§ *Vauquelin, Ann de Chim.* xxii. 208.

‖ *Swediſh Tranſ.* and *Crell's Annals for* 1785.

¶ *Ibid.*

* *Ibid.*

† *Hermſtadt, Phyſ. Chem.*

* *Scheele, Stockholm Tranſ.* 1780.

† *Ibid.*

‡ *Ibid.*

§ *Vauquelin Ann. de Chim.* xxii. 208.

maſs is obtained. If this be diſſolved in water, clarified with the white of eggs, filtrated, and evaporated to the conſiſtence of a ſyrup, it depoſites on cooling a number of brilliant, white, cubic cryſtals, which have a ſweet taſte, and for that reaſon have been called *ſugar of milk.* Fabricius Bartholet, an Italian, was the firſt European who mentioned this ſugar. He deſcribed it in his *Encyclopædia Hermetico dogmatica*, publiſhed at Boulognia in 1619; but it ſeems to have been known in India long before that period.

489 Method of obtaining ſaccholactic acid.

After Mr Scheele had obtained oxalic acid from ſugar, he wiſhed to examine whether the ſugar of milk would furniſh the ſame product. Upon four ounces of pure ſugar of milk, finely powdered, he poured 12 ounces of diluted nitric acid, and put the mixture in a large glaſs retort, which he placed in a ſand-bath. A violent efferveſcence enſuing, he was obliged to remove the retort from the ſand-bath till the commotion ceaſed. He then continued the diſtillation till the mixture became yellow. As no cryſtals appeared in the liquor remaining in the retort, after ſtanding two days he repeated the diſtillation as before, with the addition of eight ounces of nitric acid, and continued the operation till the yellow colour, which had diſappeared on addition of the nitrous acid, returned. The liquor in the retort contained a white powder, and when cold was obſerved to be thick. Eight ounces of water were added to dilute this liquor, which was then filtrated, by which the white powder was ſeparated; which being edulcorated and dried, weighed 7½ dr. The filtrated ſolution was evaporated to the conſiſtence of a ſyrup, and again ſubjected to diſtillation, with four ounces of nitric acid as before; after which, the liquor, when cold, was obſerved to contain many ſmall, oblong, four cryſtals, together with ſome white powder. This powder being ſeparated, the liquor was again diſtilled with more nitric acid as before; by which means the liquor was rendered capable of yielding cryſtals again; and by one diſtillation more, with more nitrous acid, the whole of the liquor was converted into cryſtals. Theſe cryſtals, added together, weighed five drams; and were found, upon trial, to have the properties of the oxalic acid.

Mr Scheele next examined the properties of the white powder, and found it to be an acid of a peculiar nature; he therefore called it the *acid of ſugar of milk.* It is now called the *ſaccholactic acid.*

490 Its properties.

According to Scheele, it is ſoluble in 60 parts of its weight of boiling water; but Meſſrs Hermſtadt * and Morveau † found, that boiling water only diſſolved $\frac{1}{80}$th part: it depoſited about ¼th part on cooling in the form of cryſtals ‡.

The ſolution has an acid taſte, and reddens the infuſion of turnſole §. Its ſpecific gravity, at the temperature of 53.7°, is 1,0015 ||.

Phyſ. Chem.
Encyc. Method. i. 90.
Scheele.
Id.
Morveau, id.

When diſtilled, it melts very readily, becomes black, and frothes; a brown ſalt ſublimes into the neck of the retort, which has the odour of a mixture of amber and benzoin, having an acid taſte, eaſily ſoluble in alcohol, with greater difficulty in water, and burning in the fire with a flame. There paſſes into the receiver a brown liquid, having ſome of this ſalt diſſolved in it: There remains behind a coal *, which Hermſtadt found to contain a ſmall quantity of lime. Concentrated ſulphuric acid diſtilled on this ſalt becomes black, frothes, and decompoſes it †.

* *Scheele, ibid.*
† *Id. ibid.*

491 Hermſtadt attempts to diſprove its exiſtence.

Mr Hermſtadt of Berlin had made ſimilar experiments on ſugar of milk at the ſame time with Scheele, and with ſimilar reſults; but he concluded that the white powder which he obtained was nothing elſe than oxalat of lime with exceſs of acid, as indeed Scheele himſelf did at firſt. After he became acquainted with Scheele's concluſions, he publiſhed a paper in defence of his own opinion; but his proofs are very far from eſtabliſhing it, or even rendering its truth probable. He acknowledges himſelf, that he has not been able to decompoſe this ſuppoſed ſalt: he allows that it poſſeſſes properties diſtinct from the oxalic acid; but he aſcribes this difference to the lime which it contains; yet all the lime which he could diſcover in 240 grains of this ſalt was only 20 grains; and if the alkali which he employed was a carbonat (as it probably was), theſe 20 muſt be reduced to 11. Now Morveau has ſhewn, that oxalic acid, containing the ſame quantity of lime, exhibits very different properties. Beſides, this acid, whatever it is when united with lime, is ſeparated by the oxalic, and muſt therefore be different from it, as it would be abſurd to ſuppoſe that an acid could diſplace itſelf ‡. The ſaccholactic acid muſt therefore be conſidered as a diſtinct acid, as it poſſeſſes peculiar properties.

‡ *Morveau, Encyc. Method.* i. p. 291.

492 Its compounds and affinities.

Its compounds with alkalies, earths, and metallic oxides, are denominated *ſaccholats.*

Its affinities, according to Bergman, are as follows:

Lime,
Barytes,
Magneſia,
Potaſs,
Soda,
Ammonia,
Alumina,
Jargonia §?
Metallic oxides as in *ſulphuric acid,*
Water,
Alcohol.

§ *Vauquelin, Ann. de Chim.* xxii. 208.

SECT. XIX. *Of Gallic Acid.*

493 Nut-galls.

THERE is an excreſcence, known by the name of *nut-gall*, which grows on ſome ſpecies of oaks. This ſubſtance contains a peculiar acid, called from that circumſtance *gallic acid*, the properties of which were firſt examined with attention by the commiſſioners of the academy of Dijon; and the reſult of their experiments was publiſhed in 1777, in the third volume of their Elements of Chemiſtry. In theſe experiments, however, they employed the infuſion of galls, in which the acid is combined with the tanning principle (M). It was reſerved for Scheele to obtain it in a ſtate of purity.

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(M) A ſubſtance lately diſcovered by French chemiſts, which exiſts alſo in oak-bark, and every other body which may be ſubſtituted for that bark in the operation of tanning. It reſembles the reſins in many properties; but its diſtinguiſhing property is that of forming with glue a compound inſoluble in water. When a little of the decoction of glue is dropped into an infuſion of nut-galls, a white curdy precipitate is inſtantly ſeen: This is the tanning principle combined with glue. The name *tanning principle* has been applied to it, becauſe *tanning* conſiſts in combining this principle with *ſkins*, by which they are converted into leather.

494 Diſcovery of gallic acid.

He obſerved, in an infuſion of galls made with cold water, a ſediment, which proved on examination to have a cryſtalline form and an acid taſte. By letting an infuſion of galls remain a long time expoſed to the air, and removing now and then the mouldy ſkin which formed on its ſurface, a large quantity of this ſediment was obtained; which being edulcorated with cold water, rediſſolved in hot water, filtrated, and evaporated very ſlowly, yielded an acid ſalt in cryſtals as fine as ſand*.

There is a ſhorter method of obtaining this acid in a ſtill purer ſtate than Scheele obtained it.

495 Method of obtaining it.

Pour ſulphuric ether on a quantity of powdered galls, and allow it to remain a few hours; by which time it becomes coloured. Put this tincture into a retort, and diſtil off the ether with a ſmall heat. The reſiduum poſſeſſes the colour and brittleneſs of a reſin, and has all the characters of Rouelle's reſiduous-extract; it does not attract moiſture from the atmoſphere. Diſſolve it in its own weight of water, and add ſulphuric acid, drop by drop, till the liquor has become of a manifeſtly acid taſte. It cauſes a white precipitate, which becomes coloured, and is immediately rediſſolved. At the end of ſome hours a reſinous matter will have precipitated. Decant off the fluid, dilute it with half its weight of water, filtrate and evaporate it to ¾ths in a moderate heat; add pure barytes till the liquor is no longer capable of decompoſing muriat of barytes; then filtrate it again; and on evaporation in a moderate heat ſmall white priſmatic cryſtals of gallic acid are formed on the ſides of the veſſel †.

It appears from the experiments of Deyeux, that the ſubſtance extracted from nut-galls by ether does not differ much from the extract by water ‡. Probably, then, the only reaſon for employing ether is the ſmall heat neceſſary for evaporating it.

There is ſtill another method of obtaining this acid. Diſtil nut-galls in a ſtrong heat, a white ſubſtance ſublimes, which cryſtallizes in the form of needles: This is gallic acid. If the cryſtals are impure, they may be purified by a ſecond ſublimation: but the heat muſt not be too violent, otherwiſe the cryſtals will melt into a brown maſs §. This proceſs was diſcovered by Scheele.

496 Prouſt's method.

But the moſt elegant method of obtaining gallic acid is that of Mr Prouſt. When a ſolution of muriat of tin is poured into an infuſion of nut-galls, a copious yellow precipitate is inſtantly formed, conſiſting of the tanning principle, combined with the oxide of tin. After diluting the liquid with a ſufficient quantity of water to ſeparate any portion of this precipitate which the acids might hold in ſolution, the precipitate is to be ſeparated by filtration. The liquid contains gallic acid, muriatic acid, and muriat of tin. To ſeparate the tin, a quantity of ſulphurated hydrogen gas is to be mixed with the liquid. Sulphuret of oxide of tin is precipitated under the form of a brown powder. The liquid is then to be expoſed for ſome days to the light, covered with paper, till the ſuperfluous ſulphurated hydrogen gas exhales. After this, it is to be evaporated to the proper degree of concentration, and put by to cool. Cryſtals of gallic acid are depoſited. Theſe are to be ſeparated by filtration, and waſhed with a little cold water. The evaporation of the reſt of the liquid is to be repeated till all the gallic acid is obtained from it‖.

497 Its properties.

The gallic acid thus obtained has a very acid taſte, and reddens vegetable colours. It is ſoluble in 1½ parts of boiling water, and in 12 parts of water at the temperature of the atmoſphere. Alcohol diſſolves one-fourth of its weight of this acid at the temperature of the atmoſphere. When boiling hot it diſſolves a quantity equal to its own weight.

When placed upon burning coals, gallic acid takes fire, and at the ſame time diffuſes a very ſtrong odour, which has ſomething aromatic in it. When ſtrongly heated, it melts, boils, becomes black, is diſſipated, and leaves a quantity of charcoal behind it. When diſtilled, a quantity of oxygen gas is diſengaged, an acid liquor is found in the receiver, with ſome gallic acid not decompoſed, and there remains in the retort a quantity of carbon. If what has paſſed into the receiver be again diſtilled, more oxygen gas is obtained, ſome gallic acid ſtill ſublimes, and a quantity of carbon remains in the retort. By repeated diſtillations the whole of the acid may be decompoſed. This decompoſition may be more eaſily accompliſhed by diſtilling repeatedly a ſolution of gallic acid in water. The products are oxygen gas, charcoal, and an acid liquor.

498 Its compoſition.

From theſe experiments, Mr Deyeux, who performed them, has concluded, that gallic acid is compoſed of oxygen, and a much larger proportion of carbon than enters into the compoſition of carbonic acid. But this concluſion is not warranted by the analyſis; for Mr Deyeux did not find that the quantity of oxygen gas and carbon obtained was equal to that of the gallic acid decompoſed: and in the acid liquor which came over, there evidently exiſted a quantity of water, which doubtleſs was formed during the diſtillation. Scheele, by treating gallic acid with nitric acid in the uſual manner, converted it into oxalic acid. Now it is certain that oxalic acid contains hydrogen as well as carbon. It cannot be doubted, then, that gallic acid is compoſed of oxygen, hydrogen, and carbon, in proportions not yet aſcertained. But Mr Deyeux has proved, that the quantity of carbon is very great, compared with that of the hydrogen.

Gallic acid combines with alkalies, earths, and metallic oxides, and forms compounds known by the name of *gallats*.

Its affinities have not yet been determined; but oxide of iron ſeems to have a ſtronger affinity for it than for any other ſubſtance; for gallic acid is capable of taking it from every other acid. In conſequence of this property, the infuſion of galls is employed to detect the preſence of iron in any liquid. As ſoon as it is poured in, if iron be preſent, a black or purple colour is produced.

Sect. XX. *Of Benzoic acid.*

499 Benzoin.

Benzoin or *benjamin* (as it is ſometimes called) is a kind of reſin brought from the Eaſt Indies; obtained, according to Dr Dryander, from the ſtyrax benzoe, a tree which grows in the iſland of Sumatra. This ſubſtance conſiſts partly of a peculiar acid, deſcribed as long ago as 1608 by Blaiſe de Vigenere, in his Treatiſe on Fire and Salt, under the name of *flowers of benzoin*, becauſe it was obtained by ſublimation. This acid, which is now called *the benzoic acid*, may be ſublimed from benzoin by heat; or it may be obtained by Scheele's

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* *Stockholm Tranſ.* 1786.

† *Mr J. J. Dizé Jour. de Phyſ.* Dec. 1791.

‡ *Ann. de Chim.* xvii. 8.

§ *Ibid.*

‖ *Ibid.* xxv. 225.

Scheele's proceſs, which has been deſcribed in the article CHEMISTRY, *Encycl.*

500 Properties of benzoic acid.

Benzoic acid has little or none of the peculiar odour which diſtinguiſhes benzoin. Its taſte is not acid, but ſweetiſh, and very pungent *. It hardly affects the infuſion of violets; but it reddens that of turnſole, eſpecially if that infuſion be hot †. Heat volatilizes this acid, and makes it give out a ſtrong odour, which excites coughing. When expoſed to the heat of the blow-pipe in a ſilver ſpoon, it melts, becomes as fluid as water, and evaporates without taking fire. It only burns when in contact with flame, and then it leaves no reſiduum behind. When thrown upon burning coals, it riſes in a white ſmoke. When allowed to cool after being melted, it hardens, and a radiated cruſt forms on its ſurface ‡.

It ſuffers no other alteration in the air than loſing the little of the odour of benzoin which remained to it §.

Cold water diſſolves no ſenſible quantity of it; but it is ſoluble enough in hot water: 480 grains of boiling water diſſolve 20 grains of it; 19 of theſe are depoſited, when the water cools, in long, ſlender, flat, feather-like cryſtals ‖.

Concentrated ſulphuric acid diſſolves it without heat or any other change except becoming ſomewhat brown: when water is poured into the ſolution, the benzoic acid ſeparates and coagulates on the ſurface without any alteration ¶. Nitric acid preſents preciſely the ſame phenomena, and alſo the ſulphurous and nitrous acids. Neither the muriatic, the oxy-muriatic, nor the phoſphoric acids diſſolve it. The acetous, formic, and ſebacic acids, when hot, diſſolve it preciſely as water does; but it cryſtallizes again when theſe acids cool *.

Alcohol diſſolves it copiouſly, and lets it fall on the addition of water †.

Little is known reſpecting its baſe.

501 Its combinations and affinities.

It combines with alkalies, earths, and metallic oxides, and forms ſalts known by the name of *benzoats*.

Its affinities, from the experiments of Trommſdorf, appear to be as follows:

White oxide of arſenic,
Potaſs,
Soda,
Ammonia,
Barytes,
Lime,
Magneſia,
Alumina,
Jargonia ‡?
Water,
Alcohol.

SECT. XXI. *Of Succinic Acid.*

502 Amber.

AMBER is a well-known brown, tranſparent, inflammable body, pretty hard, and ſuſceptible of poliſh, found at ſome depth in the earth, and on the ſea-coaſt of ſeveral countries. It was in high eſtimation among the ancients both as an ornament and a medicine.—When this ſubſtance is diſtilled, a volatile ſalt is obtained, which is mentioned by Agricola under the name of *ſalt of amber;* but its nature was long unknown. Boyle was the firſt who diſcovered that it was an acid §. From *ſuccinum*, the Latin name of amber, this acid has received the appellation of *ſuccinic acid.*

503 Method of obtaining ſuccinic acid.

It is obtained by the following proceſs: Fill a retort half way with powdered amber, and cover the powder with a quantity of dry ſand; lute on a receiver, and diſtil in a ſand-bath without employing too much heat. There paſſes over firſt an inſipid phlegm; then a weak acid, which, according to Scheele, is the acetous *; then the ſuccinic acid attaches itſelf to the neck of the retort; and if the diſtillation be continued, there comes over at laſt a thick brown oil, which has an acid taſte.

The ſuccinic acid is at firſt mixed with a quantity of oil. Perhaps the beſt method of purifying it is that recommended by Pott, to diſſolve it in hot water, and to put upon the filter a little cotton, previouſly moiſtened with oil of amber; this ſubſtance retains moſt of the oil, and allows the ſolution to paſs clear. The acid is then to be cryſtallized by a gentle evaporation. And this proceſs is to be repeated till the acid be quite pure.

504 Its properties,

The cryſtals are white, ſhining, and of a foliated triangular priſmatic form: they have an acid taſte, but are not corroſive: they redden tincture of turnſole, but have little effect on that of violets.

They ſublime when expoſed to a conſiderable heat, but not at the heat of a water-bath. In a ſand bath they melt, and then ſublime and condenſe in the upper part of the veſſel; but the coal which remains ſhews that they are partly decompoſed †.

One part of this acid diſſolves in 96 parts of water at the temperature of 50°, according to Spielman ‡, in 24 parts at the temperature of 52°, and in 2 parts of water at the temperature of 212°, according to Stockar de Neuforn §; but the greateſt part cryſtallizes as the water cools. According to Roux, however, it ſtill retains more of the acid than cold water is capable of diſſolving ‖.

240 grains of boiling alcohol diſſolve 177 of this acid; but cryſtals again ſhoot as the ſolution cools ¶.

505 Combinations and affinities.

The combinations of this acid are called *ſuccinats*.

Its component parts are ſtill unknown.

Its affinities, according to Morveau, are as follows:

Barytes,
Lime,
Potaſs,
Soda,
Ammonia,
Magneſia,
Alumina,
Jargonia *?
Metallic oxides as in *ſulphuric acid,*
Water,
Alcohol.

SECT. XXII. *Of Camphoric Acid.*

506 Camphor.

CAMPHOR is a well-known white cryſtalline ſubſtance, of a ſtrong taſte and ſmell, obtained from a ſpecies of laurel in the Eaſt Indies; and Mr Prouſt has ſhewn that ſeveral volatile oils contain a conſiderable quantity of it †. It is ſo volatile, that it cannot be melted in open veſſels, and ſo inflammable that it burns even on the ſurface of water.

When camphor is ſet on fire in contact with oxygen gas, it burns with a very brilliant flame; much caloric is diſengaged, water is formed, the inner ſurface of the veſſel is covered with a black matter, which is undoubtedly carbon, and a quantity of carbonic acid gas is alſo produced ‡. Hence it follows, that it is compoſed of hydrogen and carbon, at leaſt principally.

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* *Morveau, Encyc. Method. Chim.* i. 44.

† *Lichtenſtein.*

‡ *Idem.*

§ *Morveau, ibid.*

‖ *Lichtenſtein.*

¶ *Id.*

* *Id.*

† *Id.*

‡ *Vauquelin, Ann. de Chim.* xxii. 208.

§ *Boyle abridged by Shaw,* iii. 369.

* *Bergman's Notes on Scheffer.*

† *Pott.*

‡ *Inſt Chem.* § xii.

§ *De Succino.*

‖ *Morveau, ibid.* p. 72.

¶ *Wenzel.*

* *Vauquelin, Ann. de Chim.* xxii. 208.

† *Ann. de Chim.* iv. 179.

‡ *LaGrange, ibid.* xxiii. 153.

If one part of camphor and ſix parts of pulveriſed clay be mixed together, by means of alcohol, in a mortar, the mixture made up into balls, and when dry put into a retort, and diſtilled by a moderate heat—a quantity of oil comes over, and there remains in the retort a black ſubſtance, which conſiſts of the clay intimately mixed with a quantity of carbon. If the fire be not cautiouſly managed, a quantity of camphor alſo ſublimes. By this proceſs camphor is decompounded, and ſeparated into oil and carbon.

122,248 parts of camphor
produced 45,856 parts of oil
and 30,571 of carbon.

Total 76,427
Loſs 45,821

Carbonated hydrogen gas and carbonic acid were alſo formed *.

* Ann. de Chim. xxiii. 153.

The oil obtained has the following properties:

507 Oil of camphor. It has a ſharp cauſtic taſte, and leaves upon the tongue a ſenſe of coldneſs. It has an aromatic odour, approaching to that of thyme or roſemary. Its colour is a golden yellow.

When expoſed to the air, it partly evaporates, and there remains a thick brown matter with a ſharp bitteriſh taſte, which at laſt alſo evaporates.

With alkalies, it forms a ſoap, which poſſeſſes all the characters of ſoaps made with volatile oils.

Alcohol diſſolves it entirely; and when water is added to the ſolution it becomes milky, but no precipitate is produced †.

† Ibid. 159.

Theſe properties ſhew that this is a volatile oil, and conſequently it is probable that camphor is compoſed of volatile oil and carbon.

508 Camphoric acid. Mr Koſegarten, by diſtilling nitric acid off camphor eight times ſucceſſively, obtained an acid in cryſtals ‡, to which the name of *camphoric acid* has been given.

‡ Koſegarten, de Camphora, &c. 1785.

His experiments have been repeated by Mr Bouillon La Grange. He mixed together 122,284 parts of camphor with 489,136 parts of nitric acid of the ſpecific gravity 1,33, and diſtilled them. Much nitrous and carbonic acid gas were diſengaged, and part of the camphor was ſublimed; but part was converted into an acid. He returned the ſublimed camphor into the retort, poured on it the ſame quantity of nitric acid as at firſt, and diſtilled again. This proceſs he repeated till the whole camphor was acidified §. The quantity of camphoric acid obtained amounted to 53,498. The quantity of nitric acid was 2114.538.

§ Ann. de Chim. ibid.

509 Its properties. Camphoric acid thus obtained is in ſnow-white cryſtals, of the form of parallelopipedons ‖.

‖ Koſegarten.

Theſe cryſtals effloreſce in the air ¶.

¶ La Grange.

Camphoric acid has a ſlightly acid bitter taſte, and ſmell like that of ſaffron.

It reddens vegetable colours.

It is ſoluble in 200 parts of cold water, according to Koſegarten; in 96 parts of water at the temperature of 60°, according to La Grange. Boiling water diſſolves $\frac{1}{12}$th of its weight *.

* Koſegarten.

According to Koſegarten, it is inſoluble in alcohol; according to La Grange, alcohol diſſolves it, and when the ſolution is left in contact with the air of the atmoſphere, the acid cryſtallizes. It is not precipitated from its ſolution in alcohol by the addition of water †.

† Bouillon La Grange, Ann. de Chim xxvii. 40.

When this acid is placed on ignited coals, it emits a denſe aromatic fume, and is entirely diſſipated. By a gentler heat, it melts, and is ſublimed. If it be put into a heated porcelain tube, and oxygen gas be paſſed through it, the acid does not undergo any change, but is ſublimed.

By mere diſtillation, it firſt melts and then ſublimes; by which proceſs its properties are in ſome reſpect changed. It no longer reddens the tincture of turnſole, but acquires a briſk aromatic ſmell; its taſte becomes leſs penetrating, and it is no longer ſoluble either in water or the ſulphuric and muriatic acids. Heated nitric acid turns it yellow and diſſolves it. Alcohol likewiſe diſſolves it; and if this ſolution be left in contact with the air of the atmoſphere, it cryſtallizes.

Camphoric acid does not produce any change in ſulphur; alcohol and the mineral acids totally diſſolve it; and ſo likewiſe do the volatile and the fat oils.

Camphoric acid does not precipitate lime from limewater. It produces no change on the ſolution of indigo in ſulphuric acid.

510 Its combinations and affinities. It forms combinations with the alkalies, earths, and metallic oxides, which are called *camphorats*.

Its affinities, as far as aſcertained by La Grange, are as follows *:

Lime,
Potaſs,
Soda,
Barytes,
Ammonia,
Alumina,
Magneſia.

* Ann. de Chim. xxvii. 21.

Sect. XXIII. *Of Suberic Acid.*

511 Diſcovery of ſuberic acid. Cork, a ſubſtance too well known to require any deſcription, is the bark of a tree which bears the ſame name. By means of nitric acid, Brugnatelli converted it into an acid †, which has been called the *ſuberic acid*, from *Suber*, the Latin name of the cork-tree. Several chemiſts affirmed that this acid was the oxalic, becauſe it poſſeſſed ſeveral properties in common with it. Theſe aſſertions induced Bouillon la Grange to undertake a ſet of experiments on ſuberic acid. Theſe experiments, which have been publiſhed in the 23d volume of the *Annales de Chimie*, completely eſtabliſh the peculiar nature of ſuberic acid, by ſhewing that it poſſeſſes properties different from thoſe of every other acid.

† Crell's Annals, 1787.

512 Method of preparing it. To prepare it, a quantity of ſound cork grated down ſmall is to be put into a retort, ſix times its weight of nitric acid of the ſpecific gravity 1,261 poured upon it, and the mixture diſtilled by means of a gentle heat. Red vapours are immediately diſcharged; the cork ſwells up and becomes yellow, and as the diſtillation advances, it ſinks to the bottom, and its ſurface remains frothy. If that froth does not form properly, it is a proof that ſome part of the cork has eſcaped the action of the acid. In that caſe, after the diſtillation is pretty far advanced, the acid which has paſſed into the receiver is to be poured back into the retort, and the diſtillation continued till no more red vapours can be perceived; and then the retort is to be immediately taken out of the ſand-bath, otherwiſe its contents would become black and adhere to it. While the matter contained in the retort is hot, it is to be poured into a glaſs veſſel, placed upon a ſand-bath over a gentle fire, and conſtantly ſtirred with a glaſs rod. By this means it becomes gradually

gradually thick. As ſoon as white vapours, exciting a tickling in the throat, begin to diſengage themſelves, the veſſel is removed from the bath, and the maſs continually ſtirred till it is almoſt cold.

By this means an orange-coloured maſs is obtained of the conſiſtence of honey, of a ſtrong and ſharp odour while hot, but having a peculiar aromatic ſmell when cold.

On this maſs twice its weight of boiling water is to be poured, and heat applied till it becomes liquid; and then that part of it which is inſoluble in water is to be ſeparated by filtration (N). The filtered liquor becomes muddy; on cooling it depoſites a powdery ſediment, and a thin pellicle forms on its ſurface. The ſediment is to be ſeparated by filtration, and the liquor reduced to a dry maſs by evaporating in a gentle heat. This maſs is *ſuberic acid*. It is ſtill a little coloured, owing to ſome accidental mixture, from which it may be purified either by ſaturating it with potaſs and precipitating it by means of an acid, or by boiling it along with charcoal powder.

513 Its properties.

Suberic acid thus obtained is not cryſtallizable, but when precipitated from potaſs by an acid, it aſſumes the form of a powder; when obtained by evaporation it forms thin irregular pellicles.

Its taſte is acid and ſlightly bitter; and when diſſolved in a ſmall quantity of boiling water it acts upon the throat, and excites coughing.

It reddens vegetable blues; and when dropped into a ſolution of indigo in ſulphuric acid (*liquid blue*, as it is called in this country), it changes the colour of the ſolution, and renders it green.

Water at the temperature of 60° or even 70° diſſolves only $\frac{1}{57,6}$ part of its weight of ſuberic acid, and if the acid be very pure, only $\frac{1}{112}$th part: boiling water, on the contrary, diſſolves half its weight of it.

When expoſed to the air, it attracts moiſture, eſpecially if it be impure.

When expoſed to the light of day, it becomes at laſt brown; and this effect is produced much ſooner by the direct rays of the ſun.

When heated in a matraſs, the acid ſublimes, and the inſide of the glaſs is ſurrounded with zones of different colours. If the ſublimation be ſtopped at the proper time, the acid is obtained on the ſides of the veſſel in ſmall points formed of concentric circles. When expoſed to the heat of the blow-pipe on a ſpoon of platinum, it firſt melts, then becomes pulverulent, and at laſt ſublimes entirely with a ſmell reſembling that of ſebacic acid (O).

It is not altered by oxygen gas:—the other acids do not diſſolve it completely. Alcohol developes an aromatic odour, and an ether may be obtained by means of this acid.

It converts the blue colour of nitrat of copper to a green; the ſulphat of copper alſo to a geen; green ſulphat of iron to a deep yellow; and ſulphat of zinc to a golden yellow (P).

514 Its action on other bodies.

It has no action either on platinum, gold, or nickel; but it oxidates ſilver, mercury, copper, lead, tin, iron, biſmuth, arſenic, cobalt, zinc, antimony, manganeſe, and molybdenum.

With alkalies, earths, and metallic oxides, it forms compounds known by the name of *ſuberats*.

515 Its affinities.

Its affinities are as follows (Q):

Barytes,

(N) When this ſubſtance is put into a matraſs, water poured on it, and heat applied, it melts; and when the veſſel is taken from the fire and allowed to cool, one part of it, which is of the conſiſtence of wax, ſwims on the ſurface of the water, and another part precipitates to the bottom of the veſſel, and aſſumes the appearance of a whitiſh magma. When this magma is ſeparated by filtration, and waſhed and dried, a white taſteleſs powder is obtained, mixed with ligneous threads, ſoluble in acids and alkalies.

(O) An acid which ſhall be afterwards deſcribed.

(P) Owing perhaps to the preſence of a little iron in the ſulphat.

(Q) The place which the ſuberic acid occupies in the affinities of the alkalies, earths, and metallic oxides, as far as this ſubject has been inveſtigated by Bouillon La Grange, will appear by the following Tables:

POTASS.
Sulphuric acid,
Nitric,
Muriatic,
Suberic.

ALUMINA.
Sulphuric acid,
* * *
Oxalic,
Suberic.

OXIDE of MERCURY.
Sebacic acid,
* * *
Nitric,
Suberic.

SODA.
Sulphuric acid,
Nitric,
Muriatic,
Suberic.

OXIDE of TIN.
* * *
Muriatic,
Suberic.

OXIDE of LEAD.
* * *
Muriatic,
Suberic.

BARYTES.
Sulphuric acid,
Oxalic,
* * *
Muriatic,
Suberic.

OXIDE of SILVER.
Muriatic,
* * *
Sulphuric,
Suberic.

OXIDE of COPPER.
* * *
Sulphuric,
Suberic.

LIME.
Oxalic acid,
Sulphuric,
* * *
Muriatic,
Suberic.
MAGNESIA as lime.

OXIDE of MOLYBDENUM.
Suberic acid.

OXIDE of ANTIMONY.
* * *
Muriatic,
Suberic,
MANGANESE the ſame.

OXIDE

Barytes,
Potaſs,
Soda,
Lime,
Ammonia,
Magneſia,
Alumina *.

* Ann. de Chim. xxiii. 42.

516 Its compoſition.

Mr Bouillon La Grange, to whom we are indebted for all the facts relative to this acid, ſuppoſes that it is compoſed of oxygen, hydrogen, and carbon: but Mr Jameſon, in conſequence of the reſult of a ſeries of experiments which he made on charcoal, has been led to ſuſpect that it conſiſts entirely of carbon and oxygen. He found, that by the action of nitric acid upon charcoal, a brown, bitter, deliqueſcent maſs was formed, ſoluble in water, alcohol, and alkalies, and which emitted, particularly when heated, a very fragrant odour. This matter was more or leſs ſoluble in water according to the time that it had been expoſed to the action of the acid. When the nitric acid uſed was concentrated, and conſiderable in quantity, part of the charcoal was converted into an acid, which poſſeſſed the characters of the ſuberic †.

† *Jameſon's Mineralogy of Shetland and Arran*, p. 167.

Theſe facts are curious, and may extend our knowledge of the nature of vegetable acids, but they are inſufficient to prove the abſence of hydrogen in ſuberic acid, becauſe charcoal cannot eaſily be procured perfectly free from hydrogen, and becauſe ſeveral of the properties of ſuberic acid indicate the preſence of hydrogen in it, its becoming brown, for inſtance, when expoſed to the light. Mr Jameſon has obſerved, that the acid which exiſts ready formed in peat poſſeſſes the properties of ſuberic acid.

Sect. XXIV. *Of Laccic Acid.*

517 Diſcovery of white lac.

About the year 1786, Dr Anderſon of Madras mentioned, in a letter to the governor and council of that place, that neſts of inſects, reſembling ſmall cowry ſhells, had been brought to him from the woods by the natives, who eat them with avidity. Theſe ſuppoſed neſts he ſoon afterwards diſcovered to be the coverings of the females of an undeſcribed ſpecies of coccus, which he ſhortly found means to propagate with great facility on ſeveral of the trees and ſhrubs growing in his neighbourhood (r).

On examining this ſubſtance, which he called *white lac*, he obſerved in it a very conſiderable reſemblance to bees wax; he noticed alſo, that the animal which ſecretes it provides itſelf by ſome means or other with a ſmall quantity of honey, reſembling that produced by our bees; and in one of his letters he complains, that the children whom he employed to gather it were tempted by its ſweetneſs to eat ſo much of it as materially to reduce the produce of his crop. Small quantities of this matter were ſent into Europe in 1789, both in its natural ſtate and melted into cakes; and in 1793 Dr Pearſon, at the requeſt of Sir Joſeph Banks, undertook a chemical examination of its qualities, and his experiments were publiſhed in the Philoſophical Tranſactions for 1794.

518 Its analyſis.

A piece of white lac, from 3 to 15 grains in weight, is probably produced by each inſect. Theſe pieces are of a grey colour, opaque, rough, and roundiſh. When white lac was purified by being ſtrained through muſlin, it was of a brown colour, brittle, hard, and had a bitteriſh taſte. It melted in alcohol, and in water of the temperature of 145°. In many of its properties it reſembles bees wax, though it differs in others; and Dr Pearſon ſuppoſes that both ſubſtances are compoſed of the ſame ingredients, but in different proportions.

Two thouſand grains of white lac were expoſed in ſuch a degree of heat as was juſt ſufficient to melt them. As they grew ſoft and fluid, there oozed out 550 grains of a reddiſh watery liquid, which ſmelled like newly baken bread (s). To this liquid Dr Pearſon has given the name of *laccic acid* *.

* *Pearſon's Tranſl. of the Chemical Nomenclature.*

It poſſeſſes the following properties:

519 Properties of laccic acid.

It turns paper ſtained with turnſole to a red colour.

After being filtered, it has a ſlightly ſaltiſh taſte with bitterneſs, but is not at all ſour.

When heated, it ſmells preciſely like newly baken hot bread.

On ſtanding, it grows ſomewhat turbid, and depoſites a ſmall quantity of ſediment.

Its ſpecific gravity at the temperature of 60° is 1,025.

A little of it having been evaporated till it grew very turbid, afforded on ſtanding ſmall needle-ſhaped cryſtals in mucilaginous matter.

Two hundred and fifty grains of it were poured into a very ſmall retort and diſtilled. As the liquor grew warm, mucilage-like clouds appeared; but as the heat increaſed they diſappeared again. At the temperature of 200°, the liquor diſtilled over very faſt: A ſmall quantity of extractive matter remained behind. The diſtilled liquor while hot ſmelled like newly baken bread, and was perfectly tranſparent and yellowiſh. A ſhred of paper ſtained with turnſole, which had been put into the receiver, was not reddened; nor did another which had been immerſed in a ſolution of ſulphat of iron, and alſo placed in the receiver, turn to a blue colour upon being moiſtened with the ſolution of potaſs (t).

Oxide of Iron.	Oxide of Bismuth.	Oxide of Arsenic.
* * *	* * *	* * *
Sulphuric,	Muriatic,	Nitric acid,
Suberic.	Suberic.	Suberic.

Cobalt and Zinc the ſame with arſenic.

(r) The Chineſe collect a kind of wax, which they call *pe-la*, from a coccus, depoſited for the purpoſe of breeding on ſeveral ſhrubs, and manage it exactly as the Mexicans manage the cochineal inſect. It was the knowledge of this that induced Dr Anderſon to attempt to propagate his inſect.

(s) The ſame liquid appears on preſſing the crude lac between the fingers; and we are told, that when newly gathered it is replete with juice.

(t) A proof that the acid was not the pruſſic.

About one hundred grains of this diſtilled liquid being evaporated till it grew turbid, after being ſet by for a night, afforded acicular cryſtals, which under a lens appeared in a group not unlike the umbel of parſley. The whole of them did not amount to the quarter of a grain. They taſted only bitteriſh.

Another 100 grains being evaporated to dryneſs in a very low temperature, a blackiſh matter was left behind, which did not entirely diſappear on heating the ſpoon containing it very hot in the naked fire; but on heating oxalic acid to a much leſs degree, it evaporated and left not a trace behind.

Carbonat of lime diſſolved in this diſtilled liquid with effervſcence. The ſolution taſted bitteriſh, did not turn paper ſtained with turnſole red, and on adding to it carbonat of potaſs a copious precipitation enſued. A little of this ſolution of lime and of alkali being evaporated to dryneſs, and the reſiduum made red hot, nothing remained but carbonat of lime and carbonat of potaſs.

This liquid did not render nitrat of lime turbid, but it produced turbidneſs in nitrat and muriat of barytes.

To five hundred grains of the reddiſh-coloured liquor obtained by melting white lac, carbonat of ſoda was added till the effervſcence ceaſed, and the mixture was neutraliſed; for which purpoſe three grains of the carbonat were neceſſary. During this combination a quantity of mucilaginous matter, with a little carbonat of lime, was precipitated. The ſaturated ſolution being filtrated and evaporated to the due degree, afforded on ſtanding deliqueſcent cryſtals, which on expoſure to fire left only a reſiduum of carbonat of ſoda.

Lime-water being added to this reddiſh-coloured liquor produced a light purple turbid appearance; and on ſtanding there were clouds juſt perceptible.

Sulphuret of lime occaſioned a white precipitation, but no ſulphurated hydrogen gas was perceptible by the ſmell.

Tincture of galls produced a green precipitation.

Sulphat of iron produced a purpliſh colour, but no precipitation; nor was any precipitate formed by the addition firſt of a little vinegar, and then of a little potaſs, to the mixture.

Acetite of lead occaſioned a reddiſh precipitation, which rediſſolved on adding a little nitric acid.

Nitrat of mercury produced a whitiſh turbid liquor.

Oxalic acid produced immediately the precipitation of white acicular cryſtals, owing probably to the preſence of a little lime in the liquid.

Tartrite of potaſs produced a precipitation not unlike what takes place on adding tartarous acid to tartrite of potaſs (u); but it did not diſſolve again on adding potaſs.

Such were the properties of this acid diſcovered by Dr Pearſon. Its deſtructibility by fire, and its affording carbon, diſtinguiſh it from all the acids deſcribed in this article before the acetous; and its peculiar ſmell when heated, its precipitating tartrite of potaſs without forming tartar, its bitteriſh taſte, and its being converted into vapour at the temperature of 200°, diſtinguiſh it from all the acids hitherto examined *.

Sect. XXV. *Of Pyromucous Acid.*

520 Method of obtaining pyromucous acid.

Pyromucous (v) acid is procured by diſtilling ſugar or any of the ſweet juices. As they foam very much, the retort ſhould be large, and ſeven-eighths of it empty. A prodigious quantity of carbonic acid and carbonated hydrogen gas is diſengaged: A very thin light coal remains behind in the retort. Morveau found the glaſs of the retort attacked. The quantity of ſugar diſtilled was 2304 grains; the coal weighed 982 grains. There were 428 grains of a brown liquor in the receiver, conſiſting moſtly of an acid phlegm. This rediſtilled gave 313 grains of a liquor almoſt limpid, the ſpecific gravity of which was 1,0115 at the temperature of 77°. It reddened blue paper. This acid may be concentrated by freezing, or by combining it with ſome baſe, potaſs, for inſtance, and decompoſing the compound by a ſtronger acid, as, for example, the ſulphuric.

521 Its properties,

It has a very ſharp taſte. When expoſed to heat in open veſſels, it evaporates, leaving a brown ſpot. Diſtilled in cloſe veſſels, it leaves charcoal behind it.

It does not diſſolve gold as Schrickel and Lemery and ſeveral other chemiſts affirmed.

It does not attack ſilver nor mercury, nor even their oxides †. It corrodes lead, and forms ſtyptic and long cryſtals. Copper forms with it a green ſolution: With iron it forms green cryſtals; with antimony and zinc greeniſh ſolutions.

522 Combinations, and affinities.

The compounds which it forms are called *pyromucites*. Its affinities, according to Morveau, are as follows:

Potaſs,
Soda,
Barytes,
Lime,
Magneſia,
Ammonia,
Alumina,
Jargonia ‡.
Metallic oxides as in *ſulph. acid*,
Water,
Alcohol.

Sect. XXVI. *Of Pyro-lignous Acid.*

523 Method of obtaining pyro-lignous acid.

It is well known that the ſmoke of burning wood is exceedingly offenſive to the eyes: And chemiſts have long ago obſerved, that an acid might be obtained by diſtilling wood.

It is to Mr Goettling, however, and to the Dijon academicians, who repeated his experiment, that we are indebted for what knowledge we poſſeſs of the peculiar properties of this acid, which, becauſe it is obtained from wood by means of fire, has been called *the pyro-lignous acid* (w). It appears to be the ſame from what ever kind of wood it is obtained.

Mr Goettling filled an iron retort with pieces of birch tree bark, and obtained by diſtillation a thick, brown, very empyreumatic acid liquor. This liquor he allowed

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* *Phil. Tranſ.* 1794, p. 383.

† *Schrickel.*

‡ *Vauquelin, Ann. de Chim.* xxii. 208.

(u) On this addition, tartar, or acidulated tartrite of potaſs, is formed, which precipitates, becauſe it is very little ſoluble in water. The addition of potaſs diſſolves it again.

(v) Morveau called this acid *ſyrupous* acid.

(w) Goettling called it *ligneous acid.*

allowed to remain at reſt for three months, and then ſeparated from it a quantity of oil which had riſen to the top. By diſtilling this liquor again, and then ſaturating it with potaſs, and evaporating to dryneſs, he obtained a brown ſaline maſs; which, by being rediſſolved in water, and evaporated, yielded greyiſh white cryſtals: Theſe cryſtals were compoſed of pyro-lignous acid and potaſs. He poured upon them, by little and little, a quantity of ſulphuric acid; and by applying a gentle heat, the pyro-lignous acid came over in conſiderable purity *.

The Dijon academicians obtained this acid from beech wood: by diſtilling 55 ounces, they procured 17 ounces of acid; which, when rectified by a ſecond diſtillation, was of the ſpecific gravity 1,02083.

524 Its properties, combinations, and affinities.

It reddens vegetable colours: when expoſed to a ſtrong heat, it takes fire and is deſtroyed. It unites very well with alcohol.

Its compounds are called *pyro-lignites*.

Its affinities, as fixed by Mr Eloy Bourſier de Clervaux and Mr de Morveau, are as follows:

Lime,
Barytes,
Potaſs,
Soda,
Magneſia,
Ammonia,
Oxide of zinc,
——— manganeſe,
——— iron,
——— lead,
——— tin,
——— cobalt,
——— copper,
——— nickel,
——— arſenic,
——— biſmuth,
——— mercury,
——— antimony,
——— ſilver,
——— gold,
——— platinum,
Alumina,
Jargonia † ?

Sect. XXVII. *Of Pyro-tartarous Acid.*

An acid may alſo be obtained by diſtilling tartar; it is called *pyro-tartarous acid.*

525 Properties of pyro-tartarous acid.

It has an empyreumatic taſte and odour; reddens the tincture of turnſole; but has no effect on that of violets. Little is known concerning this acid, except that many of its properties are the ſame with thoſe of the pyro-lignous; and Morveau conjectures that, if properly purified, it would probably be diſcovered to be the ſame with it.

The compounds which it forms are called *pyro-tartrites*.

Its affinities are unknown. Morveau ſuppoſes that they are the ſame with thoſe of the pyro-lignous acid.

526 Vegetable acids,

The 18 preceding acids are all (except the lactic and ſaccholactic) denominated *vegetable acids*, becauſe they are obtained from vegetable ſubſtances. We have placed the lactic and ſaccholactic acids in the ſame claſs; becauſe they bear a ſtrong reſemblance to vegetable acids, and becauſe they are evidently compoſed of the ſame ingredients with them.

527 Deſtroyed by fire.

Vegetable acids are diſtinguiſhed from all the acids deſcribed in the beginning of this chapter, by their deſtructibility by fire.

528 Convertible into each other.

There is no circumſtance in chemiſtry which has attracted greater attention than the poſſibility of converting the various vegetable acids into each other by means of different proceſſes. To explain what paſſes during theſe proceſſes, it would be neceſſary to know exactly the component parts of every vegetable acid, the manner in which theſe acids are combined, and the affinities which exiſt between each of their ingredients. This, however, is very far from being the caſe at preſent. Though a vaſt number of experiments have been made on purpoſe to throw light on this very point, the difficulties which were to be encountered have been ſo great, that no accurate reſults have yet been obtained.

529 Inquiry into the proportions of their ingredients.

It follows from theſe experiments, that all the vegetable acids are compoſed, chiefly at leaſt, of oxygen, hydrogen, and carbon; but that the proportions differ in every individual acid. We ſay chiefly, becauſe it has been ſuſpected from ſome phenomena, that one or two of theſe acids contain beſides a little azot. Let us take a view of what is at preſent known of the compoſition of theſe acids in their order.

1. As to carbonic acid, its compoſition has been aſcertained with tolerable accuracy; it conſiſts of about 28 parts of carbon and 72 of oxygen.

2. By diſtilling 7680 grains of acetite of potaſs, Dr Higgens obtained the following products *:

Potaſs, - - - - -	3862,994 grains.
Carbonic acid gas, - -	1473,564
Carbonated hydrogen gas, -	1047,6018
Reſiduum, conſiſting of carbon, -	78,0000
Oil, - - - - - -	180,0000
Water, - - - -	340,0000
Deficiency (x), - - -	726,9402

This deficiency Dr Higgens found to be owing to a quantity of water and oil which is carried off by the elaſtic fluids, and afterwards depoſited by them. He calculated it, in the preſent caſe, at 700 grains of water and 26,9402 grains of oil. Now, ſince acetite of potaſs is compoſed of acetous acid and potaſs, and ſince the whole of the potaſs remained unaltered, it follows that the acetous acid was converted into carbonic acid gas, carbonated hydrogen gas, carbon, oil, and water; all of which are compoſed of oxygen, hydrogen, and carbon.

Now 1473,564 gr. of carbonic acid gas are compoſed of 1060,966 gr. of oxygen, and 415,598 gr. of carbon.

1047,6018 grains of carbonated hydrogen gas, from a compariſon of the experiments of Dr Higgens and Lavoiſier, may be ſuppoſed to conſiſt of about 714,6008 grains of carbon, and 333,0010 of hydrogen.

200,9402 grains of oil contain 163,4828 grains of carbon and 43,4574 grains of hydrogen.

1040 grains of water contain 884 grains of oxygen and 156 grains of hydrogen.

Therefore

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* Crell's Journal, 1779.

† Vauquelin, Ann. de Chim. xxii. 208.

* Higgens on Acetous Acid, p. 26.

(x) For 29,1 grains of oxygen gas had alſo diſappeared from the air of the veſſels.

Therefore 3817,006 grains of acetous acid are compoſed of 1944,966 — 29,1 = 1915,866 grains of oxygen, 532,4584 grains of hydrogen, and 1368,6816 grains of carbon. Conſequently 100 parts of acetous acid are compoſed of

50,19 oxygen,
13,94 hydrogen,
35,87 carbon.

100,00

Theſe numbers can only be conſidered as approximations to the truth; for the object of Dr Higgens was not to aſcertain the proportions of the ingredients which compoſe acetous acid; and therefore his experiments were not conducted with that rigid accuracy which would have been neceſſary for that purpoſe.

It is extremely probable, that during the acetous fermentation, or the converſion of alcohol into acetous acid, a quantity of water is formed *; and it is certain that oxygen is abſorbed. It follows from this that acetous acid contains more carbon and leſs hydrogen than alcohol. Now we have reaſon, from Lavoiſier's experiments, to believe that alcohol is formed of

51,72 oxygen,
18,40 hydrogen,
29,88 carbon.

Lavoiſier ſuppoſes that this acid contains alſo azot.

3. Acetic acid is ſuppoſed to conſiſt of the ſame baſe with acetous acid, combined with a larger proportion of oxygen; we would rather ſay, that it is acetous acid combined with oxygen.

4. When oxalic acid is diſtilled with ſix times its weight of ſulphuric acid, the products are acetous acid, ſulphurous acid, carbonic acid gas, and ſulphuric acid remains in the retort †. Hence it follows, that oxalic acid contains more carbon than acetous acid; but that it is compoſed of the ſame ingredients. It has been ſuppoſed that oxalic acid is compoſed of ſugar and oxygen. Now ſugar, according to Lavoiſier, is compoſed of

Hydrogen, - - - -	8
Oxygen, - - - -	64
Carbon, - - - -	28

Theſe proportions are rather unfavourable to that notion; at leaſt if any dependence can be put in the compoſition of acetous acid as deduced from the experiments of Dr Higgens.

5. Hermſtadt diſſolved four ounces of tartarous acid in 16 ounces of water, and kept the ſolution in a veſſel covered with paper in a warm place. In three months the taſte of the ſolution was changed, and the air in the upper part of the veſſel was found to be carbonic acid. In ſix months the ſolution was converted into acetous acid. It follows from this experiment, that tartarous acid contains more carbon than acetous acid, and that their ingredients are the ſame. If any doubts ſhould remain, the following experiment is ſufficient to remove them. Weſtrum mixed ſtrong ſulphuric acid with tartarous acid, and added mangneſe; acetous acid was produced, and a great quantity of carbonic acid gas was diſengaged. When nitric acid is diſtilled off tartarous acid, it is converted into oxalic acid, as Scheele firſt proved. Hence it has been ſuppoſed by ſome, that oxalic acid differs from tartarous merely in containing more oxygen: but this is very far indeed from being proved. According to Haſſenfratz, tartarous acid contains a conſiderable quantity of azot.

6. When citrat of lime is allowed to remain in a bottle ſlightly corked along with a little alcohol, the citric acid is gradually converted into acetous acid *. Weſtrum converted it into oxalic acid by means of nitric acid.

7. Malic acid was converted into oxalic by means of nitric acid by Scheele. It has been ſuppoſed to contain more oxygen than oxalic acid. Some of it is always formed during the common proceſs of converting ſugar into oxalic acid. Were we to judge from an experiment, which, however, was not performed with ſufficient accuracy, we would conclude that the baſe of malic acid is gum; for by diſtilling two parts of weak nitric acid off one part of gum in a very ſmall heat, we obtained a quantity of acid more in weight than the gum, which exhibited ſeveral of the diſtinguiſhing properties of malic acid. It was exceedingly light, white, and ſpongy, and attracted water very quickly from the atmoſphere, and could not afterwards be brought by evaporation to its former ſtate.

8. Scheele converted lactic acid into acetous by mere expoſure to the atmoſphere, and found that a quantity of carbonic acid was diſengaged. Hence this acid is merely the acetous with a ſmaller proportion of carbon.

9. The gallic acid, we have ſeen, contains more carbon than any of the others.

10. Nothing is known concerning the compoſition of the benzoic and ſuccinic acids. Hermſtadt ſays he converted benzoic acid to oxalic by means of nitric acid: but Morveau did not obſerve that any change was produced.

11. The baſe of camphoric is probably camphor.

Though theſe eighteen are the only acids which have hitherto been examined with attention, it cannot be doubted that the number of vegetable acids, either exiſting naturally, or at leaſt capable of being formed by art, is conſiderably greater. Morveau has lately aſcertained, that the red colours of flowers are owing to acids: This had already been conjectured by Linnæus.

Sect. XXVIII. *Of Pruſſic Acid.*

530 Diſcovery of Pruſſian blue.

About the beginning of the preſent century, Dieſbach, a chemiſt of Berlin, wiſhing to precipitate a ſolution of cochineal mixed with a little alum and ſulphat of iron, borrowed from Dippel ſome potaſs, from which that chemiſt had *diſtilled* ſeveral times his *animal oil*. On pouring in the potaſs, Dieſbach was ſurpriſed to ſee, inſtead of the red precipitate which he had expected, a beautiful blue powder falling to the bottom of the veſſel. By reflecting on the materials which he had employed, he eaſily diſcovered the method of procuring the blue powder at pleaſure †. This powder was called *Pruſſian blue*, from the place where it was diſcovered. It was announced in the Berlin Memoirs for 1710; but the proceſs was concealed, becauſe it had become a lucrative article of commerce. A method of preparing it, however, was publiſhed by Woodward in the Philoſophical Tranſactions for 1724, which he ſaid he had got from one of his friends in Germany. This method was as follows: Detonate together 4 ounces of nitre and as much tartar, in order to procure an extemporaneous alkali; then add 4 ounces of dried bullock's blood, mix the

531 Method of preparing it.

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* Hermſtadt, Crell's Annals, 1786.

† Crell, Jour. de Phyſ. 1785.

* Stahl.

† Stahl's 300 Experiments.

the ingredients well together, and put them into a crucible covered with a lid, in which there is a ſmall hole; calcine with a moderate fire till the blood emits no more ſmoke or flame capable of blackening any white body expoſed to it: increaſe the fire towards the end, ſo that the whole matter contained in the crucible ſhall be moderately but ſenſibly red. In this ſtate throw it into two pints of water, and boil it for half an hour. Decant off this water, and continue to pour on more till it come off inſipid. Add all theſe liquids together, and boil them down to two pints. Diſſolve two ounces of ſulphat of iron and eight ounces of alum in two pints of boiling water; mix this with the former liquor while both are hot. An effervеſcence takes place, and a powder is precipitated of a green colour mixed with blue. Separate this precipitate by filtration, and pour muriatic acid upon it till it becomes of a beautiful blue; then waſh it with water and dry it.

Different explanations were given of the nature of this precipitate by different chemiſts. All of them acknowledged that it contained iron, but to account for the colour was the difficult point. Brown, and Geoffroy, and Neumann, diſcovered in ſucceſſion, that a great many other animal ſubſtances beſides blood communicated to alkalies the property of forming Pruſſian blue. Macquer undertook an examination of this ſubſtance, and publiſhed the reſult of his experiments in the Memoirs of the French Academy for 1752.

532 Its compoſition diſcovered by Macquer.

He obſerved that, when alkali is added to a ſolution of iron in any acid, the iron is precipitated of a yellow colour, and ſoluble in acids; but if iron be precipitated from an acid by an alkali prepared as above deſcribed, by calcination with blood (which has been called a *Pruſſian alkali)*, it is of a green colour. Acids diſſolve only a part of this precipitate, and leave behind an inſoluble powder which is of an intenſe blue colour. The green precipitate therefore is compoſed of two different ſubſtances, one of which is Pruſſian blue; the other, as he aſcertained by experiment, is the brown or yellow oxide of iron: and the green colour is owing to the mixture of the blue and yellow ſubſtances. When heat is applied to the inſoluble precipitate, its blue colour is deſtroyed, and it becomes exactly ſimilar to common oxide of iron. It is compoſed therefore of iron and ſome other ſubſtance, which heat has the property of driving off. If this inſoluble precipitate be boiled with a very pure alkali, it loſes its blue colour alſo, and at the ſame time the alkali acquires the property of precipitating of a blue colour ſolutions of iron in acids, or it has become preciſely the ſame with the Pruſſian alkali. Pruſſian blue, therefore, is compoſed of iron and ſomething which a pure alkali can ſeparate from it, ſomething which has a greater affinity for alkali than for iron. By boiling a quantity of alkali with Pruſſian blue, it may be completely ſaturated with this ſomething, which we ſhall call *colouring matter*, and then it has loſt all its alkaline properties. No acid can ſeparate this colouring matter from iron after it is once united with it. When iron diſſolved in an acid is mixed with an alkali ſaturated with the colouring matter, a double decompoſition takes place, the acid unites with the alkali, and the colouring matter with the iron, and forms Pruſſian blue. The reaſon that, in the common method of preparing Pruſſian blue, a quantity of yellow oxide is precipitated, is, that there is not a ſufficient quantity of colouring matter (for the alkali is never ſaturated with it) to ſaturate all the iron diſplaced by the alkali; a part of it therefore is mixed with Pruſſian blue. Muriatic acid diſſolves this oxide, carries it off, and leaves the blue in a ſtate of purity. Such were the concluſions which Macquer drew from his experiments; experiments which not only diſcovered the compoſition of Pruſſian blue, but threw a ray of light on the nature of affinities, which has contributed much towards the advancement of that important branch of chemiſtry.

The nature of the colouring matter, however, was ſtill unknown. Macquer himſelf ſuppoſed that it was pure phlogiſton; but the opinion was untenable. He had ſhewn that it poſſeſſed the property of forming neutral ſalts, and therefore Bergman and Morveau ſuſpected that it was an acid.

Scheele undertook the taſk of examining its nature, and publiſhed the reſult of his experiments in the Stockholm Tranſactions for 1782.

He obſerved that the Pruſſian alkali, after being expoſed for ſome time to the air, loſt the property of forming Pruſſian blue; the colouring matter muſt therefore have left it.

533 Decompoſed by Scheele.

He put a ſmall quantity of it into a large glaſs globe, corked it up, and kept it ſome time; but no change was produced either in the air or the Pruſſian alkali. Something muſt therefore diſplace the colouring matter when the alkali is expoſed to the open air, which is not preſent in a glaſs veſſel. Was it carbonic acid gas? To aſcertain this, he put a quantity of Pruſſian alkali into a glaſs globe filled with that gas, and in 24 hours the alkali was incapable of producing Pruſſian blue. It is therefore carbonic acid gas which diſplaces the colouring matter. He repeated this experiment with this difference, that he hung in the globe a bit of paper which had been previouſly dipped into a ſolution of ſulphat of iron, and on which he had let fall two drops of an alkaline lixivium, in order to precipitate the iron. This paper was taken out in two hours, and became covered with a fine blue on adding a little muriatic acid. Carbonic acid, then, has the property of ſeparating the colouring matter from alkali without decompoſing it.

534 The colouring matter ſeparated.

He found alſo that other acids produced the ſame effect. The colouring matter then may be obtained perhaps in a ſeparate ſtate. He accordingly made a number of attempts to procure it, and at laſt diſcovered the following proceſs: He boiled together for ſome minutes two ounces of Pruſſian blue in powder, one ounce of the red oxide of mercury, and ſix ounces of water; then paſſed the whole through a filter, and waſhed the reſiduum with two ounces of boiling water. The oxide of mercury has a greater affinity for the colouring matter than the oxide of iron; it therefore unites with it, and forms with it a ſalt ſoluble in water. The iron remains behind upon the filter, and the liquid is a ſolution of the colouring matter combined with mercury. He poured this ſolution upon half an ounce of pure iron-filings, and added at the ſame time three grains of ſulphuric acid. The iron ſeparates the oxygen from the mercury, in order to combine with the ſulphuric acid; the mercury is precipitated in its metallic ſtate, and leaves behind it a quantity of ſulphat of iron and of colouring matter diſſolved in water, but not combined, as the colouring matter is unable to ſeparate the iron from the acid *.

He then diſtilled in a gentle heat; the colouring mat-

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* *Berthollet Ann. de Chimie*, i. 30.

ter came over by the time that one-fourth of the liquor had paſſed into the receiver. It was mixed, however, with a ſmall quantity of ſulphuric acid; from which he ſeparated it by diſtilling a ſecond time over a quantity of carbonat of lime. The ſulphuric acid combines with the lime and remains behind, which the colouring matter cannot do, becauſe carbonic acid has a ſtronger affinity for lime than it has. Thus he obtained the colouring matter in a ſtate of purity.

535 Its component parts. It remained now to diſcover its component parts. He formed a very pure Pruſſian blue, which he diſtilled, and increaſed the fire till the veſſel became red. The ſmall quantity of water which he had put into the receiver contained a portion of the blue colouring matter and of ammonia; and the air of the receiver conſiſted of azot, carbonic acid gas, and the colouring matter. He concluded from this experiment, that the colouring matter was compoſed of ammonia and carbon. He mixed together equal quantities of pounded charcoal and potaſs, put the mixture into a crucible, and kept it red hot for a quarter of an hour: he then added a quantity of ſal ammoniac in ſmall pieces, which he puſhed to the bottom of the melted mixture, kept it in the fire for two minutes till it had ceaſed to give out vapours of ammonia, and then threw it into a quantity of water. The ſolution poſſeſſed all the properties of the Pruſſian alkali. Thus Mr Scheele ſucceeded in forming the colouring matter; and it was conſidered as proved that it was compoſed of ammonia and carbon.

But after the publication of Scheele's experiments, it was diſcovered that ammonia itſelf is compoſed of azot and hydrogen. It became therefore a queſtion, Whether ammonia entered into the compoſition of this ſubſtance, or merely its ingredients? Whether it was compoſed of ammonia and carbon, or of azot, hydrogen, and carbon combined in a different manner? This point has been decided by the following experiments: Mr Clouet made a quantity of ammoniacal gas paſs through a red hot porcelain tube filled with charcoal, and by this proceſs formed a quantity of the colouring matter *. Here the temperature was ſo high that the ammonia muſt have been decompoſed: and the colouring matter cannot be formed by combining ammonia and charcoal except at a temperature equally high. There is reaſon therefore to ſuppoſe that the ammonia is decompoſed. When oxy-muriatic acid is mixed with the colouring matter, it communicates to it a quantity of oxygen, and cauſes it in conſequence to aſſume very different properties. When a fixed alkali or lime is added to it in this ſtate, it is immediately decompoſed, and converted into ammonia and carbonic acid gas. The colouring matter in this ſtate contains all the ingredients neceſſary to form theſe two ſubſtances, namely, azot, hydrogen, carbon, oxygen: but in order to induce the ingredients to form theſe two compounds, the aſſiſtance of an alkali or lime to combine with the carbonic acid is neceſſary; juſt as ſulphur combines more eaſily with oxygen when united with an alkali or with iron than when ſeparate †.

* *Ann. de Chim.* xi.

† *Berthollet, ibid.* i.

The colouring matter, then, which we ſhall henceforth call the *Pruſſic acid*, is compoſed of azot, hydrogen, and carbon; but the proportions of theſe ingredients have not yet been determined. It is conſidered as an acid, though the preſence of oxygen has not been proved, becauſe it has the property of forming neutral ſalts with the ſame baſes as other acids.

536 Properties of Pruſſic acid. The Pruſſic acid is exceedingly volatile, and evidently capable of exiſting in a gaſeous ſtate. It has a peculiar odour, not diſagreeable, and which has been compared to the flowers of the peach. It has a ſweetiſh and ſomewhat hot taſte, and excites cough *.

It has no affinity for alumina nor for alcohol †.

* *Scheele.*

† *Morveau.*

This ſubſtance differs exceedingly in its action from all other acids.

537 Its action on other bodies. It is capable of combining, like them, with earths, alkalies, and metallic oxides, and of forming compounds which have been denominated *Pruſſiats*. But it enters much more readily into triple compounds with alkalies or earths, and metallic oxides, than into combinations with earths or alkalies ſeparately; and though its affinity appears to be greater for alkalies and earths than for metallic oxides, yet when in a free or gaſeous ſtate it does not enter into combinations with earths or alkalies without difficulty, and it is ſeparated from them much more eaſily than from metallic oxides. Mere expoſure to the light of the ſun, or to a heat of 110°, is ſufficient for that purpoſe.

538 Its affinities. Its affinities are ſuppoſed to be as follows:

Potaſs,
Soda,
Ammonia,
Lime,
Barytes,
Magneſia,
Oxide of zinc,
——— iron,
——— mangane ſe,
——— cobalt,
——— nickel,
——— lead,
——— tin,
——— copper,
——— biſmuth,
——— antimony,
——— arſenic,
——— ſilver,
——— mercury,
——— gold,
——— platinum (Y).

Sect. XXIX. *Of Formic Acid.*

539 Diſcovery of formic acid. In the 15th century ſeveral botaniſts obſerved, with aſtoniſhment, that the flower of ſuccory, when thrown into an ant hill, became as red as blood: But it was Mr S. Fiſher who firſt diſcovered that ants poſſeſſed a peculiar acid, which he obtained by diſtilling theſe animals. His experiments were publiſhed in the Philoſophical Tranſactions for 1670. Though Hoffman afterwards

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(Y) We ſuſpect that this is not the real order of the affinities of this acid; the metallic oxides ought probably to be placed before the alkalies and earths, and the metallic Pruſſiats ought to occupy the place which is at preſent filled by the metallic oxides. The reaſons for this conjecture will appear afterwards. See Part III. chap. ii. ſect. 23. of this article.

repeated his proceſs, little was known concerning the nature of this acid till Margraf undertook its examination, and publiſhed his experiments in the Berlin Memoirs for 1749.

The ſpecies of ants from which the formic acid is obtained is the *formica rufa*, which reſide moſt commonly in woods, or at leaſt in elevated and dry places. They have been found to contain the greateſt quantity of acid in the months of June and July. If at that ſeaſon one of theſe animals be preſſed upon paper tinged with turnſole, it changes the colour of it to a moſt lively red: they even ſometimes ſtain it merely by crawling over it.

540
Methods of obtaining it.

There are two methods of obtaining the formic acid, diſtillation and lixiviation.

When the firſt method is to be employed, the ants are to be waſhed clean, dried with a gentle heat, put into a retort, and diſtilled with a moderate heat, gradually increaſed till all the acid has come over. It is mixed with an empyreumatic oil, from which it is ſeparated by paſſing it through a ſtrainer previouſly moiſtened with water. By this proceſs Meſſrs Ardviſſon and Oehrn obtained from a pound of ants 7½ ounces of acid, the ſpecific gravity of which, at the temperature of 60°, was 1,0075 [*]. Morveau obtained from 49 ounces of ants 23 ounces of pretty ſtrong acid [†]. Margraf added a quantity of water; but it is evident that this ſerves merely to weaken the acid.

When the other method is preferred, the ants are to be waſhed in cold water, put upon a clean linen cloth, and boiling water poured on them repeatedly till it can extract no more acid. The linen is then to be ſqueezed, and the ſeveral liquors mixed and filtrated. This method was firſt uſed by Ardviſſon and Oehrn: they obtained from a pound of ants an acid liquor which had more ſpecific gravity than common vinegar. It is to be purified from the oil which adheres to it by repeated diſtillations. After four diſtillations the empyreumatic oil ſtill manifeſts its preſence by its ſmell, but this ſmell vaniſhes if the acid be expoſed for ſome time to the air; a quantity of eſſential oil, however, ſtill remains, which cannot be ſeparated. The ſpecific gravity of the acid thus rectified is 1,0011 [‡].

Hermſtadt employed a third method. He expreſſed the juice of dry ants, and by this means obtained from 2 lbs. of theſe animals 21 oz. 2 dr. of juice, which on diſtillation yielded a clear pure acid, equal in ſtrength to very concentrated vinegar [§].

541
Its properties.

This acid ſeems to be capable of aſſuming a gaſeous form; at leaſt Hermſtadt obſerved, that when he put ſome of it into a bottle with a glaſs ſtopper, the ſtopper was frequently raiſed by an elaſtic fluid making its eſcape, and that after ſome days it had loſt its ſmell [||]. When this acid is boiled with nitric acid, a gas is extricated, which renders lime-water turbid, and has a very pungent odour [¶].

This acid has a ſtrong but not unpleaſant ſmell, a cauſtic taſte, and when much diluted a pleaſant acidity. When moſt concentrated, its ſpecific gravity is 1,0453 [*].

One part of this acid, mixed with 75 parts of water, gives a faint red to ſyrup of violets; mixed with 430 parts of water, it reddens paper coloured with turnſole; mixed with 1300 parts of water, it produces no effect on the infuſion of turnſole [†]. It mixes readily with alcohol.

It unites readily with the other acids. When boiled with ſulphuric acid, it becomes black. White acrid vapours riſe when the mixture becomes hot; and when it boils, a gas riſes which unites with difficulty to water and lime-water; the formic acid is again obtained, but its quantity is diminiſhed [*].

Nitric acid decompoſes it altogether, and is itſelf converted into nitrous acid. Muriatic acid does not alter it. Oxy-muriatic acts like nitric acid [†].

542
Its compounds and affinities.

Its compounds are called *formiats*.

Its affinities are the ſame with thoſe given above for the Pruſſic acid.

SECT. XXX. *Of Sebacic Acid.*

543
Diſcovery of ſebacic acid.

CHEMISTS had long ſuſpected that an acid could be obtained from tallow, on account of the acrid nature of the fumes which it emitted at a high temperature; but it was M. Grutzmacher who firſt demonſtrated this acid in a diſſertation *De Oſſium Medulla*, publiſhed in 1748 [‡]. Mr Rhodes mentioned it in 1753, and Segner publiſhed a diſſertation on it in 1754, and Crell examined its properties very fully in two diſſertations publiſhed in the Phil. Tranſ. for 1780 and 1782. It was called at firſt *acid of fat*, and afterwards *ſebacic acid*.

It may be procured by heating together a mixture of ſuet and lime. Sebat of lime is formed, which may be purified by ſolution in water. It is then to be put into a retort, and ſulphuric acid poured on it. Sebacic acid paſſes over on the application of heat.

544
Its properties,

Sebacic acid has an acid, ſharp, bitteriſh taſte, and a very pungent ſmell. It reddens tincture of litmus.

Heat cauſes it to aſſume a yellow colour.

It oxidates ſilver, mercury, copper, iron, lead, tin, zinc, antimony, mangaueſe.

It does not act upon biſmuth, cobalt, nickel. When mixed with nitric acid it diſſolves gold.

545
Compounds and affinities.

Its compounds are called *ſebats*.

Its affinities, according to Morveau, are as follows:

Barytes,
Potaſs,
Soda,
Lime,
Magneſia,
Ammonia,
Alumina,
Jargonia [§],
Oxide of zinc,
——— mangaueſe,
——— iron,
——— lead,
——— tin,
——— cobalt,
——— copper,
——— nickel,
——— arſenic,
——— biſmuth,
——— mercury,
——— antimony,
——— ſilver.

SECT. XXXI. *Of Bombyc Acid.*

546
Diſcovery of bombyc acid.

MR BOISSIER DE SAUVAGES obſerved, that the juice of the ſilkworm, in the diſeaſe called in France *muſcadine*, was acid; and Chauſſier remarked, that the ſilkworm, after being converted into a butterfly, gives out a

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[*] Diſſert. on the Acid of Ants, 1777, in Baldinger's New Magazine for Arts.

[†] Encyc. Method. i. 61.

[‡] Ardviſſon and Oehrn, ibid.

[§] Crell's Annals, 1784.

[||] Ibid.

[¶] Ardviſſon, ibid.

[*] Ibid.

[†] Morveau, p. 62.

[*] Ibid.

[†] Ibid.

[‡] Leonhardi.

[§] Vauquelin, Ann. de Chim. xxii. 208.

a liquor which turns vegetable blues to a red. He found, that during the time that the animal was forming its cocon, the acid was depoſited in a reſervoir near the anus. By means of a pair of ſciſſars he collected ſome which reddened blue paper, united with alkalies with effervеſcence, and even attacked the ſciſſars. He afterwards collected it by infuſing the chryſalids in alcohol, which diſſolved the acid, but left the impurities untouched.

This acid has never been examined with attention; ſo that almoſt all its properties are unknown.

Sect. XXXII. *Of Zoonic Acid.*

547 Method of obtaining zoonic acid. Mr Berthollet has obtained a peculiar acid by diſtilling vegetable and animal ſubſtances, to which he has given the name of the *zoonic acid* *. He procured it by diſtilling the gluten of wheat, the yeſt of beer, bones, and woollen rags; and concludes, therefore, that it may be produced by the diſtillation of all animal ſubſtances.

To obtain this acid pure, he mixed lime with the diſtilled liquid, after having ſeparated the oil, which it always contains (for the product of the diſtillation of animal ſubſtances is chiefly oil and carbonat of ammonia.) He boiled this mixture till the carbonat of ammonia was exhaled: he then filtered it, added a little more lime, and boiled it again till the ſmell of the ammonia had gone off entirely. The liquor, which now contained only zoonat of lime, he filtered again, and then added a little water impregnated with carbonic acid, in order to precipitate any lime which might happen to be diſſolved in the liquid without being combined with the zoonic acid.

After concentrating the zoonat of lime, he mixed it with phoſphoric acid, and diſtilled it in a retort. At a heat nearly equal to that of boiling water, the zoonic acid paſſes over in a ſtate of purity.

548 Its properties. The zoonic acid has an odour like that of meat when frying, and it is actually formed during that proceſs. It has an auſtere taſte.

It gives a red colour to paper tinged with turnſole.

With alkalies and earths it produces ſalts, which do not appear capable of cryſtallizing.

It forms a white precipitate in the ſolutions of acetite of lead and nitrat of mercury.

Part of the zoonic acid ſeems to be deſtroyed by the action of heat during the diſtillation of the zoonat of lime with phoſphoric acid: for the liquor, which is in ebullition, becomes brown, and grows black at the end of the operation; hence Mr Berthollet concludes that the zoonic acid contains carbon. The zoonat of ſilver, when kept, becomes gradually brown; hence he concludes that the acid contains hydrogen. Theſe concluſions he draws from a very ingenious theory of his, which has been already deſcribed in the article Bleaching in this *Supplement* †.

549 Animal acids. The five preceding acids have obtained the name of *animal acids*, becauſe they are all obtained from the animal kingdom. It can ſcarcely be doubted that a more accurate examination of animal ſubſtances will add conſiderably to the number of theſe acids.

Sect. XXXIII. *Of Arſenic Acid.*

Arsenic acid, which was firſt diſcovered by Scheele, may be produced by ſimply mixing the white oxide of arſenic with oxy-muriatic acid, and applying a heat ſufficient to ſublime the muriatic acid. The theory of this operation is evident: the white oxide has a greater affinity for oxygen than muriatic acid has; of courſe it combines with it, and is thus converted into arſenic acid, and the muriatic acid is eaſily ſublimed by applying heat. Method of obtaining arſenic acid.

Landriani has informed us, that this acid may be alſo formed by ſubliming ſeveral times ſucceſſively the white oxide of arſenic, and taking care every time to renew the air. This proceſs is equally ſimple; the oxide combines at a high temperature with the oxygen of the atmoſphere.

551 Its properties. This acid is exceedingly fixed. When expoſed to the air it attracts humidity, and at laſt becomes liquid. At the temperature of 60° it diſſolves in two-thirds of its weight of water. Its ſolution may be evaporated to dryneſs, and even converted into a glaſs, which attracts moiſture from the air, and acts powerfully on the crucible.

It is poiſonous as well as the white oxide of arſenic *.

When expoſed to a red heat, it is partly decompoſed and converted into white oxide of arſenic †.

It does not act upon gold, platinum, ſilver, mercury.

It oxidates copper, iron, lead, tin, zinc, biſmuth, antimony, cobalt, nickel, manganeſe, and arſenic, and in a very ſtrong heat, mercury and ſilver.

According to Berthollet's experiments, arſenic acid is compoſed of eight parts of white oxide of arſenic and one part of oxygen.

552 Its compounds and affinities. Its compounds are called *arſeniats.*

Its affinities are as follows:

Lime,
Barytes,
Magneſia,
Potaſs,
Soda,
Ammonia,
Oxide of zinc,
———— manganeſe,
———— iron,
———— lead,
———— tin,
———— cobalt,
———— copper,
———— nickel,
———— biſmuth,
———— mercury,
———— antimony,
———— ſilver,
———— gold,
———— platinum,
Alumina,
Jargonia ‡?
Water.

Sect. XXXIV. *Of Tungſtic Acid.*

553 Properties of tungſtic acid. Tungstic acid, or oxide of tungſten, was firſt diſcovered by Scheele; but the acid which he examined was not pure, being compoſed, as Mr Luyart has ſhewn, of nitric acid, ammonia, and tungſtic acid. The real acid is inſoluble in water, taſteleſs, and incapable of turning vegetable blues red till it has been firſt rendered

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* Ann. de Chim. xxvi. 86.

† Berthollet, Ann. de Chim. xxvi.

* Scheele.

† Id.

‡ Vauquelin, Ann. de Chim. xxii. 208.

ſoluble by being partly combined with ammonia. It is of a beautiful yellow colour, which becomes blue when expoſed to the light, or heated violently in cloſe veſſels. It does not recover its yellow colour except by calcination in the open air, and then increaſes in weight. When put into muriatic acid along with tin, zinc, or iron, the liquor becomes blue *. Treated with acetous acid, it becomes blue. When reduced to a glaſs with phoſphat of ſoda, the blue colour appears and diſappears according as the blue or yellow part of the flame is directed to it, as happens to manganeſe. Probably this blue ſubſtance is an oxide of tungſten with a ſmaller quantity of oxygen.

554
Its compounds and affinities.

Its compounds are called *tungſtats*.

Its affinities are as follows † :

Lime,
Barytes,
Magneſia,
Potaſs,
Soda,
Ammonia,
Alumina,
Jargonia ‡ ?

Sect. XXXV. *Of Molybdic Acid.*

555
Properties of molybdic acid.

Concrete molybdic acid, firſt diſcovered by Scheele, is white, and has an acid but metallic taſte. Its ſpecific gravity is 3,75 §. It is not altered in the air. When heated in a crucible till it is beginning to melt, it experiences no alteration. It remains fixed even in a great fire as long as the crucible is covered ; but the moment it is uncovered the acid riſes unaltered in a white ſmoke. It diſſolves in 570 parts of water. The ſolution reddens turnſole ; nitric acid does not affect it, but ſulphuric and muriatic acids diſſolve it by the aſſiſtance of heat.

It may be prepared by treating the ore of molybdenum with nitric acid, and waſhing the acid when formed in water.

When combined with potaſs, it forms a colourleſs ſalt.

Mixed with filings of tin and muriatic acid, it immediately becomes blue, and precipitates flakes of the ſame colour, which diſappear after ſome time, if an exceſs of muriatic acid has been added, and the liquor aſſumes a browniſh colour.

With the ſolution of nitrat of lead it forms a white precipitate, ſoluble in nitric acid.

When mixed with a little alcohol and nitric acid, it does not change its colour.

With a ſolution of nitrat of mercury, or of nitrat of ſilver, it gives a white flaky precipitate.

With the nitrat of copper it forms a greeniſh precipitate.

With ſolutions of ſulphat of zinc, muriat of biſmuth, muriat of antimony, nitrat of nickel, muriats of gold and platinum, it produces white precipitates when theſe ſolutions do not contain an exceſs of acid.

When melted with borax, it gives it a bluiſh colour.

Paper dipt in this acid becomes in the ſun of a beautiful blue colour ‖.

Sulphur is capable of partly decompoſing it by heat.

Its compounds are called *molybdats*.

Its affinities are unknown.

Sect. XXXVI. *Of Chromic Acid.*

556
Analyſis of the red lead of Siberia,

In the year 1770, Mr Pallas diſcovered in the gold mine of Bereſof, near Ekaterimbourg in Siberia, a mineral of a red colour, with a ſhade of yellow, cryſtallized in ſmall acute angled quadrangular priſms, ſometimes ſmooth, ſometimes longitudinally ſtreaked, and often hollow. Mr Macquart, profeſſor of medicine at Paris, who in 1783 had been ſent to the north by the French government in order to collect mineralogical information, brought with him a quantity of this mineral, which has been diſtinguiſhed by the name of *red lead ore of Siberia*, and in 1789 analyſed four ounces of it along with Mr Vauquelin. They found it to contain,

Lead	$36\frac{1}{9}$
Oxygen	$37\frac{5}{9}$
Iron	$24\frac{8}{9}$
Alumina	2
	$100\frac{5}{9}$

and a little ſilver *.

Mr Bindheim of Moſcow analyſed it ſoon after, and found it to contain,

Lead	60
Molybdic acid	11,66
Nickel	5,66
Oxide of iron	1
Air and water	5
Silica	4,5
	87,82

and a little copper and cobalt †.

Vauquelin examined it again in 1797, and found that all the former analyſes were inaccurate.

A hundred parts of this mineral, reduced to a fine powder, were mixed with 300 parts of the ſaturated carbonat of potaſs, and about 4000 parts of water ; and this mixture was expoſed for an hour to a boiling heat. He obſerved, 1ſt, that when theſe matters began to act upon each other there was produced a ſtrong efferveſcence, which continued a long time ; 2d, that the orange colour of the lead became a brick red ; 3d, that at a certain period the whole matter ſeemed to diſſolve ; 4th, that in proportion as the effervefcence advanced the matter reappeared under the form of a granulated powder of a dirty yellow colour ; 5th, that the liquor aſſumed a beautiful golden yellow colour. When the effervefcence had entirely ſubſided, and appeared to have no longer any action on the ſubſtances, the liquor was filtered, and the metallic duſt collected on the paper. After being waſhed and dried, it weighed no more than 78 parts: the potaſs, therefore, had taken from it 22 parts.

He poured upon the 78 parts juſt mentioned ſome of the nitric acid, diluted in 12 parts of water, which produced a briſk effervefcence. The greater part of the matter was diſſolved : the liquor aſſumed no colour, and there remained only a ſmall quantity of powder of an orange-yellow colour. The liquor of the reſiduum was ſeparated by the help of a ſyphon, the matter waſhed ſeveral times, and the waſhings united with the firſt liquor. This reſiduum, dried, weighed no more than 14 parts ; from which it follows, that the nitric acid had diſſolved 64.

He again mixed theſe 14 parts with 42 parts of the carbonat of potaſs and the neceſſary quantity of water, and

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* *Renxen.*

† *Luyarts.*

‡ *Vauquelin, Ann. de Chim.* xxii. 208.

§ *Bergman.*

‖ *Vauquelin, Philoſophical Magazine,* i. 262.

* *Ann de Chim.* i. 301.

† *Berl. Beob* iv. 2911.

and then treated them as before, and the phenomena were the ſame. The liquor, after being filtered, was united to the former; and the reſiduum, waſhed and dried, weighed no more than two parts, which were ſtill red lead, and therefore thrown away.

The two nitric ſolutions, united and evaporated, produced 92 parts of nitrat of lead, cryſtallized in octahedra, perfectly white and tranſparent. Theſe 92 parts of nitrat of lead, diſſolved in water, were precipitated by a ſolution of the ſulphat of ſoda. This produced 81 parts of the ſulphat of lead, which were equivalent to 56,68 of metallic lead.

557 And diſcovery of chromic acid. The alkaline liquors were found to contain a ſalt compoſed of potaſs combined with a peculiar acid, which Mr Vauquelin afterwards called *chromic acid.*

Theſe liquors, ſubjected to evaporation until a ſaline pellicle was formed on their ſurface, produced, on cooling, yellow cryſtals; among which there was a carbonat of potaſs, not decompoſed. Theſe cryſtals, diſſolved in water, and the ſolution united with the mother-water, the whole was mixed with weak nitric acid until the carbonat of potaſs was ſaturated. The liquor then had a very dark orange-red colour. Being united with a ſolution of the muriat of tin, newly made, it firſt aſſumed a brown colour, which afterwards became greeniſh. Mixed with a ſolution of the nitrat of lead, it immediately produced the red lead. Laſtly, evaporated ſpontaneouſly, it produced ruby-red cryſtals, mixed with cryſtals of the nitrat of potaſs. Ninety-eight parts of this mineral, decompoſed as above-mentioned, having produced 81 parts of the ſulphat of lead, 100 parts would have given 82,65, which are equivalent to 57,1 of metallic lead. " But admitting, as experiment proves (ſays Mr Vauquelin), that 100 parts of lead abſorb, in combining with acids, 12 parts of oxygen, the 57,1 of metallic lead ought to contain in the red lead 6,86 of this principle, and we ought to have for the mineralizing acid 36,4.

558 Its properties. Chromic acid cryſtallizes in the form of elongated priſms of a ruby colour.

When mixed with filings of tin and the muriatic acid, it becomes at firſt yellowiſh brown, and afterwards aſſumes a beautiful green colour.

When mixed with a little alcohol and nitric acid, it immediately aſſumes a bluiſh green colour, which preſerves the ſame ſhade even after deſiccation. Ether alone gives it the ſame colour.

With a ſolution of nitrat of mercury, it gives a precipitate of a dark cinnabar colour.

With a ſolution of nitrat of ſilver, it gives a precipitate, which, the moment it is formed, appears of a beautiful carmine colour, but becomes purple by expoſure to the light. This combination, expoſed to the heat of the blow-pipe, melts before the charcoal is inflamed. It aſſumes a blackiſh and metallic appearance. If it be then pulveriſed, the powder is ſtill purple; but after the blue flame of the lamp is brought in contact with this matter, it aſſumes a green colour, and the ſilver appears in globules diſſeminated throughout its ſubſtance.

With nitrat of copper, it gives a cheſnut red precipitate.

With the ſolutions of ſulphat of zinc, muriat of biſmuth, muriat of antimony, nitrat of nickel, and muriat of platinum, it produces yellowiſh precipitates when theſe ſolutions do not contain exceſs of acid. With muriat of gold, it produces a greeniſh precipitate.

When melted with borax or glaſs, it communicates to them a beautiful emerald green colour.

Paper impregnated with chromic acid aſſumes in the light a greeniſh colour.

When mixed with muriatic acid, the mixture was capable of diſſolving gold like aqua regia; when this mixture of the two acids is diſtilled, oxy-muriatic acid is diſengaged, and the liquor aſſumes a very beautiful green colour.

Sulphuric acid, while cold, produces no effect upon it; but when warmed, it makes it aſſume a bluiſh green colour, probably by favouring the diſengagement of oxygen.

When this acid is heated along with charcoal, it is reduced to the metal called *chromum.* It is therefore compoſed of this metal and oxygen. From Vauquelin's experiments, it appears to contain one part of chromum and two parts of oxygen.

Such are the properties of this acid, as far as they have hitherto been diſcovered. Vauquelin is the only chemiſt who has examined it; and from his memoir the above account has been taken *.

The four laſt deſcribed acids are called *metallic acids,* becauſe they are compoſed of metals and oxygen.

559 Metallic acids. It is believed that moſt of the metals, we would rather ſay of the metallic oxides, are capable of being converted into acids by being combined with oxygen. It is certain that this is the caſe with platinum; and Hermſtadt, by diſtilling nitric acid off tin, converted it into a white maſs, ſoluble in three parts of water, which has been called *ſtannic acid* †. Several more of the metallic oxides act the part of acids: But no complete ſet of experiments on this important ſubject has yet appeared.

Chap. VI. *Of* Affinity.

560 Importance of affinity. The meaning of the word *affinity* has been already explained; and it muſt appear evident, from the uſe which has been made of it in this article, that the conſideration of the nature of affinity is the moſt important part of chemiſtry. While its laws are unknown, chemiſtry is not a ſcience, but a wilderneſs of facts without beauty or regularity: every thing is equally perplexing and incomprehenſible. The chemiſt, inſtead of being able to trace the operations of Nature, is loſt in an endleſs maze of uncertainty, without a guide to conduct him, or a ray of light to illuminate his ſteps. It is the knowledge of affinity which diſpels the darkneſs, removes the confuſion, ſhews us the order which ſubſiſts in all the phenomena of nature, points out their dependence on one another, and enables us to direct them as we think proper, to make them ſubſervient to the improvement of the arts, and thus to render them the miniſters of our comforts and enjoyments.

561 It unites bodies, particle to particle. 1. When two bodies are united together by affinity, how ſmall a portion ſoever of the compound we examine, we ſhall always find it to contain both of the ingredients. From this it is evident, that affinity combines bodies, particle with particle.

By *particles* we do not mean what philoſophers have called *atoms,* or the ſmalleſt parts into which it is poſſible to divide matter; but the ſmalleſt parts which make

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* *Ann. de Chim.* xxv. 114. and *Philoſophical Magazine,* i. 279. and 361.

† *Ann. de Chim.* iv. 162.

make an integrant of any ſubſtance. Water, for inſtance, conſiſts of oxygen and hydrogen; but when we ſpeak of a particle of water, we do not mean the oxygen or the hydrogen ſeparately, but the ſmalleſt poſſible quantity of theſe combined in ſuch a manner as to form water. It is the *integrant particles* of bodies which are united by affinity. Thus ſulphuric acid is compoſed of ſulphur and oxygen combined together; and ammonia, of hydrogen and azot combined in the ſame manner. Now when ſulphuric acid and ammonia combine, it is not their elements, ſulphur, oxygen, azot, and hydrogen, which unite together, particle with particle, but the particles of the acid and the alkali as integrants. This is evident; becauſe if theſe ſubſtances be ſeparated from each other by means of a ſtronger affinity, they are found preciſely in the ſame ſtate as before they entered into combination.—When the ſubſtances which combine are *ſimple*, the ultimate and integrant particles are the ſame: But we are not certain that any of the bodies with which we are acquainted is ſimple, in the ſtrict and proper ſenſe of the word.

562
Opinions of the older chemiſts about affinity.

2. What is this *affinity* which unites bodies together? The older chemiſts thought that all ſolvents, or ſubſtances capable of diſſolving others, were compoſed of particles which had the form of wedges or hooks; that ſolution conſiſted in the inſinuation of theſe wedges or hooks between the particles of the bodies to be diſſolved; and that chemical combination was merely the linking of the different particles together by means of holes in one ſet of particles, into which the hooks or the wedges of the other ſet were thruſt. Such explanations, abſurd as they may appear, were faſhionable among chemical philoſophers till the days of Sir Iſaac Newton, who firſt aſcribed the chemical union of bodies to an *attraction* between the particles themſelves. This explanation, after a violent ſtruggle on the part of the chemiſts, has been at laſt unanimouſly adopted.

563
It is an attraction between the particles of bodies.

Affinity, then, is an *attraction* between the particles of different bodies, by which they are *drawn* towards one another, and kept united. This we take for granted, and conſider as a *fact*, without pretending to explain *how* they come to be poſſeſſed of this power, or *how* they exert it; both of which are evidently beyond the reach of the human underſtanding.

But though we cannot diſcover the manner in which affinity acts, we can ſee, at leaſt, that it follows certain laws, and that they are invariable; for ſimilar phenomena always occur when the circumſtances are the ſame.

564
Whether the ſame with gravitation.

Now what are the laws which affinity follows? There is a ſpecies of attraction which matter poſſeſſes, called *gravitation*, the laws of which were inveſtigated by Sir Iſaac Newton. Is affinity the *ſame* with gravitation, or does it follow different laws?

Upon a ſlight view of theſe two attractions, their phenomena appear very different. Gravitation acts at very great diſtances; affinity not until the bodies are mixed together: Gravitation acts on the whole maſs; affinity only on the particles: Bodies gravitate to one another directly as their maſſes, and inverſely as the ſquares of their diſtances. But how can affinity follow theſe laws, when it does not act till the bodies are apparently in contact? or ſuppoſing that it does act, how can they account for the phenomena of affinity? If barytes be preſented to a compound of ſulphuric acid and potaſs, the acid immediately leaves the alkali and combines with the earth: But had gravitation been the only power acting, ought not the barytes to have united with the ſulphat of potaſs without producing any decompoſition?

Theſe ſtriking differences have convinced many philoſophers, as they ſeem to have done Newton himſelf, that gravitation and affinity are different ſpecies of attraction. Let us not, however, embrace this concluſion vaguely, or without affixing a preciſe meaning to our words.

565
No poſitive proof that it is different.

Gravitation and chemical affinity are ſaid to be different ſpecies of attraction. But what is attraction? It is merely a general *fact*, or that tendency which is *obſerved* among all the portions of matter towards each other, but which exhibits very different appearances under different circumſtances. The tendency of matter towards matter at *ſenſible* diſtances is called *gravitation*, and its laws have been completely inveſtigated; but neither that tendency, nor theſe laws, have been, or can be, ſhewn to be *eſſential* to the exiſtence of matter. Chemical affinity is the tendency of particles towards each other at *inſenſible* diſtances, or when theſe particles are mixed together; and this tendency appears to be regulated by laws different from thoſe of gravitation. Like gravitation, it is merely an *obſerved fact*; and however different theſe facts may appear to be, they are probably both brought about by the ſame forces. It is indeed true, that gravitation is directly as the maſſes of matter, and inverſely as the ſquares of the diſtances of theſe maſſes; while the attraction, which is called *chemical affinity*, ſeems to obſerve very different rules. But we have ſhewn elſewhere (ſee OPTICS, nº 62—68, *Encycl.*; and BOSCOVICH in this *Suppl.*), that the ſame forces repel at one diſtance and attract at another; and that they may produce all the various phenomena of chemical affinity.

The difficulties to be accounted for in chemical affinities are their intenſity, their different degrees of ſtrength, and their being elective, or, which is the ſame thing, the capacity which one body has of diſplacing another.

How come affinities, it may be aſked, to differ in intenſity? Perhaps we might with propriety refer this queriſt to the ſtudy of Boſcovich's curve; but as our modern chemiſts are not generally verſant in ſuch ſtudies, we beg leave to obſerve, in this place, that we have no proof whatever of abſolute contact between bodies. On the contrary, it is highly probable, we had almoſt ſaid demonſtrable, that particles are in every inſtance at ſome diſtance from one another. For, on the ſuppoſition that two bodies were in actual contact, their attraction for each other would not only be as great as poſſible, but as great as the attraction of any other body for either of them *could poſſibly* be: Conſequently, it neceſſarily follows, that, ſince bodies chemically combined *can* be ſeparated, they are not in actual contact (A); but if they are not in contact, their diſtance from one another

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(A) Perhaps the following demonſtration, which we borrow from the ingenious Mr Broughman, will render this more evident. In fig. 7. let the body A have for P an attraction which at the diſtance of AP is proportional

Plate XVII.

another *may* vary in different caſes, and the force of affinity will vary with the diſtance. Here then is a reaſon why the affinity of different bodies varies in ſtrength. Sulphuric acid, for inſtance, has a ſtronger affinity for barytes than for lime; becauſe when the combinations are formed, the diſtance between the acid and barytes is not ſo great as that between the acid and lime.

But why do the diſtances differ? If affinity be the ſame with gravitation, it muſt tend to bring the particles nearer one another: And what then prevents the lime from approaching as near the acid as the barytes does? We reply, *the figure of its particles*. This anſwer was firſt given to the queſtion by Buffon, and it is fully adequate to ſolve the difficulty. The particles of bodies, indeed, are a great deal too minute for us to diſcover their figure by actual inſpection; but the phenomena of cryſtallization ſhew us that this difference actually exiſts.

The cryſtals of every body aſſume a peculiar figure. Now as theſe cryſtals are all formed in the ſame manner, and by the ſame law, it is impoſſible to conceive any other reaſon for their variety but the difference in the form of the particles which compoſe them.

But why does one body diſplace another? When a particle of barytes is brought within a certain diſtance of a particle of ſulphuric acid and lime combined together, affinity acts and draws them nearer to one another; and the barytes, from its figure, approaches nearer the acid than the lime could, and forms with it a compound, the figure of which is ſuch, relatively to that of the lime, that they cannot approach within a ſmall enough diſtance of each other to counteract the attraction of the earth. Accordingly no compound is formed; for all that is meant by two particles having formed a compound, is, that their attraction for each other is greater than the attraction of the ſurrounding bodies for either.

566
Conſequently it ought to be conſidered as the *ſame*.

Having thus ſeen that none of the phenomena of *affinity* are inconſiſtent with their reſulting from the forces which bring about the phenomena of gravitation, we have a right to conclude, that it is at leaſt highly probable, that all the motions of the corporeal world are produced by the ſame power which, though not eſſential to matter, was impreſſed upon every atom of it by the Great Creator when he formed this univerſe; and that as the effects of this power are modified according to the ſituation of the bodies on which it acts, they are known by the different names of *gravity*, *adheſion*, *coheſion*, and *affinity*.

Gravity is the attraction between bodies ſo diſtant, that the maſſes alone influence the reſult, and that the power may be conſidered as placed in the centre of the attracting bodies.

Adhesion ſuppoſes a diſtance too ſmall for our ſenſes. It has been demonſtrated to be proportional to the number of touching points, which depends upon the figure of the particles that form the bodies.

Cohesion takes place only between particles of the ſame nature. Theſe, inſtead of touching only in one ſuperficies, as in adheſion, touch in every point where their figure will allow contact: conſequently the force of coheſion alſo muſt depend upon the figure of the particles.

Affinity unites bodies of a different nature, not merely by one ſuperficies, as *adheſion* does, but particle to particle, like *coheſion*; and the moſt perfect contact is formed that the figure of the particles will admit. Therefore, in this caſe alſo, the intenſity depends upon the figure of the particles.

567
Saturation explained.

3. If we make the attempt, we ſhall find that water will not diſſolve any quantity of common ſalt that we pleaſe. Water which refuſes to take up any more is ſaid to be *ſaturated* with ſalt. Neither can we combine *any* quantity of potaſs with a given portion of ſulphuric acid: we may add as much of it as we pleaſe, indeed; but if we evaporate the liquid, in order to obtain the ſalt in cryſtals, we ſhall find that only *part* of the potaſs has united with the acid, and that the reſt has cryſtallized ſeparately. From theſe examples, it muſt appear evident, that bodies combine with one another by affinity only in certain proportions; or, which is the ſame thing, that a determinate number of particles of each of the ingredients goes to the formation of an integrant particle of the compound, and that into this integrant *no additional particles* of either ingredient *can* be admitted. Let us ſuppoſe, for inſtance, that the particles of ſulphuric acid are tetrahedrons, and that the particles of potaſs are of ſuch a form, that one of them can attach itſelf to each of the ſides of the acid particle: In that caſe an integrant particle of ſulphat of potaſs would be compoſed of five particles, one of acid and four of alkali; for it is evident, that juſt four particles of potaſs would combine with every particle of acid, and that the acid would then be ſaturated, or, which is the ſame thing, would be incapable of receiving any more alkaline particles into combination with it. Let us ſuppoſe now, that there is juſt as much potaſs as ſaturates the acid; if more acid be poured in, it cannot enter into combination with the potaſs, becauſe all the potaſs is already combined with acid.

Thus it appears evident, from the nature of affinity, that the ingredients in every combination muſt mutually *ſaturate* each other, and that no more of either can be

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tional to PM; then let P move towards A, ſo as to come to the ſituation P', and let the attraction here be $P'M'$; as it is continual during the motion of P to P', MM' is a curve line. Now in the caſe of the attraction of bodies for one another, PM is leſs than $P'M'$; and conſequently MM' does not ever return into itſelf, and therefore it muſt go *ad infinitum*, having its arc between AB and AC, to which it approaches as aſymptotes, the abſciſſa always repreſenting the diſtance, and the ordinate the attraction at that diſtance. Let P' now continue its motion to P'', and M' will move M''; and if P'' meets A, or the bodies come into perfect contact, $P''M''$ will be infinite; ſo that the attraction being changed into coheſion will be infinite, and the bodies inſeparable, contrary to univerſal experience; ſo that P can never come nearer to A than a given diſtance. *Nicholſon's Journal*, I. 555.

be admitted into the compound than what is neceſſary to produce this ſaturation. It follows equally, that there can be *no union* without ſaturation, except there be a deficiency in ſome one of the ingredients: For ſuppoſing that there is a ſufficient number of particles of potaſs, and that every particle of ſulphuric acid requires four of them, as before, for ſaturation, the very ſame cauſe that produces the union of one, two, or three particles of potaſs with a particle of acid, muſt produce the union of all the four.

Even when there is a deficiency of one of the ingredients, ſaturation muſt equally take place; for thoſe particles of acid that happen to be neareſt the alkali muſt ſtill be ſaturated; becauſe the affinity of all the acid particles for alkali was originally equal, and the difference of the diſtance muſt give the ſuperiority to thoſe that are neareſt; and thoſe particles of acid that are once ſaturated with potaſs cannot be deprived of it by any of the other particles, otherwiſe the affinity of ſome particles of ſulphuric acid for potaſs would be greater than that of others; which is abſurd.

It will no doubt be objected to all this that there are innumerable inſtances of additional portions of ſome one of the ingredients being received into a compound after ſaturation, and that ſome ſubſtances ſeem to be equally well ſaturated with different doſes of another. Oxygen, for inſtance, combines with azot in three different proportions, and forms nitrous gas, nitrous acid, and nitric acid. The metals, too, form, in the ſame manner, different oxides; and a great many inſtances of the ſame kind occur among the neutral ſalts.

But it ought to be remembered, that the concluſions againſt which theſe objections are urged, are conſequences deduced, we think fairly, from a propoſition which we conſider as demonſtrated, that *affinity is a ſpecies of attraction* (B). Theſe phenomena cannot therefore be admitted as valid objections, except it can be ſhewn that they are really *incompatible* with theſe concluſions. Now that this is not the caſe, has been ſhewn, in the moſt ſatisfactory manner, by Morveau*. Theſe apparent exceptions are owing to an affinity which exiſts between the compound as an integrant and one of its ingredients, and are not inſtances of various degrees of ſaturation, but of the formation of new compounds. According to this very ingenious idea, which, we believe, firſt originated with Bergman, and was firſt ſeen in its full extent by Morveau, we have formerly explained in what manner the various metallic oxides are formed: the firſt oxide is a compound of the metal and oxygen; the ſecond, of the firſt oxide and oxygen; the third, of the ſecond oxide and oxygen; and ſo on. In the ſame manner we have explained the various combinations of azot and oxygen: and the explanation may eaſily be extended to every other caſe. Theſe apparent objections, then, are not incompatible with the above concluſions, but perfectly conſiſtent with them; and conſequently they cannot be admitted as of any force.

* Encyc. Method. i. 560.

There is one phenomenon, indeed, which proves, independent of theſe concluſions, that theſe combinations are actually formed in the manner we have ſuppoſed, and which therefore merits particular attention. The phenomena is, that the affinity between the two ſimple ſubſtances is *almoſt always greater* than that between the compound and any of its ingredients. The affinity, for inſtance, between azot and oxygen is greater than that between nitrous gas and oxygen; and the affinity between nitrous gas and oxygen greater than that between nitrous acid and oxygen: For if nitrous gas be mixed with nitric acid, the whole is converted into nitrous acid; but no change whatever is produced when nitric and nitrous acids, or nitrous gas and nitrous acid, are mixed: and every ſubſtance which is capable of decompoſing nitrous gas is capable alſo of decompoſing nitrous and nitric acids; but many ſubſtances are capable of decompoſing nitrous and nitric acids which have no effect upon nitrous gas. In the ſame manner, the affinity between ſulphur and oxygen is greater than that between ſulphurous acid and oxygen: for when ſulphur is mixed with ſulphuric acid, the whole is converted into ſulphurous acid; but no change takes place when ſulphur and ſulphurous acid, or ſulphurous and ſulphuric acids are mixed together. A great many inſtances of the ſame kind might eaſily be produced, if theſe were not ſufficient to eſtabliſh the point. This curious fact affords a very ſtrong proof that the baſes, as well as the quantity of oxygen, is different in almoſt all the vegetable acids. Did the tartarous, oxalic, and acetous acids, for inſtance, conſiſt of the ſame baſe with various doſes of oxygen; were the tartarous compoſed of the baſe and oxygen; the oxalic, of tartarous acid and oxygen; the acetous, of oxalic acid and oxygen—in that caſe, a mixture of acetous and tartarous acids ought to form oxalic acid: but that this does not happen, any one may convince himſelf by actual experiment.

We do not mean to affirm that this fact, though it is certainly very often true, holds in all caſes; in ſome, perhaps, the reverſe may be true, though we do not recollect at preſent any inſtance of that kind.

568 Of the ſtrength of affinity.

4. Since the affinity of almoſt every two bodies for each other differs *in ſtrength* from that between every other two, it becomes an important problem *to determine the ſtrength of every affinity in numbers*. The ſolution of this problem would give a clearneſs and preciſion to chemiſtry equal to that of any other branch of natural philoſophy whatever, and enable it to advance with a degree of rapidity hitherto thought unattainable. No wonder, then, that this problem has occupied the attention of ſome of the moſt eminent philoſophers who have dedicated their time to chemiſtry.

569 Attempts to aſcertain it.

If the obſervations formerly made, in order to ſhew that

(B) Were any farther proof of this propoſition required, we would obſerve, that *coheſion* acts as an antagoniſt to affinity, and may be often rendered ſo ſtrong as to prevent affinity from acting with efficacy. Thus alumina and jargonia, when ſufficiently heated, become inſoluble in acids, without undergoing any other alteration than that of an increaſe of coheſion by their particles being brought nearer each other; for deſtroy this coheſion, and they become as ſoluble as ever. Now it follows from this, that if coheſion be *attraction*, ſo muſt *affinity*. The experiments of Morveau, to be afterwards mentioned, demonſtrate, that *adheſion* and *affinity* are produced by the ſame cauſe: Conſequently, if adheſion be attraction, ſo muſt affinity.

that the difference in the ſtrength of affinities depends upon the different forms of the particles which have an affinity for each other, be concluſive, it is evident that the certain method of learning the ſtrength of affinities would be to diſcover the forms of the parricles of all bodies. But no method has hitherto been diſcovered by which it is poſſible of becoming acquainted with the figure of the particles of bodies. The experiments indeed of the Abbé Hauy (afterwards to be deſcribed) point out a method by which the primary figure of cryſtals may be inveſtigated with a good deal of plauſibility; but this leaves the knowledge of the figure of the particles which compoſe theſe cryſtals ſtill uncertain.

As nobody, therefore, has attempted to take this road, in order to calculate the ſtrength of affinities, let us at preſent conſider the different methods which have been propoſed for that purpoſe, that we may ſee whether any of them will anſwer the end intended.

570 By Wenzel, Wenzel ſuppoſed that the time taken by one body to diſſolve another is a meaſure of the affinity which ſubſiſts between them. But the hypotheſis of that ingenious philoſopher will not bear the teſt of examination; for the *time* of ſolution evidently depends upon circumſtances unconnected with affinity. The coheſion of the body to be diſſolved, and the nature of the compound formed, muſt occaſion very great differences in the time of ſolution of different bodies, even on the ſuppoſition that their affinities were all the ſame.

571 Fourcroy, Fourcroy propoſed to meaſure the affinity of bodies by the difficulty of ſeparating them after they are combined: but we have no method for meaſuring this difficulty. Lavoiſier and De la Place, indeed, propoſed *caloric* for this purpoſe; but there are many compounds which caloric cannot ſeparate; and it never produces a ſeparation except by means of its affinity for one or other of the ingredients of the compound. Before caloric, therefore, could be employed as a meaſure, it would be neceſſary to know exactly the ſtrength of its own affinity for every other ſubſtance; which is juſt a caſe of the problem to be reſolved.

572 Macquer, Macquer ſuppoſed that the affinity of bodies for one another was in the compound ratio of the facility of their union and the difficulty of their ſeparation: But as we are in poſſeſſion of no method of aſcertaining either of theſe, it is evident that this theory, even allowing it to be juſt (which it certainly is not), could be of no uſe for aſſiſting us to calculate the force of affinities.

573 Morveau, Another method has been propoſed by the diſtinguiſhed philoſophical chemiſt Mr de Morveau (c).

In 1713 Dr Brook Taylor made ſome experiments on the adheſion of ſurfaces; and concluded from them, that the force of adheſion might be determined by the weight neceſſary to produce a ſeparation. But in 1772, Meſſrs La Grange and Cigna, obſerving that the ſurfaces of water and oil adhere together, and taking it for granted that theſe two liquids *repel* each other, concluded, in conſequence, that their adheſion was not owing to *attraction*; and hence inferred, that *adheſion*, in general, is always owing to the preſſure of the atmoſphere. This concluſion induced Morveau to examine the ſubject: he found that adheſion was *not affected* by the preſſure of the atmoſphere; for it required the ſame weight to ſeparate a diſk of glaſs (30 lines in diameter) from the ſurface of mercury in the open air, and under an exhauſted receiver. He obſerved that the ſame diſk adhered to water with a force of 258 grains, and to the ſolution of potaſs, though denſer, only with a force of 210. This reſult not only proved that adheſion was owing to attraction, but made him conceive the poſſibility of applying this method to the calculation of affinities: For the force of adheſion being neceſſarily proportional to the points of contact, and this being the caſe alſo with affinity, it is evident that the adheſion and the affinity between the ſame ſubſtances are proportional, and that therefore the knowledge of the one would furniſh us with the ratio of the other.

Struck with this idea, he conſtructed cylinders of different metals, perfectly round, an inch in diameter and the ſame in thickneſs, and having a ſmall ring in their upper ſurface, by which they might be hung exactly in equilibrium. He ſuſpended theſe cylinders, one after another, to the beam of a balance; and after counterpoiſing them exactly, applied them to a quantity of mercury placed about two lines below them, making them ſlide along its ſurface, to prevent any air from lodging between them and the mercury. He then marked exactly the weight neceſſary to overcome their adheſion, taking care to change the mercury after every experiment. The table of the reſults is as follows:

Gold adheres to mercury with a force of	446 gr.
Silver, - - - - - - -	429
Tin, - - - - - - -	418
Lead, - - - - - - -	397
Biſmuth, - - - - - -	372
Platinum, - - - - - -	282 *
Zinc, - - - - - - -	204
Copper, - - - - - -	142
Antimony, - - - - - -	126
Iron, - - - - - - -	115
Cobalt, - - - - - - -	8

* *Morveau, Ann de Chim.* xxv. 10.

The differences of theſe reſults cannot be owing to the preſſure of the air, which was the ſame in all; nor do they correſpond to the denſities of the metals; nor can they be owing to accidental differences in the poliſh of the cylinders, for a plate of rough iron adheres more ſtrongly to mercury than one of the ſame diameter exquiſitely poliſhed;—but they follow preciſely the order of affinity, and therefore may be conſidered as the meaſure of the ſtrength of the affinity between theſe different metals and mercury. They furniſh us alſo with a convincing proof that *affinity* is *attraction*, and the ſame ſpecies of attraction with *adheſion*; and that therefore, if the one be reducible to *gravitation*, ſo muſt the other.

Mr Achard, convinced of the importance of Mr Morveau's obſervations, made a great many experiments on *adheſion*, and publiſhed the reſult of them in 1780. He

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(c) Now Mr Guyton: we have uſed the old name all along in the text to avoid ambiguity.

proved that the force of adheſion was not affected by alterations in the height of the barometer, but that its force became weaker as the heat of the fluid increaſed (D); and that the temperature remaining the ſame, the force of adheſion increaſed in the ſame ratio with the ſurfaces of the adhering bodies. He made about 600 experiments on the adheſion of different ſolids and fluids, proved that the force of adheſion did not depend on the denſities of the adhering bodies, nor on the different coheſive force of the fluids; and, after a laborious calculation, concluded that it depended on the figure of the particles of the adhering fluid and ſolid.

Theſe experiments and calculations of Mr Achard are certainly of importance; and we would have given them here, had not the objects of them been ſubſtances which can furniſh but few data for calculating the force of affinities.

This method of meaſuring the force of affinities ſeems to be an accurate one, and if it could be applied to every caſe of affinity, would, in all probability, enable us to ſolve the problem which we are now conſidering: But, unfortunately, its application is very limited, being confined to thoſe caſes alone in which one of the bodies can be preſented in a fluid, and the other in a ſolid ſtate. Nor can it be applied indiſcriminately to all thoſe caſes; for whenever the coheſion of any liquid is much inferior to the force of its adheſion to any ſolid, the ſeparation takes place in the particles of the liquid itſelf, and conſequently we do not obtain the meaſure of its adheſion to the ſolid, but of its own coheſion, and that, too, imperfectly. Thus, for inſtance, Mr Achard found that ſealing-wax adhered to water with a force of 92 grains, and to alcohol only with a force of $53\frac{3}{4}$ths; yet we know that ſealing-wax has a greater affinity for alcohol than for water; becauſe alcohol diſſolves it, which water is incapable of doing. The difference in the reſult in this inſtance was evidently owing to the ſmaller coheſion of alcohol. Mr Morveau's method muſt therefore be confined to thoſe caſes in which the coheſion of the liquid is ſtronger than its adheſion to the ſolid, which may be known by the ſurface of the ſolid not being moiſtened; and to thoſe in which the coheſion is not much inferior to the adheſion; for then, it is evident, that the force of coheſion will be increaſed as the force of adheſion. Let us ſuppoſe, for inſtance, that two ſolids, A and B, are made to adhere to the ſurface of a liquid, and that A can only form an adheſion with 50 particles of the liquid, whilſt B adheres to 100; it is evident that a much ſmaller force will deſtroy the coheſion of the 50 particles to which A adheres with the reſt of the liquid, than what will be required to deſtroy the coheſion of the 100 particles united to B with the ſame liquid *.

The method of Mr Morveau, then, may be applied with accuracy in both caſes; and *when* they occur can only be determined by experiment. It cannot, however, be applied indiſcriminately even then; for unleſs the ſolid and the fluid be preſented in ſuch a ſtate that no gas is extricated when the adheſion takes place, an accurate judgment cannot be formed of the force of adheſion. When marble (carbonat of lime), for inſtance, is applied to the ſurface of ſulphuric acid, there is an extrication of gas, which very ſoon deſtroys the adheſion, and prevents an accurate reſult. Were it poſſible to employ quicklime inſtead of marble, this would be prevented; or if this cannot be accompliſhed, why might not lime be employed, united with ſome acid that would not aſſume a gaſeous form, and at the ſame time has a weaker affinity than ſulphuric acid for lime? Why might not the phoſphat of lime, for inſtance, be uſed, which may be reduced to a ſtate of hardneſs ſufficiently great for the purpoſe? The extrication of gas, during the application of metals to the ſurfaces of acids, might be prevented by oxidating their ſurfaces. It is true, indeed, this could not be done with all the metals, on account of the nature of the oxide, but it might with ſeveral; copper, for inſtance, and ſilver. It cannot be doubted, that by theſe methods, and other contrivances that might be fallen upon, a ſufficient number of reſults might be obtained to render this method of the greateſt importance. It is rather ſurpriſing, therefore, that it has never been proſecuted.

574
And Kirwan.

Mr Kirwan has propoſed another method of ſolving the problem. While he was engaged in his experiments on the ſtrength of acids, he obſerved that the quantity of real acid neceſſary to ſaturate a given quantity of each of the baſes, was inverſely as the affinity between the reſpective baſes and the acid; and that the quantity of each of the baſes neceſſary to ſaturate a given quantity of acid was directly as the affinity between the baſe and the acid. Thus 100 grains of each of the acids require more alkali for ſaturation than lime, and more lime than magneſia, as may be ſeen in the following table:

100 grains of	Potaſs.	Soda.	Lime.	Amm.	Mag.	Alum.
Sulphuric acid	215	165	110	90	80	75
Nitric acid	215	165	96	87	75	65
Muriatic acid,	215	158	89	79	71	55

He concluded, therefore, that the affinity between acids and their baſes may be eſtimated by the quantity of baſes neceſſary for ſaturation. Thus the affinity between potaſs and ſulphuric acid is 215, and that between nitric acid and lime 96 *.

We have mentioned formerly, that the principle on which Mr Kirwan calculated the ſtrength of the acids was founded on a miſtake. It muſt follow of courſe, therefore, that the numbers which reſult from it muſt alſo be wrong. This Mr Kirwan has acknowledged, and ſeems to have given up all thoughts of aſcertaining the ſtrength of affinities by this method. But before it be abandoned altogether we wiſh the following obſervations were conſidered.

575
Attempt t
remedy th
defects of
his method

Bergman long ago eſtabliſhed as a principle, under the name of a chemical paradox, that *the ſtronger any ſalt was, the leſs of any other it required for ſaturation.* Thus, according to him,

100

* *Morveau, Encyc. Method. Chim.* art. *Adheſion.*

* *Phil. Tranſ.* 1783.

(D) Strictly ſpeaking, this is owing not ſo much to a decreaſe of the force of adheſion, as of that of the coheſion of the fluid itſelf.

100 parts of potaſs require	78,5	Sulphuric acid,
	64	Nitric,
	51,5	Muriatic,
	42	Carbonic,
100 parts of ſoda - -	177	Sulphuric,
	135,5	Nitric,
	125	Muriatic,
	80	Carbonic.

This propoſition, which has been admirably illuſtrated by Morveau *, evidently reſolves itſelf into the two following:

1. A *baſe* requires *the more* of an acid for ſaturation *the ſtronger* its affinity for that acid is.

2. An *acid* requires *the more* of any baſe for ſaturation *the greater affinity* it has for that baſe.

In order to judge of the truth of the firſt of theſe propoſitions, let us examine the following table, drawn up from the experiments of Bergman, Wenzel, and Kirwan.

	BERGMAN.			WENZEL.			KIRWAN.		
100 parts of	Sulphuric.	Nitric.	Muriatic.	Sulphuric.	Nitric.	Muriatic.	Sulphuric.	Nitric.	Muriatic.
Barytes	15,4		30,8						
Potaſs	78,6	64	51,5	82,4	107,7	54	81,8	87,1	78,2
Soda	175	135,5	125	125,8	166,6	83	129,4	136,1	114,2
Lime	143,7	134,4	70,45	147,74	195,6	103,6	141	180	86
Magneſia	173,67	159,25	82,92	181,8	257,15	122,27	170,5	255	104,275
Ammonia				142,42	201,22	96,25	187,5	233	116
Alumina	211,11		220,2	77,7	68,7	38,6			

It is evident at firſt ſight, that Bergman's experiments correſpond exactly with the propoſition. To ſaturate, according to him, 100 parts of potaſs, requires 78,6 of ſulphuric acid, 64 of nitric, and 51,5 of muriatic acid. There is only one deviation from the propoſition in the whole table, and this regards barytes, which, according to him, is ſaturated with 15,4 of ſulphuric and 30,8 of muriatic acid. But Mr Morveau has ſhewn, by ſeveral accurate experiments, that barytes requires much more ſulphuric acid for ſaturation than Bergman ſuppoſed *. And Klaproth has ſhewn, that 100 parts of barytes require 49,2 of ſtrong ſulphuric acid for ſaturation †. And Dr Withering's calculation ‡ agrees almoſt exactly with this; nor does that of Fourcroy differ much from it §. Inſtead of 15,4 of ſulphuric acid, therefore, which, according to Bergman, are neceſſary to ſaturate 100 of barytes, it ſhould be 42,8.

The firſt and laſt columns of Wenzel and Kirwan's experiments agree equally well with the propoſition, but the ſecond deviates from it completely. Wenzel probably might have been miſled by the manner of performing his experiments; but the ſame objection does not ſeem to lie againſt thoſe of Kirwan.

It can ſcarcely be doubted, however, to whatever cauſe the error is to be imputed, that the numbers in the ſecond column of Mr Kirwan's table are too large. The following experiment of Morveau is ſufficient to ſhew this.

According to Mr Kirwan's experiments, the proportions of acid and alkali in the four following ſalts are as under:

Sulphat of potaſs { Acid 100
Potaſs 108,7

Sulphat of lime { Acid 100
Lime 80,6

Nitrat of potaſs { Acid 100
Potaſs 83,33

Nitrat of lime { Acid 100
Lime 34,4.

Now when ſulphat of potaſs and nitrat of lime are mixed together, a double decompoſition takes place, and ſulphat of lime and nitrat of potaſs are formed. Let theſe two ſalts be mixed together; let the quantity of ſulphat of potaſs be ſuch, that the acid contained in it amounts to 100; and let a more than ſufficient quantity of nitrat of lime be added, to ſaturate the ſulphuric acid with lime. It is evident that for that purpoſe 80,6 of lime muſt be preſent; and the quantity of nitric acid combined with theſe 80,6 muſt be 234,4. This quantity would require for ſaturation 195,32 of potaſs, but there are only 108,7 in the mixture; conſequently there ought to exiſt in the mixture, after the mutual decompoſition of the ſalts, 64,87 of nitric acid in a ſtate of liberty. Such would be the reſult, provided Mr Kirwan's numbers were accurate; but the fact is, that no ſuch exceſs of acid exiſts in the mixture †; and conſequently the quantity of nitric acid contained in nitrat of lime is ſtated too high by Mr Kirwan. Although therefore Mr Kirwan's tables do not coincide with the propoſition which we are conſidering, this is not to be conſidered as a proof of its falſehood; as there is reaſon, from the experiment above deſcribed, to ſuſpect ſome error in the data from which Mr Kirwan calculated the ſtrength of the acids.

The truth of the ſecond propoſition may be judged of by the following Tables:

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* Encyc. Method. Chim. i. 597.

* Encyc. Method. Chim. i. 591.

† Chim. Ann. ii. 1785.

‡ Phil. Tranſ. 1784.

§ Ann. de Chim. iv. 65.

† Ann. de Chim. xxv. 295.

According to BERGMAN.

100 parts of	Baryt.	Potaſs.	Soda.	Lime.	Magn.	Amm.	Alum.
Sulp. acid	646	127,5	56,5	69,5	578	42	473
Nitric acid		148,4	74,4	74,4	62,8		
Mur. acid	324,7	194	78	141,9	120,5		40

According to WENZEL.

100 parts of	Byryt.	Potaſs.	Soda.	Lime.	Magn.	Amm.	Alum.
Sulp. acid		120,8	79,16	67,2	55	70,2	128
Nitric acid		92,7	60	51,1	38,8	49,7	147,8
Mur. acid		183,8	119,2	96,5	81,7	103,9	259

According to KIRWAN.

100 parts of	Baryt.	Potaſs.	Soda.	Lime.	Magn.	Amm.	Alum.
Sulp. acid		122,2	77,2	70,4	57,3	53,3	
Nitric acid		112	73,8	55,5	39,2	44,8	
Mur. acid		168,6	133	112,7	89,9	78,5	

It appears that all the table of Bergman agrees with the propoſition except the numbers which correſpond to ſulphat of ſoda, ſulphat of alumina, nitrat of lime, and muriat of ſoda, which the late experiments of Mr Kirwan have ſufficiently ſhewn to be inaccurate.

Wenzel's table correſponds exactly, except the columns under ammonia and alumina, which Morveau has proved to be inaccurate.

Kirwan's table correſponds exactly, except with regard to the quantity of ammonia neceſſary to ſaturate muriatic acid, which does not appear to have been accurately determined by experiment.

Let us therefore take the truth of theſe two propoſitions for granted, and let us conſider every deviation from them as an error; and let us ſee whether they will enable us to diſcover the abſolute affinity of ſulphuric, nitric, and muriatic acids, for their reſpective baſes.

TABLE I. *Quantity of Baſe neceſſary to Saturate* 100 *Parts of the three Acids.*

100 parts	Baryt.	Potaſs.	Soda.	Lime.	Magn.	Amm.
Sulph. acid	233,3	123,3	78,7	68,3	56,8	49,3
Nitric acid	258,4	148,4	95,6	74,4	62,8	54,8
Muriat. acid	324,7	188,8	126,1	116,7	97,3	78,5

TABLE II. *Quantity of Acid neceſſary to Saturate* 100 *Parts of the ſix Baſes.*

100 parts	Sulph. acid.	Nitric acid.	Mur. acid.
Barytes	42,8	38,7	30,8
Potaſs	81	64	52,9
Soda	126,7	101,4	79
Lime	145,7	134,4	87,5
Magneſia	176,2	159,25	105,4
Ammonia	202,6	182,4	127,25

The firſt of theſe tables repreſents the affinity between the ſame acid and its various baſes; and the ſecond that of the baſes for the different acids. If it were required to know the ratios of the affinity which different baſes have for any particular acid, the firſt table, ſuppoſing it accurate, would give it exactly. In like manner, if it were required to know the ratios of the affinity of the acids for the various baſes, we would find them in the ſecond table.

576
And to conſtruct tables of affinity.

But if we wiſhed to know what was the affinity between one acid and baſe, compared with that between another acid and a different baſe; or if we wanted to have not the relative but the abſolute affinity between two bodies—it is plain that we could not find it in either of the tables; for the abſolute affinity muſt conſiſt of two things, the affinity which the acid has for the baſe, and the affinity which the baſe has for the acid. Now the firſt table gives us the one of theſe, and the ſecond the other; ſo that in order to repreſent affinity in abſolute numbers, the two tables muſt be multiplied into one another. This was the miſtake into which Mr Kirwan fell. His method conſiſted merely in conſtructing a table like our firſt, which (ſuppoſing the numbers accurate) gave only the affinity between the baſes and the ſame acid, but left out the affinity between the different acids and the ſame baſe; conſequently the different columns could not be compared with each other.

It is evident, however, that if the tables were multiplied together in their preſent ſtate, they could not poſſibly give an accurate table of affinities. For that purpoſe, it is neceſſary to put the ſame number in the firſt column of each table, and then to ſubſtitute other numbers in the remaining columns, having the ſame ratio to one another with the numbers in the original columns. This is done in the following Tables:

TABLE I. *Ratios of the Affinity of ſix Baſes for three Acids.*

	Barytes.	Potaſs.	Soda.	Lime.	Magn.	Amm.
Sulph. acid	100,00	52,85	33,73	29,27	24,34	21,12
Nitric acid	100,00	57,43	36,98	28,77	24,28	19,59
Mur. acid	100,00	58,11	38,81	35,70	29,94	24,15

TABLE

TABLE II. *Ratios of the Affinity of three Acids for ſix Baſes.*

	Sulph. acid.	Nitric acid.	Mur. acid.
Barytes	100,00	90,42	74,54
Potaſs	100,00	79,01	65,30
Soda	100,00	80,03	62,35
Lime	100,00	92,24	60,05
Magneſia	100,00	90,34	59,68
Ammonia	100,00	90,02	62,77

TABLE III. *Affinity between three Acids and ſix Baſes in Abſolute Numbers.*

	Sulph. acid.	Nitric acid.	Mur. acid.
Barytes	10000	9042	7454
Potaſs	5285	4537	3794
Soda	3373	2969	2419
Lime	2927	2653	2143
Magneſia	2434	2193	1786
Ammonia	2112	1763	1515

On the ſuppoſition that the two propoſitions mentioned above were ſtrictly true, and that the numbers which we fixed upon were preciſely the quantities of acid and baſe neceſſary to ſaturate each other reciprocally, this laſt table would repreſent accurately in numbers the ſtrength of the affinities of the three acids for each of the ſix baſes reſpectively.

We muſt acknowledge, however, that the truth of theſe propoſitions has not hitherto by any means been ſufficiently proved; but a great number of facts concur to render them exceedingly probable, and highly worthy of the attention of chemical philoſophers. And we hope that the method propoſed by Morveau, and which had been previouſly practiſed by Richter, of verifying theoretical calculations of the compoſition of the ſalts, by mixing together two ſalts which mutually decompoſe each other, and aſcertaining whether the reſult correſponds with calculation, will be followed out, and that it will be the means of enſuring more accuracy than it has hitherto been poſſible to obtain.

No one will ſuſpect that any thing which has here been ſaid is meant as a reflection on the ingenious chemiſts who have attempted to ſolve this moſt difficult of all chemical problems, the proportion of the ingredients which enter into the compoſition of the ſalts. Mr Kirwan, in particular, is entitled to the greateſt praiſe for the perſevering induſtry with which he has proſecuted the ſubject, for the candour which he has diſplayed, and for the new rout which he has opened to the chemical philoſopher. Though this problem has not hitherto been ſolved, and though the difficulties which ſurround it are almoſt inſurmountable, we may hope much from the general ſenſe which is at preſent entertained of its importance, and from the zeal and abilities of thoſe philoſophers who have particularly turned their attention to it.

In the mean time, the following Table of the ſtrength of affinities by Morveau, though the numbers be arbitrary, will be found of very great uſe *.

* Encyc. Method. Chim. i. 773.

577
Morveau's table of affinity.

	Sulph. acid	Nitric acid.	Muriat. acid	Acetous acid.	Carbonic acid.
Barytes	66	62	36	28	14
Potaſs	62	58	32	26	9
Soda	58	50	31	25	8
Lime	54	44	24	19	12
Ammonia	46	38	21	20	4
Magneſia	50	40	22	17	6
Alumina	40	36	18	15	2 (D)

5. Although every chemical combination is produced by the ſame general law, yet as their phenomena vary ſomewhat according to circumſtances, affinities have, for the ſake of greater perſpicuity, been divided into claſſes. Theſe claſſes may be reduced to *three*—*ſimple*, *compound*, and *diſpoſing* affinities.

578
Three claſſes of affinity.

The *firſt claſs* comprehends all thoſe caſes in which only *two bodies combine* together; as, for inſtance, ſulphuric acid and potaſs, oxygen and carbon. The affinities which belong to this claſs are known by the name of *ſimple* or *ſingle affinities*. Although one of the ſubſtances to be combined happens to be already united with another body, the combination is ſtill reckoned a caſe of ſingle affinity. Thus ſuppoſe the ſulphuric acid previouſly combined with magneſia, and forming with it the ſalt called *ſulphat of magneſia*, as ſoon as potaſs is preſented, the acid leaves the earth (which is precipitated), and unites with the alkali. Even when three bodies combine, it often happens that the union is produced merely by ſingle affinity. Thus, when ſome potaſs is dropped into tartarous acid, part of the acid unites with the alkali, and forms tartrite of potaſs; after this the remainder of the acid combines with the tartrite juſt formed, and compoſes a new ſalt known by the name of *acidulous tartrite of potaſs*, or *tartar*. This is evidently nothing elſe than two inſtances of ſimple affinity immediately following each other.

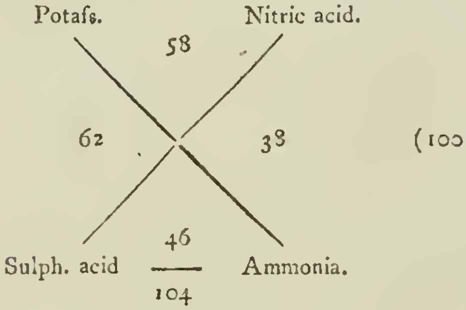
579
Viz. ſimple affinity,

When more than three bodies are mixed, decompoſitions and new combinations often take place, which could

580
Compound affinity,

(D) This table, however, does not correſpond quite accurately to all the phenomena. For inſtance, according to it, ſulphat of barytes is not decompoſed by carbonat of ſoda, although the contrary takes place in fact.

could not have been produced had the bodies been preſented in a different ſtate. If, for inſtance, into a ſolution of ſulphat of potaſs there be poured nitric acid, no decompoſition is produced, becauſe the ſulphuric acid has a ſtronger affinity for potaſs than nitric acid has. For the very ſame reaſon, ammonia may be poured into the ſolution without producing any change. But if nitrat of ammonia be poured in, a decompoſition inſtantly takes place, and two new bodies, *ſulphat of ammonia* and *nitrat of potaſs*, are formed. Such caſes of decompoſition form the *ſecond claſs of affinities*. They were called by Bergman caſes of *double elective attraction*; a name which is exceedingly proper when there are only four bodies concerned. But as there are often more than four, it is neceſſary, as Mr Morveau has obſerved, to employ ſome more comprehenſive term. We ſhall therefore call the affinities belonging to this claſs *compound affinities* (E); and comprehend under the term all caſes where more than three bodies are preſent, and produce combinations which would not have been formed without their united action. In theſe caſes the affinity of all the various bodies for each other acts, and the reſulting combination is produced by the action of thoſe affinities which are ſtrongeſt. The manner in which theſe combinations and decompoſitions take place, was firſt clearly explained by Dr Black. Let the affinity between potaſs and ſulphuric acid be = 62; that between nitric acid and ammonia = 38; that between the ſame acid and potaſs = 58; and that between the ſulphuric acid and ammonia = 46. Now, let us ſuppoſe that all theſe forces are placed ſo as to draw the ends of two cylinders croſſing one another, and fixed in the middle in this manner,

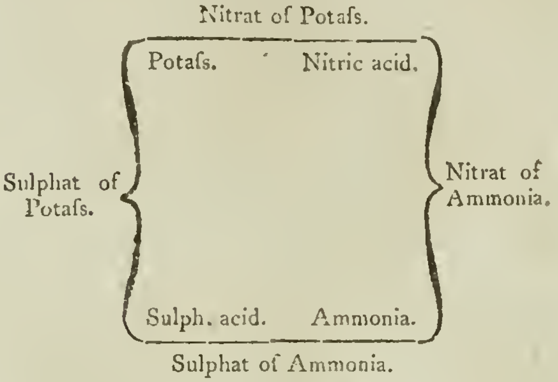


It is evident, that as 58 and 46 = 104, are greater than 62 + 38 = 100, they would overcome the other forces and ſhut the cylinders. Juſt ſo the affinity between potaſs and nitric acid, together with that between ſulphuric acid and ammonia, overcomes the affinity between potaſs and ſulphuric acid, and that between nitric acid and ammonia, and produces new combinations.

In all caſes of compound affinity, there are two kinds of affinities to be conſidered; 1*ſt*, Thoſe affinities which tend to preſerve the old compound, theſe Mr Kirwan has called *quieſcent* affinities; and thoſe which tend to deſtroy them, which he has called *divellent* affinities.

Thus, in the inſtance above given, the affinity between potaſs and ſulphuric acid, and that between nitric acid and ammonia, are quieſcent affinities, which endeavour to preſerve the old compound; and if they are ſtrongeſt, it is evident that no new compound can take place. On the contrary, the affinity between potaſs and nitric acid, and that between ſulphuric acid and ammonia, are divellent affinities; and as they are in this caſe ſtrongeſt, they actually deſtroy the former combinations and form new ones.

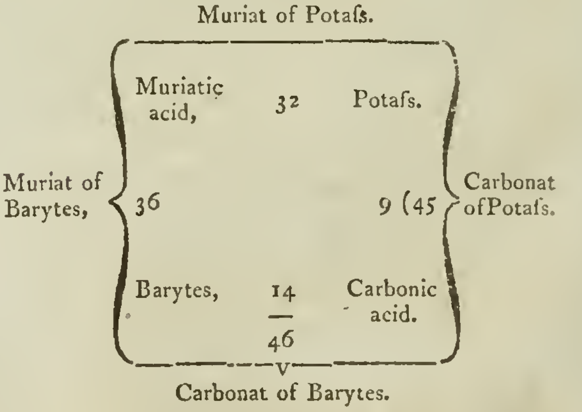
Bergman, who publiſhed a great many caſes of compound affinities, employed to explain them a method ſomewhat different from this. He would have repreſented the above caſe in the following manner:



At the four corners of an imaginary ſquare are placed the four ſubſtances, ſo that one acid ſhall be diagonally oppoſite to another. On the right and left ſide of the ſquare are placed the old compounds, each on the ſide of its own ingredients, and above and below are placed the new compounds.

Mr Elliot improved this method of Bergman, by adding numbers expreſſive of the affinity of the various ſubſtances. It is in caſes of compound affinity that the ratios of affinities, if we were poſſeſſed of them, would be peculiarly uſeful. For it is evident, that if we knew the ſtrength of affinities in abſolute numbers, we would be able to determine before hand all the caſes of compound affinity.

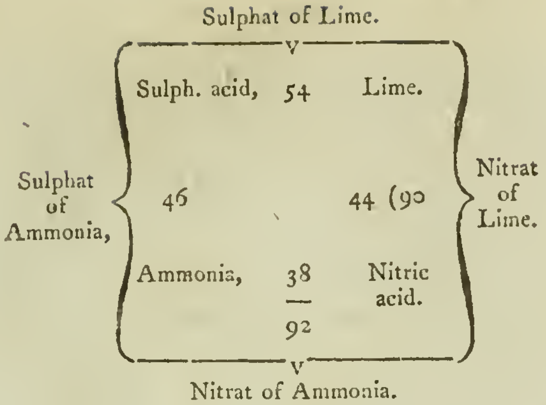
If we knew, for inſtance, that the affinity between the muriatic acid and barytes were = 36; that between the ſame acid and potaſs = 32; the affinity between potaſs and carbonic acid = 9; and that between the ſame acid and barytes = 14;—we would be certain, previous even to experiment, that when muriat of barytes and carbonat of potaſs are mixed, a double decompoſition would take place; which we know from experiment to be actually the caſe.



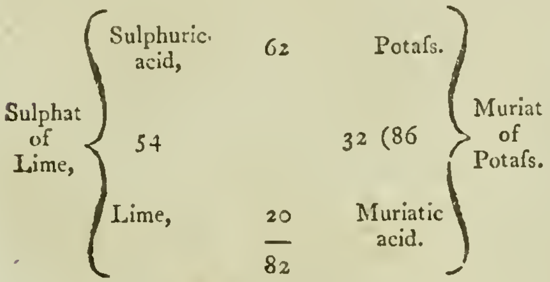
Another inſtance of decompoſition by compound affinities.

Sulphat

(E) Morveau called them *affinité par concours.*

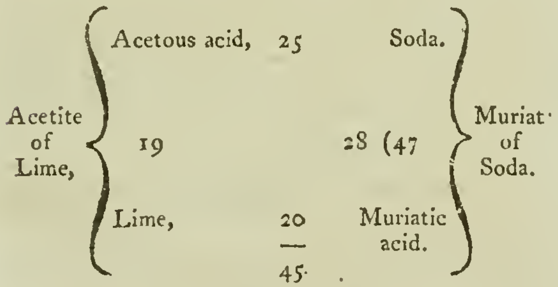


Suppoſing Morveau's numbers exact, it follows alſo, even prior to experiment, that no decompoſition takes place when ſulphat of lime and muriat of potaſs are mixed;



for the quieſcent affinities are 86, and the divellent only 82.

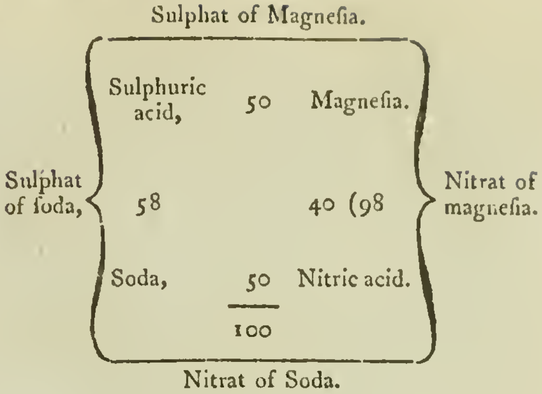
Nor when acetite of lime and muriat of ſoda are mixed;



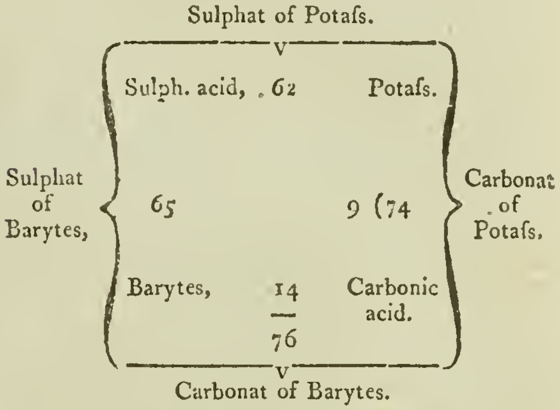
becauſe the quieſcent affinities are 47, and the divellent only 45. Theſe caſes where no decompoſition takes place have been called by Morveau caſes of *inverſe* compound affinity.

Morveau has propoſed the following improvements in repreſenting theſe caſes of compound affinities*.

When decompoſition does not take place, nothing is to be written above and below the ſquare, as in the two laſt examples. When a new compound remains diſſolved, a ſtraight line is to be placed between it and the ſquare, as in the following ſcheme.



When a new compound is precipitated, a line bent downwards in the middle is to be placed between it and the ſquare, as in the following ſcheme:



When a new compound is ſublimed, the line between it and the ſquare is to be pointed upwards in the middle, thus ⌐——^——¬.

When a new compound is partly diſſolved and partly precipitated, the line placed between it and the ſquare is to aſſume the following ſhape: ——⌐——¬.

When it is partly diſſolved and partly ſublimed, the following is the line to be uſed: ——⌄——¬.

581 And diſpoſing affinity.

The third claſs of affinities has been called by Mr Morveau *diſpoſing affinities*, becauſe they *diſpoſe* ſubſtances to combine that would not otherwiſe have done it. Suppoſe, for inſtance, that ſulphur is preſented to oxygen gas, it does not manifeſt any affinity for it; but combine it previouſly with potaſs, and it unites with oxygen with avidity. Its previous union with potaſs, in this caſe, *diſpoſed* it to unite with oxygen. The cauſe of this curious affinity is not yet well underſtood. If we conſider what it was that prevented the ſulphur and oxygen from combining, we ſhall find that it can only be its own attraction of coheſion, and the affinity between the oxygen and caloric which are combined. Whatever then diminiſhes this attraction of coheſion, or of *aggregation* as it has been called, muſt facilitate the union of

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* Encyc. Method. Chim. i. 555.

of the ſulphur with oxygen. This is done in ſome meaſure by the potaſs. Beſides, if affinity depends upon the figure of particles, it is evident that there muſt be an affinity between the new compound and oxygen: but the moment the oxygen approaches within a certain diſtance of the ſulphur, it unites with it, as its affinity is much greater for that ſubſtance than for the compound.

The following is another inſtance of this curious affinity: Sugar, as Lavoiſier has proved, is compoſed of oxygen, hydrogen, and carbon: Now if concentrated ſulphuric acid be poured upon ſugar, the oxygen and hydrogen combine, and form water, which unites with the acid, and the carbon is precipitated. In this caſe, the preſence of the acid *diſpoſed* the oxygen and hydrogen to combine. In what manner this new combination is produced, it would not be eaſy to explain: not by weakening the attraction of coheſion; for we do not ſee how the acid could produce that effect. The only explanation that can be given, is to ſuppoſe that the ſulphuric acid, when it approaches within a certain diſtance of the oxygen and hydrogen, attracts them; and that this attraction, together with the affinity between the oxygen and hydrogen, is greater than that which produces the combination between the ingredients of the ſugar themſelves: the conſequence of which muſt be decompoſition.

582
Why bodies require different temperatures to unite,

6. We come now to one of the moſt difficult queſtions in chemiſtry—Why do bodies require different temperatures in order to unite? and why does the preſence of caloric in many caſes favour or rather produce union, while it prevents or deſtroys it in others?

Theſe queſtions were propoſed at the end of the ſecond Chapter of this article; and we reſerved them for this place, not becauſe we hoped to be able to anſwer them in a ſatisfactory manner, but becauſe no intelligible anſwer could be given till the nature of affinity had been previouſly conſidered. Some ſubſtances, phoſphorus for inſtance, combine with oxygen at the common temperature of the atmoſphere; others, as carbon, require a higher temperature; and others, as hydrogen and azotic gas, do not combine except at a very high temperature. To what are theſe differences owing?

In anſwer to this queſtion, we obſerve, that the attraction of *coheſion* evidently oppoſes that of *affinity.* Thoſe bodies which we preſent to combine together are generally aggregates, or, which is the ſame thing, conſiſt of many ſimilar particles united by coheſion: for we have no method of ſeparating bodies into their integrant particles, except *affinity.* Now we can conceive the attraction of coheſion between the particles of a body to be ſo great as to prevent them altogether from obeying the impulſe of affinity. That this actually happens in ſome caſes cannot be doubted: for if pure alumina be formed into a paſte, and heated ſufficiently, it becomes ſo hard that no acid can act upon it; yet its nature is not in the leaſt changed: by proper trituration, it may be again rendered ſoluble; and when precipitated from this new ſolution, it has recovered all its original properties. The effect of the fire, then, was merely to increaſe the coheſion, by ſeparating all the water, and allowing the particles to approach nearer each other.

It is evident, that whatever diminiſhes the coheſion which exiſts between the particles of any body, muſt tend to facilitate their chemical union with the particles of other bodies. This is the reaſon that bodies combine more eaſily when held in ſolution by water, or when they have been previouſly reduced to a fine powder. Now caloric poſſeſſes the property of diminiſhing coheſion. And one reaſon why ſome bodies require a high temperature to cauſe them to combine is, that at a low temperature the attraction of *coheſion* is in them ſuperior to that of affinity; accordingly, it becomes neceſſary to weaken that attraction by caloric till it becomes inferior to that of affinity. The quantity of caloric neceſſary for this purpoſe muſt vary according to the ſtrength of the coheſion and of the affinity; it muſt be inverſely as the affinity, and directly as the coheſion. Wherefore, if we knew preciſely the force of the coheſion between the particles of any body, and of the affinity between the particles of that body and of any other, we could eaſily reduce the temperature neceſſary to calculation.

That caloric or temperature acts in this manner cannot be doubted, if we conſider that other methods of diminiſhing the attraction of coheſion may be ſubſtituted for it with ſucceſs. A large lump of charcoal, for inſtance, will not unite with oxygen at ſo low a temperature as the ſame charcoal will do when reduced to a very fine powder; and charcoal will combine with oxygen at a ſtill lower temperature, if it be reduced to its integrant particles, by precipitating it from alcohol, as Dr Prieſtley did by paſſing the alcohol through red hot copper. And to ſhew that there is nothing in the nature of oxygen and carbon which renders a high temperature neceſſary for their union, if they be preſented to each other in different circumſtances, they combine at the common temperature of the atmoſphere; for if nitric acid, at the temperature of 60°, be poured upon charcoal powder, well dried in a cloſe crucible, the charcoal takes fire, owing to its combining with the oxygen of the acid *: And in ſome other ſituations carbon is ſo completely divided, that it is capable of combining with the oxygen of the atmoſphere, or, which is the ſame thing, of catching fire at the common temperature. This ſeems to be the caſe with it in thoſe pyrophori that are formed by diſtilling to dryneſs ſeveral of the neutral ſalts which contain acetous acid †. Theſe obſervations are ſufficient to ſhew that caloric is in many caſes neceſſary in order to diminiſh the attraction of *coheſion.*

But there is a difficulty ſtill remaining, How comes it that certain bodies will combine with oxygen without the aſſiſtance of any foreign heat, provided the combination be once begun, though a quantity of caloric is neceſſary to begin the combination? and that other bodies require to be ſurrounded by a great quantity of caloric during the whole time of their combining with oxygen? Alcohol, for inſtance, if once kindled, burns till it is quite conſumed; and this is the caſe with oils alſo, provided they be furniſhed with a wick.

We muſt obſerve, in the firſt place, that we would err very much, were we to ſuppoſe that a high temperature is not as neceſſary to theſe ſubſtances during the whole of their combuſtion as at the commencement of it; for Mr Mongé found, on making the trial, that a candle would not burn after the temperature of the air around it was reduced below a certain point.

All ſubſtances which continue to burn after being once kindled are *volatile*, and they burn the eaſier in proportion

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* *Prouſt and Morveau, Encyc. Methad Chim.* i. 474.

† *Morveau, ibid.*

proportion to that volatility. The application of a certain quantity of caloric to alcohol volatilizes part of it; that is to ſay, diminiſhes the attraction of its coheſion ſo much that it combines with oxygen. The oxygen which enters into this combination gives out as much heat as volatilizes another portion of the alcohol; which combines with oxygen in its turn; more heat is given out; and thus the proceſs goes on. Oils and tallow exhibit the very ſame phenomena; only as they are leſs volatile, it is neceſſary to aſſiſt the proceſs by means of the capillary attraction of the wick, which confines the action of the caloric evolved to a ſmall quantity of oil, and thus enables it to produce the proper effect. In ſhort, then, every ſubſtance which is capable of continuing to burn, after being once kindled, is volatile, or capable of being converted into vapour by the degree of heat at firſt applied. The reaſon that a live coal will not burn when ſuſpended inſulated in the air, is not, as Dr Hutton ſuppoſed*, becauſe its *light* is diſſipated; but becauſe the coal cannot be converted into vapour by the degree of heat which it contains, and becauſe the coheſion of its particles is too great to allow it to combine with oxygen without ſome ſuch change. There are ſome coals, however, which contain ſuch a quantity of bitumen that they will burn even in the ſituation ſuppoſed by Dr Hutton, and continue to burn, provided they be furniſhed with any thing to act as a wick. It is needleſs to add, that bitumen, like oil, is eaſily converted into vapour.

* On *Light* and *Heat.*

But this explanation, inſtead of removing our difficulties, has only ſerved to increaſe them: For if caloric only acts by diminiſhing the attraction of coheſion, and converting theſe ſubſtances into vapour, why do not all elaſtic fluids combine at once without any additional caloric? why do not oxygen and hydrogen, when mixed together in the ſtate of gas, unite at once and form water? and why do not oxygen and azot, which are conſtantly in contact in the atmoſphere, unite alſo and form nitrous gas? Surely it cannot be the attraction of coheſion that prevents this union. And if it be aſcribed to their being already combined with caloric, how comes it that an additional doſe of one of the ingredients of a compound decompoſes it? Surely, as Mr Mongé has obſerved, this is contrary to all the other operations in chemiſtry.

That the particles of fluids are not deſtitute of an attraction for each other, is evident from numberleſs facts. The particles of water draw one another after them in caſes of capillary attraction; which is probably owing to the attraction of coheſion. It is owing to the attraction of coheſion, too, that ſmall quantities of water form themſelves into ſpheres: Nor is this attraction ſo weak as not to be perceptible. If a ſmall plate of glaſs be laid upon a globule of mercury, the globule, notwithſtanding the preſſure, continues to preſerve its round figure. If the plate be gradually charged with weights one after another, the mercury becomes thinner and thinner, and extends itſelf in the form of a plate; but as ſoon as the weights are removed, it recovers its globular figure again, and puſhes up the glaſs before it. Here we ſee the attraction of coheſion, not only ſuperior to gravitation, but actually overcoming an external force*. And if the workman, after charging his plate of glaſs with weights, when he is forming mirrors, happen to remove theſe weights, the mercury which had been forced from under the glaſs, and was going to ſeparate, is drawn back to its place, and the glaſs again puſhed up. Nor is the attraction of coheſion confined to ſolids and liquids; it cannot be doubted, that it exiſts alſo in gaſes; at leaſt it is evident, that there ſubſiſts an attraction between gaſes of a different kind: for although oxygen and azotic gas are of different gravities, and ought therefore to occupy different parts of the atmoſphere, we find them always mixed together; and this can only be aſcribed to an attraction. And were we to allow, with Humbolt and ſeveral other chemiſts, that theſe two gaſes are chemically combined in atmoſpherical air, an opinion contradicted by a late experiment in France (F); ſtill the exiſtence of carbonic acid gas in every part of the atmoſphere can only be aſcribed (if the inaccuracy of the expreſſion may be tolerated) to a kind of coheſion. And whoever has been accuſtomed to pneumatic experiments, muſt have obſerved that ſmall portions of *air*, as well as water, form themſelves into ſpheres, and that the attraction of coheſion is ſo ſtrong in gaſes, that large globules of them often adhere by a ſingle point to the bottom of veſſels filled with heavy fluids: whereas, had there been no attraction of coheſion, every part of the globule ought to have aſcended to the ſurface of the fluid, except the particles immediately in contact with the veſſel. Allowing, then, that there is an attraction of coheſion between the particles of gaſes, let us ſee whether that will not aſſiſt us in removing the difficulty.

* *Morveau, Affinité,* p. 543.

583 Explained.

It ſeems evident, in the firſt place, that the affinity between the baſes of the gaſes under conſideration and oxygen is greater than their affinity for that doſe of caloric which produces their elaſtic form; for when they are combined with oxygen, the ſame doſe will not ſeparate them again. Let us take hydrogen for an inſtance: The affinity of hydrogen is greater for oxygen than for the caloric which gives it its gaſeous form; but the oxygen is alſo combined with caloric, and there exiſts an attraction of coheſion between the particles of the hydrogen gas; the ſame attraction ſubſiſts between thoſe of oxygen gas. Now the ſum of all theſe affinities, namely, the affinity between hydrogen and caloric, the affinity between oxygen and caloric, the coheſion of the particles of the hydrogen, and the coheſion of the particles of oxygen—is greater than the affinity between the hydrogen and oxygen; and therefore no decompoſition can take place. Let the affinity between

Oxygen and caloric be	50
Hydrogen and caloric	50
Coheſion of oxygen	4
Coheſion of bydrogen	2
Sum of quieſcent affinities,	106
The affinity of oxygen and hydrogen,	105

The quieſcent affinities being greater than the divellent affinities, no decompoſition can take place.

(F) Air brought by means of a balloon from a great height in the atmoſphere was found to contain leſs oxygen gas than the ſame quantity of air near the ground.

Let now a quantity of caloric be added to the oxygen and hydrogen gas, it has the property of expanding them, and of courſe of diminiſhing their coheſion; while its affinity for them is ſo ſmall that it may be neglected. Let us ſuppoſe that it diminiſhes the coheſion of the oxygen 1, and of the hydrogen alſo 1, their coheſion will now be 3 and 1; and the quieſcent affinities being only 104, while the divellent are 105, the decompoſition would of courſe take place, and a quantity of caloric would thus be ſet at liberty to produce the ſame effects upon the neighbouring particles.

Thus, then, caloric acts only by diminiſhing coheſion: And the reaſon that it is required ſo much in gaſeous ſubſtances, and in thoſe combinations into which oxygen enters, is the ſtrong affinity of oxygen and the other baſes of the gaſes for caloric; for, owing to the repulſion which exiſts between the particles of that ſubtile ſubſtance, an effect is produced by adding large doſes of it, contrary to what happens in other caſes. The more of it is accumulated, the ſtronger is the repulſion between its particles; and therefore the more powerful is its tendency to fly off: and as this tendency is oppoſed by its affinity for the body and the coheſion of its particles, it muſt diminiſh both theſe attractions.

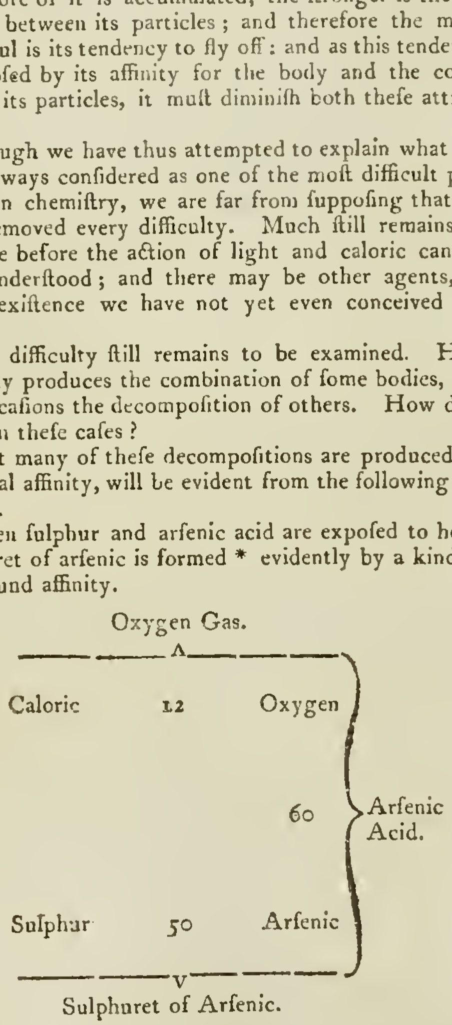
Though we have thus attempted to explain what has been always conſidered as one of the moſt difficult problems in chemiſtry, we are far from ſuppoſing that we have removed every difficulty. Much ſtill remains to be done before the action of light and caloric can be fully underſtood; and there may be other agents, of whoſe exiſtence we have not yet even conceived the idea.

One difficulty ſtill remains to be examined. Heat not only produces the combination of ſome bodies, but alſo occaſions the decompoſition of others. How does it act in theſe caſes?

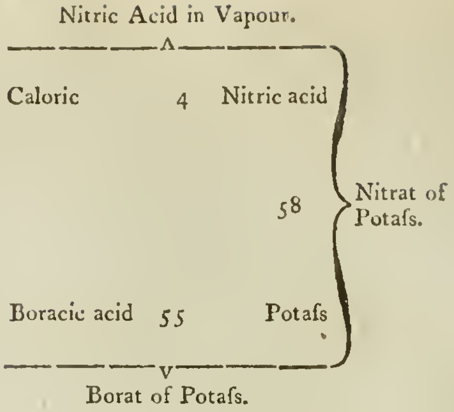
584 How heat decompoſes bodies.

That many of theſe decompoſitions are produced by chemical affinity, will be evident from the following examples.

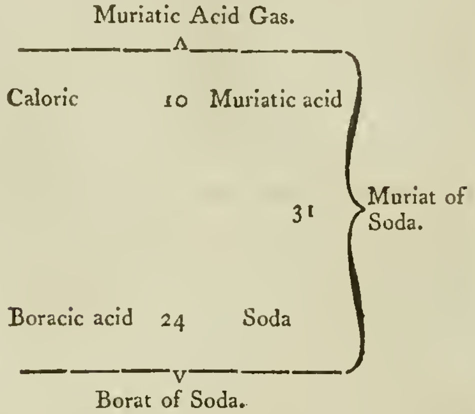
When ſulphur and arſenic acid are expoſed to heat, ſulphuret of arſenic is formed * evidently by a kind of compound affinity.



In the ſame manner, when nitrat of potaſs and boracic acid are expoſed to heat, the nitric acid is volatilized, and borat of potaſs is left behind.



By the ſame compound affinity boracic acid and heat decompoſes muriat of ſoda.



In the ſame manner, it would be eaſy to explain how all the decompoſitions by the *dry way*, as it is called, are produced.

But how comes caloric to decompoſe water after having produced the union of oxygen and hydrogen? The union, we have ſeen, was probably brought about by the play of oppoſite affinities; but in the ſeparation, caloric ſeems to act by its peculiar power, or the repulſion which exiſts between its particles. When caloric combines with an integrant particle of water, this repulſion muſt ſeparate the component parts ſomewhat from one another; conſequently it muſt weaken their affinity; for every increaſe of diſtance produces that effect. Now let us ſuppoſe that the affinity between oxygen and hydrogen is 105, and that the affinity between caloric and each of theſe bodies is 50: as ſoon as the particles of oxygen and hydrogen are ſo far ſeparated from each other that their affinity is leſs than 100, they will unite with caloric in preference, becauſe the ſum of their affinities for caloric is equal to 100; conſequently, whenever that takes place water will be decompoſed. Hence we ſee the reaſon why more heat is always neceſſary to produce the decompoſition of bodies than what produced their union.

Caloric poſſeſſes another ſingular property, that of changing the compound affinities of bodies, even when it

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* *Pelletier.*

it does not appear to enter as an ingredient. What we mean will appear evident from the following examples:

Muriat of ammonia, }
Carbonat of magneſia, } decompoſe each other at the ordinary temperature of the atmoſphere, and form muriat of magneſia and carbonat of ammonia: but, on the contrary,

Muriat of magneſia, and }
Carbonat of ammonia, } decompoſe each other at a high temperature; for inſtance, at 212°. The products are muriat of ammonia and carbonat of magneſia *.

Again, if muriat of ſoda and ſulphat of magneſia be mixed together at a low temperature, for inſtance at zero, they decompoſe each other, and muriat of magneſia and ſulphat of ſoda are formed; but no decompoſition takes place at a temperature above 32°.—Muriat of ſoda, and ſulphat of alumina, exhibit preciſely the ſame phenomena †.

Laſtly, ſulphat of magneſia and carbonat of ammonia decompoſe each other at the ordinary temperature; but at 212° the carbonic acid flies off, and the remaining ſubſtances form a triple ſalt ‡.

The laſt of theſe phenomena appears owing to the affinity between carbonic acid and caloric, and the two firſt to the affinity between muriat of ammonia and caloric, for that ſalt is volatilized.

It would not be ſo eaſy to explain the mutual decompoſition of muriat of ſoda and ſulphat of magneſia at a low temperature. It is probably connected with the alterations in the diſtance of the ingredients of chemical compounds, which are produced by the preſence and abſence of caloric.

585 f Count umford's pinion re- ecting af- nity.

From the important part which caloric acts in chemical combinations, Count Rumford has been lately induced to ſuſpect that this ſubtile fluid is the *only agent* by which they are produced.

That caloric is a *neceſſary* agent in all chemical decompoſitions and new combinations, we very readily allow; becauſe we know no other cauſe except caloric to prevent the particles of bodies from actual contact; in which caſe decompoſition would be impoſſible: and if this be the ſenſe in which that ingenious philoſopher aſcribes chemical combinations to caloric, we very readily agree with him; but if he ſuppoſes that caloric is the *agent* by which the particles of bodies are brought near each other, and the *force* by which they adhere to one another, we cannot help thinking that he is miſtaken: For that bodies, chemically combined, are kept near each other by ſome force, cannot poſſibly be denied. Now, what is that force? We have ſaid, after Newton, an *attraction between the particles themſelves*; acknowledging, at the ſame time, that we are unable to explain what that is.

Count Rumford ſeems to ſuppoſe that there is no ſuch thing as attraction between the particles themſelves, but that caloric is the agent which keeps them together. If ſo, how does caloric perform this office? For our part, we do not pretend to underſtand it any more than the nature of attraction; nor do we ſee that it is poſſible to render it more intelligible. But there is another queſtion of ſtill greater importance, What are the proofs that caloric is the only agent in all caſes of chemical combinations? For our part, we can think of no proof that can render this opinion in the ſmalleſt degree plauſible.

Has this celebrated and candid philoſopher conſidered this ſubject with his uſual accuracy? If heat be a body, it cannot ſurely be the cauſe of affinity, unleſs it be poſſeſſed of properties which, ſo far from being proved, have not even been ſuſpected. On the contrary, if it be a property of matter, what property is it? If it be a peculiar motion, as Count Rumford ſuſpects, we would aſk if it be poſſible for any motion whatever, independent of attraction, to produce the permanent union of two bodies?

Weſtrum, Ann. de Chim. ii. 18.

Scheele and Gren, Ann. de Chim. xxiii.

Fourcroy, Ann. de Chim. ii. 91.

PART III. OF DOUBLY COMPOUND BODIES.

THE bodies which conſiſt of combinations of thoſe ſubſtances that have been denominated *compound*, and which, for that reaſon, we have ventured to call *doubly compound bodies*, may be reduced to three claſſes:

Soaps,
Neutral ſalts,
Hydroſulphurets.

Theſe ſhall form the ſubject of the three following Chapters; and we ſhall finiſh this part of the article with ſome obſervations on *cryſtallization*.

CHAP. I. *Of* SOAPS.

THE compounds into which *oils* enter without decompoſition have been denominated *ſoaps*.

Oils are capable of combining with alkalies, earths, and metallic oxides; they are capable alſo of combining with ſeveral of the acids. There are therefore two claſſes of ſoaps; 1. Alkaline, earthy, and metallic ſoaps, which, for the ſake of brevity, we ſhall call *alkaline ſoaps*; and, 2. Acid ſoaps. Theſe two claſſes form the ſubject of the two following Sections.

SECT. I. *Of Alkaline Soaps.*

As there are a great number of oils, all or moſt of which are capable of combining with alkalies, earths, and oxides, it is natural to ſuppoſe that there are as many genera of alkaline ſoaps as there are oils. That there are differences in the nature of ſoaps correſponding to the oil which enters into their compoſition, is certain; but theſe differences are not of ſufficient importance to require very particular deſcription. We ſhall therefore deſcribe all the alkaline ſoaps together, and notice, as we go along, ſome of the moſt important differences reſulting from the oily ingredients.

586 Common hard ſoap.

1. Soap of ſoda, or common ſoap. The word *ſoap* (*ſapo*, σαπων) firſt occurs in the works of Pliny and Galen, and is evidently derived from the old German word *ſepe* (G). Pliny informs us, that ſoap was firſt diſcovered by the Gauls; that it was compoſed of tallow and

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(G) *Beckmann's Hiſtory of Inventions*, III. 239.—A ſimilar word is ſtill uſed by the common people of Scotland.

and aſhes; and that the German ſoap was reckoned the beſt *.

587 Method of forming it.

Soap may be prepared by the following proceſs. A quantity of the ſoda of commerce, which is a carbonat of ſoda, and which is often called *barilla* from the name of a plant, by burning which it is procured in great quantities in Spain, is pounded and mixed in a wooden veſſel, with about a fifth part of its weight of lime, ſlacked and paſſed through a ſieve immediately before. Upon this mixture a quantity of water is poured, conſiderably more than what is ſufficient to cover it, and allowed to remain on it for ſeveral hours. The lime attracts the carbonic acid from the ſoda, and the water becomes ſtrongly impregnated with the pure alkali. This water is then drawn off by means of a ſtop-cock, and called the *firſt ley*. Its ſpecific gravity ſhould be about 1,200.

Another quantity of water is then to be poured upon the ſoda, which, after ſtanding two or three hours, is alſo to be drawn off by means of the ſtop-cock, and called the *ſecond ley*.

Another portion of water is poured on; and after ſtanding a ſufficient time, is drawn off like the other two, and called the *third ley*.

Another portion of water may ſtill be poured on, in order to be certain that the whole of the ſoda is diſſolved; and this weak ley may be put aſide, and employed afterwards in forming the firſt ley in ſubſequent operations.

A quantity of oil, equal to ſix times the weight of the ſoda uſed, is then to be put into the boiler, together with a portion of the *third* or *weakeſt ley*, and the mixture muſt be kept boiling, and agitated conſtantly by means of a wooden inſtrument. The whole of the third ley is to be added at intervals to the mixture; and after it is conſumed, the *ſecond ley* muſt be added in the ſame manner. The oil becomes milky, combines with the alkali, and after ſome hours it begins to acquire conſiſtence. A little of the *firſt ley* is then to be added, not forgetting to agitate the mixture conſtantly. Portions of the firſt ley are to be added at intervals; the ſoapy ſubſtance acquires gradually greater conſiſtency, and at laſt it begins to ſeparate from the watery part of the mixture. A quantity of common ſalt is then to be added, which renders the ſeparation much more complete. The boiling is to be continued ſtill for two hours, and then the fire muſt be withdrawn, and the liquor muſt be no longer agitated. After ſome hours repoſe the ſoap ſeparates completely from the watery part, and ſwims upon the ſurface of the liquor. The watery part is then to be drawn off; and as it contains a quantity of carbonat of ſoda, it ought to be reſerved for future uſe.

The fire is then to be kindled again; and, in order to facilitate the melting of the ſoap, a little water, or rather weak ley, is to be added to it. As ſoon as it boils, the remainder of the firſt ley is to be added to it at intervals. When the ſoap has been brought to the proper conſiſtence, which is judged of by taking out ſmall portions of it and allowing it to cool, it is to be withdrawn from the fire, and the watery part ſeparated from it as before. It is then to be heated again, and a little water mixed with it, that it may form a proper paſte. It is then to be poured into the veſſels proper for cooling it; in the bottom of which there ought to be a little chalk in powder, to prevent the ſoap from attaching itſelf to it. In a few days the ſoap will have acquired ſufficient conſiſtence to be taken out, and formed into proper cakes (H).

The uſe of the common ſalt in the above proceſs is to ſeparate the water from the ſoap; for common ſalt has a ſtronger affinity for water than ſoap has.

Olive oil has been found to anſwer beſt for making ſoap, and next to it perhaps tallow may be placed: but a great variety of other oils may be employed for that purpoſe, as appears from the experiments of the French chemiſts above quoted. They found, however, that lintſeed oil and whale oil were not proper for making *hard ſoaps*, though they might be employed with advantage in the manufacture of *ſoft ſoaps*. Whale oil has been long uſed by the Dutch for this laſt purpoſe.

Soap may alſo be made without the aſſiſtance of heat; but in that caſe a much longer time and a larger proportion of alkali is neceſſary.

588 Its ſophiſtication.

Manufacturers have contrived various methods of ſophiſticating ſoap, or of adding ingredients which increaſe its weight without increaſing its value. The moſt common ſubſtance uſed for that purpoſe is water; which may be added in conſiderable quantities, eſpecially to ſoap made with tallow (the ingredient uſed in this country), without diminiſhing its conſiſtency. This fraud may be eaſily detected, by allowing the ſoap to lie for ſome time expoſed to the air. The water will evaporate from it, and its quantity will be diſcovered by the diminiſhing of the weight of the ſoap. As ſoap ſophiſticated in this manner would loſe its water by being kept, manufacturers, in order to prevent that, keep their ſoap in ſaturated ſolutions of common ſalt; which do not diſſolve the ſoap, and at the ſame time, by preventing all evaporation, preſerve, or rather increaſe, the weight of the ſoap. Meſſrs Darcet, Lelievre, and Pelletier, took two pieces equal in weight of ſoap ſophiſticated in this manner, and placed the one in a dry place in the open air, and the other in a ſaturated ſolution of common ſalt. After a month, the firſt had loſt $\frac{56}{100}$ of its weight, the other had gained about $\frac{10}{100}$ parts *. Various other methods have been fallen upon to ſophiſticate ſoap; but as they are not, we hope, generally known, it would be doing an injury to the public to deſcribe them here.

589 Proportion of its ingredients.

Different chemiſts have analyſed ſoap, in order to aſcertain the proportions of its ingredients; but the reſult of their experiments is various, becauſe they uſed ſoap containing various quantities of water. From the experiments of Darcet, Lelievre, and Pelletier, it appears that ſoap newly made and expoſed to ſale contains

9,75 Oil,
1,37 Alkali,
4,87 Water.

Soap is ſoluble both in water and in alcohol. Its properties as a detergent are too well known to require any deſcription.

It

* *Pliny*, lib. xviii. c. 51.

* *Ann. de Chim.* xix. 336.

(H) See the *Memoir of Darcet, Lelievre*, and *Pelletier*, in the *Ann. de Chim.* XIX. 253.

It is decompoſed by lime, and by compound affinity (1) by ſulphat of lime, nitrat of lime, muriat of lime, and probably all the ſalts which contain lime.

590 Soft ſoap. 2. Soap of potaſs.—Potaſs may be ſubſtituted for ſoda in making ſoap, and in that caſe preciſely the ſame proceſs is to be followed. It is remarkable, that when potaſs is uſed, the ſoap does not aſſume a ſolid form; its conſiſtence is never greater than that of hog's lard. This is what in this country is called *ſoft ſoap*. Its properties as a detergent do not differ materially from thoſe of *hard ſoap*, but it is not nearly ſo convenient for uſe. The alkali employed by the ancient Gauls and Germans in the formation of ſoap was potaſs: hence we ſee the reaſon that it is deſcribed by the Romans as an unguent.

Some perſons have affirmed that they knew a method of making hard ſoap with potaſs. Their method is this: After forming the ſoap in the manner above deſcribed, they add to it a large quantity of common ſalt, boil it for ſome time, and the ſoap becomes ſolid when cooled in the uſual way. That this method may be practiſed with ſucceſs has been aſcertained by Meſſrs Darcet, Lelievre, and Pelletier; but then the hard ſoap thus formed does not contain potaſs, but ſoda: for when the common ſalt (muriat of ſoda) is added, the potaſs of the ſoap decompoſes it, and combines with its muriatic acid, while at the ſame time the ſoda of the ſalt combines with the oil, and forms hard ſoap: and the muriat of potaſs formed by this double decompoſition is diſſolved in the water, and drawn off along with it*.

* *Ann. de Chim.* xix. 321.

Chaptal has lately propoſed to ſubſtitute wool in place of oil in the making of ſoap. The ley is formed in the uſual manner, and made boiling hot, and ſhreds of woollen cloth of any kind are gradually thrown into it; they are ſoon diſſolved. New portions are to be added ſparingly, and the mixture is to be conſtantly agitated. When no more cloth can be diſſolved, the ſoap is made†. This ſoap is ſaid to have been tried with ſucceſs. It might doubtleſs be ſubſtituted for ſoap with advantage in ſeveral manufactures, provided it can be obtained at a cheaper rate than the ſoaps at preſent employed.

† *Ibid.* xxi. 27.

Fiſh, too, have been lately ſubſtituted for oil with equal ſucceſs. The only diſadvantage which ſoap made in this manner is liable to, is a diſagreeable ſmell, from which it cannot eaſily be freed.

591 Soap of ammonia. 3. Soap of ammonia.—This ſoap was firſt particularly attended to by Mr Berthollet. It may be formed by pouring carbonat of ammonia on ſoap of lime. A double decompoſition takes place, and the ſoap of ammonia ſwims upon the ſurface of the liquor in the form of an oil; or it may be formed with ſtill greater eaſe by pouring a ſolution of muriat of ammonia into common ſoap diſſolved in water. We have formed it often by mixing cauſtic ammonia and oil‡.

‡ *Berthollet, Mem. Par.* 1780, or *Nicholſon's Journal*, i. 170

It has a more pungent taſte than common ſoap. Water diſſolves a very ſmall quantity of it; but it is eaſily diſſolved in alcohol. When expoſed to the air, it is gradually decompoſed.

592 Soap of lime. 4. Soap of lime.—This ſoap may be formed by pouring lime-water into a ſolution of common ſoap. It is inſoluble both in water and alcohol. Carbonat of fixed alkali decompoſes it by compound affinity*. It melts with difficulty, and requires a ſtrong heat.

* *Thouvenel.*

593 Soap of magneſia, 5. Soap of magneſia.—This ſoap may be formed by mixing together ſolutions of common ſoap and ſulphat of magneſia.

It is exceedingly white. It is unctuous, dries with difficulty, and preſerves its whiteneſs after deſiccation. It is inſoluble in boiling water. Alcohol and fixed oil diſſolve it in conſiderable quantity. Water renders its ſolution in alcohol milky. A moderate heat melts it; a tranſparent maſs is formed, ſlightly yellow, and very brittle†.

† *Berthollet, ibid.*

594 Of alumina, 6. Soap of alumina.—This ſoap may be formed by mixing together ſolutions of alum and of common ſoap. It is a flexible ſoft ſubſtance, which retains its ſuppleneſs and tenacity when dry. It is inſoluble in alcohol, water, and oil. Heat eaſily melts it, and reduces it to a beautiful tranſparent yellowiſh maſs‡.

‡ *Ibid.*

595 Of barytes, 7. Soap of barytes reſembles almoſt exactly the ſoap of lime§.

§ *Ibid.*

596 Of mercury, 8. Soap of mercury.—This ſoap may be formed by mixing together a ſolution of common ſoap and of corroſive muriat of mercury. The liquor becomes milky, and the ſoap of mercury is gradually precipitated. This ſoap is viſcid, not eaſily dried, loſes its white colour when expoſed to the air, and acquires a ſlate colour, which gradually becomes deeper, eſpecially if expoſed to the ſun or to heat. It diſſolves very well in oil, but ſparingly in alcohol. It readily becomes ſoft and fluid when heated‖.

‖ *Ibid.*

597 Of zinc, 9. Soap of zinc.—This ſoap may be formed by mixing together a ſolution of ſulphat of zinc and of ſoap. It is of a white colour, inclining to yellow. It dries ſpeedily, and becomes friable¶.

¶ *Ibid.*

598 Of cobalt, 10. Soap of cobalt.—This ſoap, made by mixing nitrat of cobalt and common ſoap, is of a dull leaden colour, and dries with difficulty, though its parts are not connected.

599 Of nickel, Mr Berthollet obſerved, that towards the end of the precipitation there fell down ſome green coagula, much more conſiſtent than ſoap of cobalt. Theſe he ſuppoſed to be a ſoap of nickel, which is generally mixed with cobalt*.

* *Ibid.*

600 Of tin, 11. Soap of tin.—It may be formed by mixing common ſoap with a ſolution of tin in nitro-muriatic acid. It is white. Heat does not fuſe it like other metallic ſoaps, but decompoſes it†.

† *Ibid.*

601 Of iron, 12. Soap of iron.—Formed by means of ſulphat of iron. It is of a reddiſh brown colour, tenacious, and eaſily fuſible. When ſpread upon wood, it ſinks in and dries. It is eaſily ſoluble in oil, eſpecially of turpentine. Berthollet propoſes it as a varniſh‡.

‡ *Ibid.*

602 Of copper, 13. Soap of copper.—Formed by means of ſulphat of copper. It is of a green colour, has the feel of a reſin, and becomes dry and brittle. Hot alcohol renders its colour deeper, but ſcarcely diſſolves it. Ether diſſolves it, liquefies it, and renders its colour deeper and more beautiful. It is very ſoluble in oils, and gives them a pleaſant green colour§.

§ *Ibid.*

603 Of lead, 14. Soap of lead.—It may be formed by means of acetite

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(1) In this and the following chapter, *compound affinity* is not taken always in its ſtrict and proper ſenſe, but is applied to all thoſe decompoſitions in which the affinities of more than three bodies *act*.

acetite of lead. It is white, tenacious, and very adheſive when heated. When fuſed, it is tranſparent, and becomes ſomewhat yellow if the heat be increaſed*.

604 Of ſilver, 15 Soap of ſilver.—It may be formed by means of nitrat of ſilver. It is at firſt white, but becomes reddiſh by expoſure to the air. When fuſed, its ſurface becomes covered with a very brilliant iris; beneath the ſurface it is black †.

605 Of gold, 16. Soap of gold.—It is at firſt white, and of the conſiſtence of cream. It gradually aſſumes a dirty purple colour, and adheres to the ſkin ſo that it is difficult to efface the impreſſion ‡.

606 And of mangaueſe. 17. Soap of mangaueſe.—It is at firſt white, but it aſſumes in the air a reddiſh colour, owing evidently to the abſorption of oxygen. It ſpeedily dries to a hard brittle ſubſtance, and by liquefaction aſſumes a brown blackiſh colour §.

We owe the following reſinous ſoaps to Mr Mezaize.

607 Soap of turpentine and potaſs. 18. Soap of turpentine and potaſs.—576 grains of turpentine were diſſolved in 9216 grains of alcohol, and then 576 grains of potaſs were added. The alcohol was diſtilled off at a boiling water heat. There remained in the retort 648 grains of a browniſh ſoapy matter, which when ſpread on glaſs appeared tranſparent. There remained alſo nearly the ſame quantity of potaſs diſſolved in water. This ſoap was put in a veſſel for ſix weeks; during which time 72 grains of ſolution of potaſs ſeparated from it. It had aſſumed the conſiſtence of honey. Its colour was browner. It was completely ſoluble in water: the ſolution was milky. It diſſolved alſo in alcohol. It had no diſagreeable taſte. Vinegar decompoſed it.

608 Soap of benzoin, 19. Soap of benzoin and potaſs.—By treating 9216 grains of alcohol, 1728 grains of benzoin, and 576 grains of potaſs, as above, 1728 grains of a ſoap were obtained, browner than that of turpentine, of an odour a little aromatic. When left in a cellar for ſix weeks, it became ſolid. Its ſolution in water was yellowiſh. Vinegar decompoſed it. This compound is the ſame with Starkey's ſoap.

609 Of balm of Peru, 20. Soap of balm of Peru and potaſs—1152 grains of balm, 2304 grains of potaſs, and 9216 grains of alcohol, produced a ſoap of a reddiſh colour, and pretty conſiſtent.

610 Of guaiac, 21. Soap of guaiac and potaſs.—1728 grains of guaiac was diſſolved in 18648 grains of alcohol, and the ſolution filtered, and to this 1728 grains of potaſs were added, and the ſoap obtained as above. It was ſolid, of a brown colour at firſt, which afterwards became green on the ſurface, but remained unaltered within. Its ſolution in water was greeniſh. It had no diſagreeable taſte. It diſſolved in alcohol, and formed a green tincture. Vinegar decompoſed it.

611 And of ſcammony. 22. Soap of ſcammony and potaſs.—By the above proceſs a ſoap was obtained with ſcammony pretty conſiſtent, of a brown colour, ſoluble in water, and not decompoſed by the water of pits from which ſelenites is obtained. It has no diſagreeable taſte. Its ſolution in alcohol is of a deep amber colour ‖.

Sect. II. *Of Acid Soaps.*

612 Method of forming acid ſoaps. Sulphuric acid may be combined with oils in the following manner: Put two ounces of it into a glaſs mortar, and add, by little and little, three ounces of the oil nearly boiling hot, triturating it conſtantly. A ſubſtance is obtained of the conſiſtence of turpentine. Diſſolve it in about ſix ounces of boiling water, and the ſoap will unite into a maſs as the water cools If it ſtill contain an exceſs of acid, diſſolve it again in boiling water, and continue this proceſs till the ſoap is perfectly neutralized.

613 Acid ſoap of lintſeed oil, 1. Soap of ſulphuric acid and lintſeed oil.—It diſſolves entirely in water. The ſolution is opaque, of a bluiſh white colour, viſcid, and frothes when agitated. Alcohol diſſolves it. The ſolution is tranſparent and brown. Potaſs decompoſes it, forming ſulphat of potaſs. The oil ſwims on the top, of the conſiſtence of wax. Ammonia decompoſes it; and if too much be added it forms ſoap of ammonia. Magneſia, lime, nitric acid, and muriatic acid, alſo decompoſe it. Diſtilled, it yielded a few drops of water and an oil, which coagulated, and was of the conſiſtence of wax.

614 Of almond oil. 2. Soap of ſulphuric acid and oil of almonds.—Soluble in water; ſolution milky. Frothes. Soluble in alcohol; ſolution brown and tranſparent. Potaſs, lime, nitric acid, muriatic acid, ſulphurous acid (the oil ſeparated aſſumed the conſiſtence of turpentine), tartar, acidulous oxalat of potaſs, ſal ammoniac, muriat of lead and zinc decompoſe it. It is not decompoſed by vinegar, boracic acid, acetite of ammonia, borax, copper, tin, nor lead. When diſtilled, there paſſed over a little water and an oil, which coagulated and ſmelt very rancid: there remained behind a coal.

615 Of olive oil, 3. Soap of ſulphuric acid and olive oil.—It is brown, and of the conſiſtence of wax. Solution in hot water white, opaque, viſcid; frothes. Solution in alcohol tranſparent and brown. Potaſs, ammonia, magneſia, nitric acid, muriatic acid, vinegar, nitre, ſal ammoniac, acetite of lead and white oxide of lead, decompoſe it.

616 Of butter of cocao, 4. Soap of ſulphuric acid and butter of cocao.—It is hard, and marbled like Venice ſoap. Solution in water grey, opaque, viſcid; frothes. Solution in alcohol yellow and tranſparent. Potaſs, ammonia, nitric, muriatic, and acetous acids, tartar, ſal ammoniac, tartrite of potaſs, acetite of lead, and zinc in powder, decompoſe it. When diſtilled, there came over water, an oil that coagulated, and a few drops of a black oil, which alſo congealed: both were rancid.

617 Of wax, 5. Soap of ſulphuric acid and wax.—It is white, and becomes very hard. Its ſolution in water is white, and opaque, and frothes: Its ſolution in alcohol is yellow and tranſparent. Potaſs, ammonia, nitric and muriatic acids, decompoſe it.

618 Of ſpermaceti, 6. Soap of ſulphuric acid and ſpermaceti.—It is brown. It diſſolves in water: the ſolution is milky, viſcid, and frothes on agitation. It diſſolves in alcohol; the ſolution is tranſparent and yellow. It is decompoſed by as much alkali as ſaturates the acid: if more be added, it unites with the oil, and forms a new ſoap. Lime and magneſia decompoſe it. The oil is alſo ſeparated, and appears in the form of a coagulum on adding to the ſolution nitric acid, muriatic acid, tartar, nitre, nitrat of ſoda, common ſalt, and zinc in powder; but not on adding vinegar, tin, lead.

619 Of oil of eggs, 7. Soap of ſulphuric acid and oil of eggs.—Its ſolution in water is white, opaque, viſcid; frothes: that in alcohol yellow and tranſparent. Alkalies decompoſe it; but if too much be added a new ſoap is formed. Nitric and muriatic acids ſeparate the oil of the conſiſtence of wax,

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* *Berthollet, ibid.*

† *Ibid.*

‡ *Ibid.*

§ *Ibid.*

‖ *Jour. de Phyſ.* xv. 441.

wax, the firſt yellow, the laſt a deep brown. Nitre, ſal ammoniac, acetite of lead, iron filings, zinc powder, decompoſe it; vinegar, borax, filings of lead do not.

To unite this acid with the eſſential oils, three ounces were put into a glaſs mortar, and four ounces of the oil were added drop by drop, and care taken to prevent its becoming hot: equal parts of water were then poured on, and the whole heated ſlowly nearly to the temperature of boiling water: on cooling, the ſoap united into a brown maſs.

620 Of turpentine, 8. Soap of ſulphuric acid and turpentine. It is brown, and of the conſiſtence of ſoft wax. Its ſolution in water is grey, opaque, viſcid; frothes: Its ſolution in alcohol is brown and tranſparent. Alkalies decompoſe it: with too much it forms at the boiling heat a new ſoap.

Nitric and muriatic acids ſeparated the oil thickened, as did alſo white oxide of lead, muriat of lead, muriat of ſoda and iron filings; but acetous acid, boracic acid, tartrite of potaſs, and tin filings, produced no ſuch effect.

621 And of amber oil. 9. Soap of ſulphuric acid and amber oil.—Its ſolution in water and alcohol as in the laſt ſoap. Alkalies, magneſia, and lime, decompoſed it. Nitric and muriatic acids ſeparated the oil of the conſiſtence of wax. Tartar, ſal ammoniac, muriat of antimony, acetite of lead, iron filings, decompoſed it; vinegar, acetite of ammonia, and lead did not.

Mr Achard, to whom we owe theſe ſoaps *, could not ſucceed in his attempts to form ſoaps with nitric and muriatic acids.

* *Journ. de Phyſ.* xvi. 109.

CHAP. II. *Of* NEUTRAL SALTS.

622 Salt explained. THE word *ſalt* has been uſed in chemiſtry in a very extenſive, and not very definite ſenſe. Every body which is ſapid, eaſily melted, ſoluble in water, and not combuſtible, has been called a *ſalt*.

Salts were conſidered by the older chemiſts as a claſs of bodies intermediate between earths and water. Many diſputes aroſe about what bodies ought to be comprehended under this claſs, and what ought to be excluded from it. Acids and alkalies were allowed by all to be ſalts; but the difficulty was to determine concerning earths and metals. Several of the earths poſſeſs all the properties which have been aſcribed to ſalts; and the metals are capable of entering into combinations which poſſeſs ſaline properties. It is needleſs for us to enter into this diſpute at preſent, as we have taken the liberty, in imitation of ſome of the beſt modern chemiſts, to expunge the claſs of ſalts altogether, and to arrange thoſe ſubordinate claſſes, which are uſually referred to it, under diſtinct heads.

623 Neutral ſalt explained. The word *neutral ſalt* was originally applied excluſively to combinations of acids and alkalies, which were conſidered as ſubſtances poſſeſſing neither the properties of acids nor alkalies, but properties intermediate between the two. But the word is now always taken in a more extenſive ſenſe, and ſignifies all compounds formed by the combination of acids with alkalies, earths, or metallic oxides. In theſe compounds, the earth, alkali, or oxide, is denominated the *baſe*. Each order of ſalts is denominated after the acid which enters into its compoſition; and every individual ſalt is diſtinguiſhed by ſubjoining the name of its baſe. Thus all the ſalts into which ſulphuric acid enters are called *ſulphats*, and the ſalt formed by the combination of ſulphuric acid and potaſs is called *ſulphat of potaſs*.

It is evident, then, that there muſt be as many orders of neutral ſalts as there are acids; and as many ſalts in each order as there are alkalies, earths, and metallic oxides, ſuppoſing every acid capable of combining with every one of theſe ſubſtances. But beſides theſe ſimple combinations of one acid and one baſe, there are others more complex, compoſed of two acids combined with one baſe, or two baſes combined with one acid, or a neutral ſalt combined with an acid or a baſe. Theſe combinations have been called *triple ſalts*; and they increaſe the number of neutral ſalts very conſiderably.

In the following ſections we ſhall take a ſhort view of the properties of the principal neutral ſalts at preſent known; for this wide and important region of chemiſtry is ſtill very far from being completely explored.

SECT. I. *Of Sulphats.*

SULPHURIC acid is capable of combining with all the alkalies, with alkaline earths, alumina, jargonia, and the greater number of the metallic oxides. The principal neutral ſalts which it forms are as follows:

624 Sulphat of potaſs. 1. Sulphat of potaſs.—This ſalt may be formed by ſaturating diluted potaſs with ſulphuric acid, and then evaporating the ſolution gently till cryſtals are formed. It ſeems to have been known at a very early period by chemiſts, and a great variety of names were given to it, according to the manner of forming it, or the fancy of the operator. Some of theſe names were, *ſpecificum purgans*, *nitrum fixum*, *arcanum duplicatum*, *panacea holſatica*, *ſal de duobus*, *ſal polychreſt glaſeri*, &c.; but it was commonly known by the name of *vitriolated tartar* till the French chemiſts called it *ſulphat of potaſs*, when they formed their new nomenclature in 1787 (K).

615 Its properties. When the ſolution of ſulphat of potaſs is ſufficiently diluted, it affords by evaporation hexahedral pyramids, or ſhort hexangular priſms, terminated by one or more hexangular pyramids. But theſe cryſtals vary much in their figure, according to the care with which they are prepared.

It has a very diſagreeable bitter taſte. Its ſpecific gravity is 2,298 *.

* *Briſſon.*

It is ſoluble in the temperature of 60° in 16 times its weight of water; in a boiling heat, it is ſoluble in 5 times its weight †.

† *Bergman.*

According to Bergman, it is compoſed of 40 parts of acid, 52 parts of alkali, and 8 of water; but according to Kirwan, whoſe experiment has been already deſcribed, it is compoſed of 45 parts of acid and 55 of alkali.

It ſuffers no alteration in the air.

When placed upon burning coals, it breaks into pieces with a noiſe reſembling a number of ſmall exploſions ſucceeding each other at ſhort intervals (L), but ſuffers no other alteration. In a red heat it melts.

It has hitherto been applied to little uſe. It is a

purgative,

(K) Bergman called it *alkali vegetabile vitriolatam*, and Morveau *vitriol of potaſs*.

(L) This is called *decrepitation*.

purgative, but its diſagreeable taſte prevents it from being much employed for that purpoſe.

It often has an exceſs of acid, owing, as Mr Bergman and Morveau have very ingeniouſly explained, to an affinity which exiſts between this ſalt and ſulphuric acid.

It is decompoſed by compound affinity by the following ſalts :

Nitrat of ſoda (M),
———— lime,
———— barytes*,
———— ſtrontites †,
———— ammonia,
———— magneſia,
———— mercury,

Nitrat of ſilver,
———— lead,
Acetite of barytes,
Muriat of lime ‡,
———— lead §,
———— magneſia?
———— ſoda ||.

It is ſometimes luminous in the dark, as Mr Giobert has obſerved ¶.

626 Sulphat of ſoda.

2. Sulphat of ſoda.—This ſalt was firſt diſcovered by Glauber a German chemiſt, and for that reaſon was long known by the name of *Glauber's ſalt*. He himſelf called it *ſal mirabile*. It may be prepared by ſaturating ſoda with ſulphuric acid, but is more uſually obtained by decompoſing common ſalt in order to procure muriatic acid.

Its cryſtals are tranſparent, and when formed by ſlow evaporation, are ſix-ſided priſms terminated by dihedral ſummits.

Its taſte at firſt has ſome reſemblance to that of common ſalt, but ſoon becomes very diſagreeably bitter.

It is ſoluble in 2,67 times its weight of water at the temperature of 60°, and in 0,8 of boiling water.

It is compoſed, according to Bergman, of 27 parts of acid, 15 of alkali, and 58 of water ; but, according to the experiments of Kirwan, of 22 parts of acid, 17 of alkali, and 61 of water.

When expoſed to the air, it loſes great part of its water, and falls into a white powder (N).

When expoſed to heat, it firſt undergoes the *watery fuſion* (O), then its water is evaporated, it is reduced to a white powder, and at laſt in a red heat it melts. Mr Kirwan has obſerved, that part of the acid, as well as the water, is driven off by the application of a ſtrong heat *.

This ſalt is uſed as a purgative.

It often combines with an exceſs of acid.

It is decompoſed by compound affinity, by the following ſubſtances :

Nitrat of lime,
———— magneſia,
Muriat of potaſs,
———— ſoda,
———— magneſia,
———— lime †,

Acetite of barytes,
———— potaſs,
———— lime,
Carbonat of barytes,
———— potaſs.

617 Sulphat of ammonia.

3. Sulphat of ammonia.—This ſalt was diſcovered by Glauber, and called by him *ſecret ſal ammoniac*. It was alſo called *vitriolated ammoniac*. It may be prepared by ſaturating ammonia with ſulphuric acid.

Its cryſtals are generally ſmall ſix-ſided priſms, whoſe planes are unequal, terminated by ſix-ſided pyramids.

It has a ſharp bitter taſte.

It is ſoluble in twice its own weight of water at the temperature of 60°, and in its own weight of boiling water.

According to Mr Kirwan, it is compoſed of 29,7 of alkali, 55,7 of ſulphuric acid, and 14,16 of water *.

When expoſed to the air, it ſlowly attracts moiſture.

When heated, it firſt decrepitates, then melts, and in cloſe veſſels ſublimes, but with ſome loſs of its alkali †.

It has not hitherto been applied to any uſe.

It is apt to contain an exceſs of acid.

It is decompoſed by compound affinity by the following ſalts :

Nitrat of lime,
———— magneſia,
———— mercury?
Muriat of potaſs,
———— ſoda,
———— barytes,
———— lime,
———— magneſia,
———— mercury*,
Acetite of potaſs,

Acetite of ſoda,
———— barytes,
———— lime,
———— magneſia,
Carbonat of potaſs,
———— ſoda,
———— barytes,
———— lime,
———— magneſia,
Phoſphat of lime †.

628 Sulphat of barytes.

4. Sulphat of barytes.—This ſubſtance was firſt diſcovered by Scheele. It abounds in nature. It is generally in the form of a hard, very heavy, ſtone.

It is ſometimes found cryſtallized ; but the variety of forms is ſo great that they baffle all deſcription.

It is ſoluble in 43,000 times its weight of water at the temperature of the atmoſphere ||.

Sulphuric acid diſſolves it when concentrated and boiling, but it is precipitated by the addition of water.

When expoſed to heat it melts, and, if the heat be very ſtrong, gradually diſſipates.

629 Bologna ſtone.

After being heated red hot, it has the property of being luminous in the dark. This was firſt obſerved in a variety of this ſubſtance known by the name of Bologna ſtone. Lemery informs us, that this property was firſt diſcovered by an Italian ſhoemaker named Vincenzo Caſciarolo. This man found a Bologna ſtone at the foot of Mount Paterno, and its brightneſs and gravity made him ſuppoſe that it contained ſilver. Having expoſed it to the fire, doubtleſs in order to extract from it the precious metal, he obſerved that it was luminous in the dark. Struck with the diſcovery, he repeated the experiment, and it conſtantly ſucceeded with him.

From an experiment of Mr Klaproth, it appears to be compoſed of 33 parts of acid and 77 of barytes.

It is decompoſed by compound affinity by the following ſalts :

Nitrat of ſoda,
———— lime,
———— ammonia,

Nitrat of magneſia,
Carbonat of potaſs,
———— ſoda *.

630 Sulphat of lime.

5. Sulphat of lime.—This ſubſtance was well known to the ancients under the name *gypſum* ; but the compoſition of gypſum was not known till Margraf and Macquer analyſed it, and proved that it was compoſed of ſulphuric acid and lime. The artificial compound

* *Kirwan.*
† *Id.*
‡ *Bergman.*
§ *Id.*
|| *Fucbs, Ann. de Cbim.* vi. 29.
¶ *Ann. de Cbim.* x. 40.
* *Iriſh Tranſ.* iv.
† *Scheele.*
* *Iriſh Tranſ. ibid.*
† *Kirwan's Mineral.* ii 1.
* *Bergman.*
† *Delkeſkamp Ann. de Cbim.* vi. 37.
|| *Kirwan's Min* i. 136.
|| *Afswelius.*

(M) Moſt of theſe double decompoſitions in this and the following ſections are inſerted on the authority of Morveau. See his Table of *Affinity*, page 360 of this article.

(N) This is called *efflореſcing*.

(O) When ſubſtances melt by means of the water they contain on the application of heat, they are ſaid to undergo the watery fuſion.

pound formed by the union of theſe two bodies was formerly called *ſelenite*.

It is found cryſtallized in various forms, ſometimes tranſparent and ſometimes opaque; and when pure it is of a white colour.

It has a ſlightly nauſeous taſte, ſcarcely perceptible except by drinking a glaſs of water impregnated with it *.

It is ſoluble in 500 parts of water at the temperature o. 60°, but much more ſoluble in boiling water.

It is compoſed, according to Bergman, of 46 parts of acid, 32 of earth, and 22 of water: according to the late experiments of Mr Kirwan, when ſo far dried as ſtill to retain its glaſſy appearance, it contains 48 of acid, 34 of earth, and 18 of water; which differs very little from the determination of Bergman.

It is not affected by expoſure to the air.

It is ſoluble in ſulphuric acid.

When expoſed to heat, it undergoes a kind of watery fuſion, but afterwards it cannot be melted by the ſtrongeſt heat. In a clay crucible indeed it fuſes at 130° Wedgewood, owing evidently to the preſence of the clay.

631
Plaſter of Paris.

When heated red hot and cooled, it is called *plaſter of Paris*; a ſubſtance ſo uſeful for caſting moulds, &c. on account of its property of becoming ſolid almoſt immediately when reduced into a paſte with water.

By compound affinity it is decompoſed by the following ſubſtances:

Acetite of barytes,
——— potaſs,
Carbonat of barytes,

Carbonat of potaſs,
——— ſoda,
——— magneſia?
——— alumina †.

632
Sulphat of ſtrontites.

6. Sulphat of ſtrontites. This ſalt, firſt formed by Dr Hope, is a white powder deſtitute of taſte. It is ſoluble in 3840 parts of boiling water. Sulphuric acid diſſolves it readily when aſſiſted by heat, but it is precipitated by the addition of water to the ſolution ‡.

633
Sulphat of magneſia.

7. Sulphat of magneſia. This ſalt was firſt obſerved in the ſprings at Epſom in England by Grew in 1675; but Dr Black was the firſt who accurately aſcertained its compoſition. It has been called *Epſom ſalt*, *ſal catharticus amarus*, and *Seydler ſalt*.

It cryſtallizes in quadrangular priſms, whoſe plains are equal, ſurmounted by quadrangular pyramids.

It has an exceſſively bitter taſte.

At the temperature of 60° it is ſoluble in its own weight of water, and in $\frac{3}{4}$ths of its weight of boiling water. The volume of water is increaſed $\frac{1}{4}$th by adding the ſalt §.

It is inſoluble in alcohol.

It is compoſed, according to Bergman, of 19 parts of earth, 33 of acid, and 48 of water; according to Mr Kirwan, of 17 parts of earth, 29,46 of acid, and 53,54 of water.

When expoſed to the air it effloreſces, and is reduced to powder.

When expoſed to heat it undergoes the watery fuſion, and by increaſing the temperature its water is evaporated, but it cannot be decompoſed by means of heat.

It is ſometimes employed as a cathartic, but its chief uſe is to furniſh magneſia by its decompoſition.

It is decompoſed by compound affinity by the following ſalts.

Muriat of potaſs,
——— ſoda (P),
——— lime,
Acetite of barytes,
——— potaſs,

Acetite of lime,
Carbonat of barytes,
——— potaſs,
——— ſoda *,
——— ammonia (Q).

634
Sulphat of ammonia and magneſia.

8. Sulphat of ammonia and magneſia. This triple ſalt was diſcovered by Mr Fourcroy. Into the ſolution of 100 parts of ſulphat of magneſia in 500 parts of water, 12 parts of ammonia being poured, a very ſmall quantity of magneſia was precipitated, and a conſiderable quantity more on the addition of another doſe of ammonia; but farther additions had no effect. From the magneſia precipitated, it appeared that 38 parts of the ſulphat had been decompoſed. There remained, therefore, 62 parts in ſolution, mixed with a large quantity of ammonia. By evaporation, 92 parts of a white tranſparent rhomboidal ſalt were obtained, evidently compoſed of ſulphuric acid, ammonia, and magneſia, in the proportions that would have formed 62 parts of ſulphat of magneſia and 30 of ſulphat of ammonia, and probably conſiſting of a combination of theſe two ſulphats †.

635
Sulphat of alumina.

9. Sulphat of alumina. This ſalt may be formed by diſſolving alumina in ſulphuric acid. It has an aſtringent taſte, is very ſoluble in water, and cryſtallizes in thin plates which have very little conſiſtence ‡. Little attention has hitherto been paid to this ſalt, which was never properly diſtinguiſhed from *alum* till two memoirs, one by Vauquelin and another by Chaptal, on the nature of alum, made their appearance in the 22d volume of the *Annales de Chimie*. This ſalt generally contains an exceſs of acid, and is not neutralized without conſiderable difficulty §.

636
Alum.

10. Sulphat of alumina and potaſs, or alum. The στυπτηρια of the Greeks, and the *alumen* of the Romans, was a native ſubſtance, which appears to have been nearly related to *green vitriol* or *ſulphat of iron*; and which conſequently was very different from what we at preſent denominate *alum*. From the reſearches of Profeſſor Beckmann, it appears that we owe the diſcovery of alum to the Aſiatics; but at what period, or by what means, the diſcovery was made, is altogether unknown.

It continued to be imported from the Eaſt till the 15th century, when a number of alum works were eſtabliſhed in Italy. In the 16th century it was manufactured in Germany and Spain; and during Queen Elizabeth's reign an alum work was eſtabliſhed in England by Thomas Chalomer.

The alum of commerce is uſually obtained from earths containing ſulphur and clay, or ſulphuric acid and clay.

637
Its compoſition,

The compoſition of alum has been but lately under-

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* *Macquer.*

† *Bergman.*

‡ *Dr Hope, Tranſ. Edin.* iv. 10.

§ *Bergman.*

* *Bergman.*

† *Ann. de Chim.* iv. 211.

‡ *Vauquelin, Ann. de Chim.* xxii. 277. and *Chaptal, ibid.* 294.

§ *Ibid.* p. 277.

(P) Only below the temperature of 32°. *Scheele, Gren, Ann. de Chim.* xxiii.

(Q) Only below the temperature of 212°. *Fourcroy, Ibid.* ii. 291.

ſtood with accuracy. It has been long known, indeed, that one of its ingredients is ſulphuric acid (R); and the experiments of Geoffroy, Hellot, Pot, Margraf, and Macquer, proved inconteſtibly that alumina is another ingredient. But ſulphuric acid and alumina are incapable of forming alum: Manufacturers knew, that the addition of a quantity of potaſs, or of ammonia, or of ſome ſubſtance containing theſe alkalies, is almoſt always neceſſary; and it was proved, that in every caſe in which ſuch additions are unneceſſary, the earth from which the alum is obtained contained already a quantity of potaſs. Various conjectures were made about the part which potaſs acts in this caſe; but Chaptal and Vauquelin appear to have been the firſt chemiſts that aſcertained, by deciſive experiments, that alum was a triple ſalt, compoſed of ſulphat of alumina and of potaſs united together (S)

638 And properties.

Alum cryſtallizes in large octahedrons, compoſed of two tetrahedral pyramids, applied to each other at their baſes.

It has a ſweetiſh and aſtringent taſte, and always reddens the tincture of turnſole.

It is ſoluble at the temperature of 60°, in from 10[*] to 15[†] times its own weight of water, according to its purity; pure alum being moſt inſoluble. Seventy-five parts of boiling-water diſſolve 100 of alum[‡].

[*] Neumann and Chaptal.
[†] Kirwan and Chaptal.
[‡] Bergman.

A hundred parts of alum contain, according to Kirwan, 17,62 parts of acid, 18 of earth (and alkali), and 64,38 of water[§].

[§] Kirwan's Min. ii. 14.

When expoſed to the air it effloreſces ſlightly.

When expoſed to a gentle heat it undergoes the watery fuſion. A ſtrong heat cauſes it to ſwell and foam, and to loſe about 44 *per cent.* of its weight, conſiſting chiefly of water of cryſtallization[||]. What remains is called *calcined* or *burnt alum*, and is ſometimes uſed as a corroſive.

[||] Ibid.

Alum is of great importance as a mordant in dyeing, and is uſed alſo in ſeveral other arts.

By compound affinity it is decompoſed by the following ſalts.

Nitrat of ſoda,
——— lime,
——— ammonia,
——— magneſia,
Muriat of barytes,
——— potaſs,
——— ſoda,
——— lime,
——— ammonia,
——— magneſia,
Acetite of barytes,

Acetite of potaſs,
——— ſoda,
——— lime,
——— ammonia,
——— magneſia,
Carbonat of barytes,
——— potaſs,
——— ſoda,
——— lime,
——— ammonia,
——— magneſia.

639 Homberg's pyrophorus.

If three parts of alum and one of flour or ſugar be melted together in an iron ladle, and the mixture dried till it becomes blackiſh and ceaſes to ſwell; if it be then pounded ſmall, put into a glaſs phial, and placed in a ſand-bath till a blue flame iſſues from the mouth of the phial, and after burning for a minute or two be allowed to cool (T), a ſubſtance is obtained known by the name of *Homberg's pyrophorus*, which has the property of catching fire whenever it is expoſed to the open air, eſpecially if the air be moiſt.

This ſubſtance was accidentally diſcovered by Homberg about the beginning of the 18th century, while he was engaged in his experiments on the human fæces. He had diſtilled a mixture of human fæces and alum till he could obtain nothing more from it by means of heat; and four or five days after, while he was taking the reſiduum out of the retort, he was ſurpriſed to ſee it take fire ſpontaneouſly. Soon after Lemery the Younger diſcovered that honey, ſugar, flour, or almoſt any animal or vegetable matter, could be ſubſtituted for human fæces; and afterwards Mr Lejoy de Suvigny ſhewed that ſeveral other ſalts containing ſulphuric acid might be ſubſtituted for alum[*]. Scheele proved, that alum deprived of potaſs was incapable of forming pyrophorus, and that ſulphat of potaſs might be ſubſtituted for alum[†]. And Mr Prouſt has ſhewn, that a number of neutral ſalts, compoſed of vegetable acids and alkalies, or earths, when diſtilled by a ſtrong fire in a retort, left a reſiduum which took fire ſpontaneouſly on expoſure to the air.

[*] See Macquer's Dict.
[†] Scheele on Fire, and on Pyrophorus.

Theſe facts have thrown a great deal of light on the nature of Homberg's pyrophorus, and enabled us in ſome meaſure to account for its ſpontaneous inflammation. It has been aſcertained, that part of the ſulphuric acid is decompoſed during the formation of the pyrophorus, and of courſe a part of the alkaline baſe becomes uncombined with acid, and the carbon, which gives it its black colour, is evidently divided into very minute particles. It has been aſcertained, that during the combuſtion of the pyrophorus a quantity of oxygen is abſorbed, The inflammation ſeems to be owing to a *diſpoſing affinity*. Part of the carbon and of the ſulphur attract oxygen from the atmoſphere, in order to combine with the potaſs, and the caloric diſengaged produces a temperature ſufficiently high to kindle the reſt of the carbon.

Alum is capable of combining with alumina, and of forming what has been called *alum ſaturated with its earth*, which is an inſoluble, taſteleſs, earthy-like ſubſtance.

It is capable alſo, as Chaptal informs us, of combining with ſeveral other baſes, and of forming many triple ſalts, which have never yet been examined with attention[‡].

[‡] Ann. de Chim. xxii. 293.

11. Sulphat

(R) Some chemiſts have thought proper to call the ſulphuric acid, obtained by diſtilling alum, *ſpirit of alum*.

(S) This they did in the two memoirs above quoted, and which were firſt publiſhed in the 22d volume of the *Annales de Chimie*. An account of Vauquelin's memoir has been already given under the article ALUM in this *Supplement*. Chaptal's memoir is no leſs intereſting. This celebrated chemiſt appears, from the facts ſtated in the 23d volume of the *Annales*, p. 222. to have made his diſcovery before Vauquelin: who, however, was ignorant of what Chaptal had done, as he informs us in the *Ann. de Chim.* xxv. 107. that his paper was read to the Inſtitute a fortnight before that of Chaptal's came to Paris. He informs us, too, that Deſcroiſilles had long before made the ſame diſcovery, and that he had publiſhed it in Berthollet's *Art de la Teinture*.

(T) Care muſt be taken not to keep it too long expoſed to the heat.

640 Sulphat of jargonia.

11. Sulphat of jargonia (u). In order to combine jargonia with acids, they ſhould be poured upon it while it is yet moiſt, after being precipitated from ſome of its ſolvents; for after it is dry, acids do not act upon it without difficulty. By this method ſulphat of jargonia is eaſily formed. It is white, and without ſenſible taſte. Heat expels the acid from it, and the jargonia remains in a ſtate of purity. At a high temperature charcoal converts it into a ſulphuret, which is ſoluble in water, and which, by evaporation, furniſhes cryſtals of hydroſulphuret (t) of jargonia *.

Klaproth informs us, that with exceſs of acid ſulphat of jargonia forms tranſparent ſtelliform cryſtals, ſoluble in water, and having an aſtringent taſte †.

12. Sulphat of iron. There are two ſulphats of iron, which were firſt accurately diſtinguiſhed by Mr Prouſt. The one contains the green oxide, the other the red oxide of iron. We ſhall, in imitation of Mr Prouſt, denominate them from their colours.

641 Green ſulphat of iron.

The *green ſulphat of iron.*—This ſalt, which is compoſed of ſulphuric acid and green oxide of iron, is found native, and was known to the ancients. It is mentioned by Pliny under the names of *miſy*, *ſory*, *calchantum* ‡. It was formerly called *green vitriol.*

It is generally prepared by expoſing native ſulphuret of iron, a very abundant mineral, to air and moiſture.

Its cryſtals are of a light green colour, and in the form of rhomboidal parallelopipeds.

It has a ſharp aſtringent taſte.

It is ſoluble in ſix times its weight of water at the temperature of 60°, and in $\frac{3}{4}$ths of its weight of boiling water §.

It is inſoluble in alcohol.

According to Bergman, it is compoſed of 39 parts of acid, 23 of oxide, and 38 of water; but according to Mr Kirwan, of 26 parts of acid, 28 (v) of oxide, and 46 of water.

When expoſed to the air, it effloreſces; but if it be moiſtened, it is gradually converted into red ſulphat of iron.

When heated, it firſt aſſumes a yellow colour, loſes its water and its acid; if the heat be increaſed, nothing remains but a yellow powder.

The Pruſſic alkali precipitates from the ſolution of this ſalt a white powder, which gradually becomes blue by attracting oxygen *.

It is uſed in dyeing, and in making ink, &c.

It is decompoſed by compound affinity by

Nitrat of ſilver,
Muriat of ſoda †.

642 Red ſulphat of iron.

The *red ſulphat of iron* may be formed by expoſing a ſolution of green ſulphat to the air, or by treating it with nitric acid. It was formerly called *mother water of vitriol.*

Little is known of its properties, except that it is deliqueſcent, incryſtallizable, and ſoluble in alcohol.

It was firſt accurately examined by Mr Prouſt.

The green ſulphat of iron generally contains ſome of it, which may be ſeparated by means of alcohol.

It is alone capable of forming Pruſſian blue with the Pruſſic acid, and of ſtriking a black colour with the gallic acid ‡.

We have obſerved, that when it is diluted with water, and an exceſs of ſulphuric acid is poured in, it is again ſlowly converted into green ſulphat.

643 Sulphat of zinc.

13. Sulphat of zinc.—This ſalt, according to the beſt accounts, was diſcovered at Rammelſberg in Germany, about the middle of the 16th century. Many aſcribe

* *Vauquelin, Ann. de Chim.* xxii. 199.

† *Jour. de Phyſ.* xxxvi. 187.

‡ *Lib.* xxxiv. c. 12.

§ *Bergman.*

* *Prouſt.*

† *Ballen and Tutben, Ann. de Chim.* xi. 320.

‡ See *Prouſt's paper, Nicholſon's Journal*, i. 435.

(u) *Jargonia*, or, as the French chemiſts call it, *zirconia*, has been diſcovered in great abundance in France by Morveau, who found that the hyacinths of Expailly contained more than half their weight of it. From Vauquelin's analyſis they appear to be compoſed of

32	parts of ſilica,
64	jargonia,
2	oxide of iron.

Jargonia has been examined with great care by theſe two philoſophers, the experiments of Klaproth have been confirmed, and ſeveral new properties of it have been diſcovered. Perhaps a more detailed account than we have hitherto given of this new earth may not be unacceptable to our readers.

Jargonia is a white powder, its ſpecific gravity is conſiderable, it has a feel reſembling that of ſilica, it has no taſte, and is inſoluble in water. When ſeparated from its ſolutions by pure alkalies, it retains, when expoſed to the air to dry, a pretty conſiderable quantity of water, which renders it tranſparent, and gives it a reſemblance to gum arabic both in its colour and fracture.

When expoſed to the heat of the blow-pipe it does not melt; but Vauquelin melted it by expoſing it ſurrounded with charcoal in a porcelain crucible to an intenſe heat for an hour and a half. Its ſpecific gravity was then 4,35, its colour was grey, and its hardneſs ſuch that it was capable of ſcratching glaſs. It melts with borax, and forms a tranſparent and colourleſs glaſs; but phoſphat of ſoda and the fixed alkalies do not attack it.

It is inſoluble in the fixed alkalies, has very little affinity for carbonic acid, and is precipitated from its ſolutions together with iron by the Pruſſic alkali.

Its affinities, as far as they have been aſcertained by Vauquelin, are as follows:

Vegetable acids, order unknown,
Sulphuric acid,
Muriatic,
Nitric.

See upon this ſubject the Memoirs of Morveau and Vauquelin, *Ann. de Chim.* xxi. 72. and xxii. 179.

(t) Theſe curious ſalts form the ſubject of the next chapter.

(v) Perhaps the quantity of oxide is ſomewhat over-rated here; for before it was examined by Mr Kirwan, it had aſſumed a red colour: it muſt therefore have been converted into the brown or red oxide by attracting oxygen from the atmoſphere.

aſcribe the invention to Julius Duke of Brunſwick. Henkel and Neumann were the firſt chemiſts who proved that it contained zinc; and Brandt firſt aſcertained its compoſition completely *. It is generally formed for commercial purpoſes from ſulphuret of zinc or *blende*, as it is called. This ſalt is called alſo *white vitriol*.

* *Beckmann's Hiſt. of Inventions*, art. *Zinc.*

It is of a white colour, and its cryſtals are rhomboidal priſms, terminated by quadrangular pyramids: there is generally a ſlight defect in two of the oppoſite angles of the priſm, which produces a quadrangular ſection †. Its ſpecific gravity is 2,000.

† *Bergman*, ii. 327.

It has a ſharp ſtyptic taſte.

It is ſoluble in 2,28 parts of water at the temperature of 60°; but in a much ſmaller quantity of boiling water ‡.

‡ *Ibid.*

It is compoſed, according to Bergman, of 40 (v) parts of acid, 20 of oxide, and 40 of water: Kirwan ſuppoſes that it is compoſed of 12 parts of acid, 26,4 of zinc, 20 of oxide, 41,6 of water (w).

According to Bergman, this ſalt is not altered in the air; others affirm that it effloreſces. This, no doubt, depends upon the place where it is kept.

Heat decompoſes this ſalt.

644
Sulphat of manganeſe.

14. Sulphat of manganeſe.—This ſalt was firſt obtained by Scheele (x): It is compoſed of ſulphuric acid and white oxide of manganeſe.

Its cryſtals are oblique parallelopipeds; they are of a white colour, and very bitter §.

§ *Scheele*,

Theſe cryſtals are decompoſed by a ſtrong red heat, and the ſulphuric is converted into ſulphurous acid by the oxide attracting its oxygen, and being changed into black oxide ‖.

‖ *Id.*

645
Sulphat of nickel.

15. Sulphat of nickel.—This ſalt, which is compoſed of ſulphuric acid and oxide of nickel, was firſt deſcribed by Bergman. Its cryſtals are in the form of decahedrons, compoſed of two quadrangular truncated pyramids; they are of a green colour ¶.

¶ *Bergman*, ii. 268.

646
Sulphat of cobalt.

16. Sulphat of cobalt.—This ſalt was firſt mentioned by Mr Brandt. Its cryſtals are of a reddiſh colour; but if any nickel be preſent, they are green.

647
Sulphat of lead.

17. Sulphat of lead.—This ſalt has been long known: it is compoſed of ſulphuric acid and white oxide of lead. The cryſtals are white, ſmall, and moſt commonly needle-ſhaped: according to Sage, they are tetrahedral priſms.

It is ſoluble in 18 parts of water,

Heat decompoſes it.—It is very cauſtic.

18. Sulphat of tin.—Nothing is known concerning this ſalt, except that it cryſtallizes in fine needles interlaced with one another *.

* *Monnet.*

648
Sulphat of copper.

19. Sulphat of copper.—This ſalt appears to have been known to the ancients. It is generally obtained by evaporating thoſe waters which naturally contain it. It is called alſo *blue vitriol*.

Its cryſtals are of a deep blue colour; they are in the form of oblong rhomboids. Its ſpecific gravity is 2,230.

It has a very ſtrong ſtyptic taſte; and indeed is employed as a cauſtic.

It is ſoluble in four parts of water at the temperature of 60°; but in a much ſmaller quantity of boiling water *.

It is compoſed, according to Bergman, of 46 parts of acid, 26 of oxide of copper, and 28 of water. Kirwan ſuppoſes it to contain 27,68 of acid, 35 of oxide, and 37,32 of water †.

* *Bergman.*

† *Miner.* ii. 23.

When expoſed to the air, it effloreſces, and is covered with a yellowiſh grey powder.

It requires a very ſtrong heat to decompoſe it.

It has the property of communicating a green colour to flame.

It is uſed in the preparation of ſeveral paints, and for a variety of other purpoſes.

It is decompoſed by compound affinity by acetite of lead.

649
Sulphat of biſmuth,

20. Sulphat of biſmuth.—Little is known of this ſalt, except that it is with difficulty cryſtallized, and is very deliqueſcent.

650
Antimony,

21. Sulphat of antimony.—This ſalt does not cryſtallize. It is eaſily decompoſed by heat.

651
Arſenic,

22. Sulphat of arſenic.—This ſalt is ſcarcely known. It does not appear to be cryſtallizable. It is decompoſed by water.

652
White ſulphat of mercury.

23. White ſulphat of mercury.—This ſalt may be formed by boiling together two parts of mercury and three of concentrated ſulphuric acid, and ſtopping the proceſs whenever the mercury is converted into a white maſs. This maſs, in order to remove the exceſs of acid, is to be waſhed repeatedly with ſmall portions of water, till it ceaſes to redden turnſole. The ſulphat of mercury, thus obtained, is very white. Its cryſtals are either ſmall plates or priſms. Its taſte is not very cauſtic. It is ſoluble in 500 parts of water at the temperature of 55°, and in 287 parts of boiling water. It is compoſed of 83 parts of white oxide of mercury, 12 of ſulphuric acid, and 5 of water ‡. It is not altered by expoſure to the air. Heat decompoſes it.

‡ *Fourcroy, Ann. de Chim.* x. 299.

This ſulphat is capable of combining with a new portion of acid: It was in that ſtate before it was waſhed with water. This ſalt, which may be called *acidulous white ſulphat of mercury*, has a very cauſtic taſte, and is corroſive. It reddens vegetable blues. It is ſoluble in 157 parts of water at the temperature of 55°, and in 33 parts of boiling water §.

§ *Fourcroy, ibid.*

653
Yellow ſulphat of mercury.

24. Yellow ſulphat of mercury.—This ſalt may be obtained by continuing to boil the preceding mixture of mercury and ſulphuric acid till the mercury aſſumes a yellow colour. It appears to be compoſed of yellow oxide of mercury and a ſmall portion of ſulphuric acid. It is ſoluble in 2000 parts of water at the temperature of 55°, and in 600 parts of boiling water. The ſolution is colourleſs. It was formerly called *turbith mineral* ‖.

‖ *Fourcroy, ibid.*

654
Sulphat of ammonia and mercury.

25. Sulphat of ammonia and mercury.—This triple ſalt may be formed by pouring ammonia into a ſolution of ſulphat of mercury. If only a ſmall quantity of ammonia be uſed, a copious blackiſh precipitate takes place, part of which is converted into running mercury by expoſure to light; and conſequently is black oxide of mercury; the remaining part is the triple ſalt. If a large quantity of ammonia be uſed, only the black oxide is

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(v) There is evidently ſome miſtake in this ſtatement; it does not correſpond with what he ſays elſewhere.

(w) *Mineralogy*, ii. 24. We do not underſtand this ſtatement.

(x) Weſtfield, indeed, obtained it; but he miſtook it for ſulphat of magneſia.

is precipitated; for the triple ſalt is rendered much more ſoluble by an exceſs of ammonia. As this exceſs evaporates, the ſalt cryſtallizes. The cryſtals are polygons, very brilliant and hard. It has a ſharp, auſtere, metallic taſte. It has no peculiar odour. It is ſcarcely ſoluble, except with exceſs of ammonia. It is compoſed, according to Fourcroy's analyſis, of 18 parts of ſulphuric acid, 33 of ammonia, and 39 of oxide of mercury. Heat decompoſes it. The products obtained by diſtilling it are, a little ammonia, azotic gas, a little pure mercury, ſome *ſulphite of ammonia*; and there remains yellow ſulphat of mercury *.

This triple ſalt may be formed alſo by pouring ammonia upon acidulous ſulphat of mercury, or on yellow ſulphat of mercury †.

655
Sulphat of ſilver.

26. Sulphat of ſilver.—This ſalt is formed by pouring ſulphuric acid on oxide of ſilver. Its cryſtals are ſmall needles. It melts when expoſed to a ſtrong heat, but does not ſublime.

It is decompoſed by muriat of lead ‡.

27. Sulphat of gold.—This ſalt is unknown.

28. Sulphat of platinum.—Unknown.

29. Sulphat of tungſten.—Probably no ſuch combination is poſſible.

30. Sulphat of molybdenum.—Probably impoſſible.

656
Sulphat of uranium,

31. Sulphat of uranium.—This ſalt was firſt formed by Mr Klaproth. He formed it by pouring ſulphuric acid on the oxide of uranium. Nothing farther is known of it, except that its cryſtals are ſmall, and of a yellow colour.

657
Titanium,

32. Sulphat of titanium.—This ſalt was firſt formed by Mr M'Gregor. It does not appear, from Klaproth's experiments, to be cryſtallizable.

658
Tellurium.

33. Sulphat of tellurium.—When one part of tellurium is mixed cold in a well-ſtopped veſſel with a hundred parts of concentrated ſulphuric acid, the latter gradually aſſumes a beautiful crimſon red colour: when a ſmall quantity of water is added, drop by drop, the colour diſappears, and the metal is precipitated in the form of black flakes. The ſolution is deſtroyed by heat, the colour diſappears, and the metal ſeparates in the ſtate of a white oxide. When ſulphuric acid is diluted with two or three parts of water, and a ſmall quantity of nitric acid is added, it diſſolves a conſiderable quantity of tellurium. The ſolution is tranſparent and colourleſs, and is not decompoſed by the addition of a larger quantity of water §.

SECT. II. *Of Sulphites.*

SALTS compoſed of ſulphurous acid united reſpectively with alkalies, earths, or oxides, are called *ſulphites*. Thoſe hitherto examined are the following:

659
Sulphite of potaſs.

1. Sulphite of potaſs.—This ſalt was firſt formed by Stahl; but was firſt accurately deſcribed by Berthollet, Fourcroy, and Vauquelin.

It may be formed by paſſing ſulphurous acid into a ſaturated ſolution of carbonat of potaſs till all efferveſcence ceaſes. The ſolution becomes hot, and cryſtallizes by cooling ‖.

Its cryſtals are white and tranſparent; their figure that of rhomboidal plates. Its cryſtallization often preſents ſmall needles diverging from a common centre ¶.

Its taſte is penetrating and ſulphurous. At the common temperature of the atmoſphere, it is ſoluble in its own weight of water, but much more ſoluble in boiling water.

When expoſed to the air, it effloreſces, becomes opaque and hard, and is gradually converted into *ſulphat of potaſs* by abſorbing oxygen.

When expoſed to a ſudden heat, it decrepitates, loſes its water: at a red heat ſome ſulphurous vapours are emitted; at laſt a portion of ſulphur ſeparates, and the reſiduum is ſulphat of potaſs, with a ſlight exceſs of alkali.

Nitric and oxy-muriatic acids convert it into ſulphat of potaſs by imparting oxygen.

It decompoſes the oxides of gold, ſilver, mercury, the red oxide of lead, the black oxide of mangaueſe, and the brown oxide of iron. When the green oxide of iron and the white oxide of iron are boiled with it in water, and an acid added, a precipitate takes place of theſe bodies united to ſome ſulphur, and the ſalt is converted into a ſulphat: at the ſame time ſulphurated hydrogen gas is emitted.

By compound affinity it is decompoſed by

All ſalts with baſe of ſoda, except the borat and carbonat;

All metallic ſalts except carbonats;

All neutral ſalts whoſe acid has a ſtronger affinity for potaſs than ſulphurous acid has *.

660
Sulphite of ſoda.

2. Sulphite of ſoda.—This ſalt was firſt accurately deſcribed by Fourcroy and Vauquelin.

It is white and perfectly tranſparent. Its cryſtals are four-ſided priſms, with two very broad ſides and two very narrow ones, terminated by dehedral pyramids.

Its taſte is cool and ſulphurous.

It is ſoluble in four times its weight of cold water, but it is more ſoluble in hot water.

It is compoſed of 18,8 parts of ſoda, 31,2 of acid, and 50 of water.

By expoſure to air, it effloreſces, and is ſlowly converted into a ſulphat.

When expoſed to heat, it undergoes the watery fuſion, and afterwards exhibits preciſely the ſame phenomena as the ſulphite of potaſs.

Metallic oxides and ſalts affect it preciſely as they do ſulphite of potaſs.

It is decompoſed by compound affinity by carbonat of potaſs, and the other ſalts which decompoſe ſulphite of potaſs †.

661
Sulphite of ammonia.

3. Sulphite of ammonia.—This ſalt was firſt deſcribed by Fourcroy and Vauquelin ‡.

It cryſtallizes in ſix-ſided priſms terminated by ſix-ſided pyramids.

Its taſte is cool and penetrating like that of the other ammoniacal ſalts, but it leaves a ſulphurous impreſſion in the mouth.

It is ſoluble in its own weight of cold water. Its ſolubility is increaſed by heat.

It is compoſed of 29,07 parts of ammonia, 60,06 of acid, and 10,87 of water.

When expoſed to the air, it attracts moiſture, and is ſoon converted into a ſulphat.

Heat volatilizes it without decompoſition.

Its habitudes with metallic oxides and ſalts are nearly the ſame with thoſe of the above deſcribed ſulphites, only it is capable of forming with ſeveral of them triple ſalts §.

662
Sulphite of barytes.

4. Sulphite of barytes.—This ſalt was firſt deſcribed by Berthollet ‖.

It is incryſtallizable; it has no perceptible taſte; and is perfectly inſoluble in water ¶.

It

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* Fourcroy, ibid.

† Ibid.

‡ Bergman.

§ Klaproth, Philoſophical Mag. i. 80.

‖ Fourcroy, and Vauquelin, Nicholſon's Journ. i. 317.

¶ Ibid.

* Ibid.

† Ibid.

‡ Fourcroy and Vauquelin Nicholſon's Journ. i. 317.

§ Ibid.

‖ Ann. de Chim. ii. 57.

¶ Fourcroy and Vauquelin.

It is compoſed of 59 parts of barytes, 39 parts of acid, and 2 of water.

It does not eaſily change into a ſulphat by expoſure to air; but heat produces this effect *.

663 Sulphite of lime.

5. Sulphite of lime.—This ſalt was firſt deſcribed by Berthollet †.

Its cryſtals are ſix-ſided priſms, terminated each by a very long pyramid ‡.

It has ſcarcely any taſte; however, when kept long in the mouth, it communicates to the tongue a taſte which is manifeſtly ſulphurous.

It is very ſparingly ſoluble in water, except with exceſs of acid.

It is compoſed of 47 parts of lime, 48 of ſulphurous acid, and 5 of water.

By contact of air it is converted into a ſulphat, but very ſlowly.

Heat converts it into a ſulphat by depriving it of a portion of ſulphur.

It is decompoſed by compound affinity by

Carbonates of alkalies, Fluats of alkalies,
Phoſphats of alkalies, Moſt metallic ſalts §.

664 Sulphite of magneſia.

6. Sulphite of magneſia.—This ſalt was firſt deſcribed by Fourcroy and Vauquelin.

Its cryſtals are white and tranſparent, and in the form of depreſſed tetrahedrons.

Its taſte is mild and earthy at firſt, and afterwards ſulphurous.

It is ſparingly ſoluble in water, except when there is an exceſs of acid.

It is compoſed of 16 parts of magneſia, 39 of acid, and 45 of water.

It becomes opaque when expoſed to the air; is very ſlowly converted into a ſulphat.

By expoſure to heat, it ſoftens, ſwells up, and becomes ductile like gum; a ſtrong heat decompoſes it altogether.

It is decompoſed by

Alkaline ſalts,
Earthy ſalts, except thoſe of alumina ||.

665 Sulphite of alumina.

7. Sulphite of alumina.—Firſt formed by Berthollet.

It does not cryſtallize, but is converted into a ſoft ductile maſs. It is not ſoluble in water, but becomes abundantly ſo when there is an exceſs of acid.

It is compoſed of 44 parts of alumina, 32 of acid, and 24 of water.

Heat decompoſes it ¶.

666 Sulphite of iron

8. Sulphite of iron.—It was firſt formed by Berthollet.

Its cryſtals are white, and have but very little of the ſtyptic taſte of iron ſalts *.

Berthollet alſo formed the ſulphites of zinc and tin, but he has not deſcribed them.

Sect. III. *Of Nitrats.*

Those ſalts, in the compoſition of which the nitric acid forms one ingredient, are called *nitrats*.

667 Nitre.

1. Nitrat of potaſs, nitre, or ſaltpetre.—As this ſalt is produced naturally in conſiderable quantities, particularly in Egypt, it is highly probable that the ancients were acquainted with it; but ſcarcely any thing certain can be collected from their writings. If Pliny mentions it at all, he confounds it with ſoda, which was known by the names of *nitron* and *nitrum*. It is certain, however, that it has been known in the eaſt from time immemorial. Roger Bacon mentions this ſalt in the 13th century under the name of *nitre*.

It cryſtallizes in ſlender oblong hexagonal priſms, often ſtriated, terminated by hexagonal pyramids obliquely truncated. Its ſpecific gravity is 1,920.

Its taſte is ſharp, bitteriſh, and cooling.

It is ſoluble in ſeven times its weight of water at the temperature of 60°, and in nearly its own weight of boiling water *.

According to Bergman, it is compoſed of 31 parts of acid, 61 of potaſs, and 8 of water; but this proportion of acid is undoubtedly too ſmall. According to Mr Kirwan, it is compoſed of 41,2 of acid, 46,15 of alkali, and 12,65 of water †.

It is not altered by expoſure to the air.

When expoſed to a ſtrong heat, it melts; and congeals by cooling into an opaque maſs, which has been called *mineral cryſtal*. If the heat be continued, the acid is gradually decompoſed and driven off. When the ſolution of nitre is expoſed to a boiling heat, part of the ſalt is evaporated along with the water, as Wallerius, Kirwan, and Lavoiſier, obſerved ſucceſſively. When nitre is expoſed to heat along with many combuſtible ſubſtances, its acid is decompoſed; the combuſtible ſeizes the oxygen, and at the ſame time a lively white flame appears, attended with a decrepitation: this is called the *detonation of nitre*.

Nitre mixed with charcoal and ſulphur in proper proportions forms *gunpowder*.

Nitre is decompoſed by compound affinities by

Acetite of barytes.

668 Reproduction of nitre.

No phenomenon has excited the attention of chemical philoſophers more than the continual reproduction of nitre in certain places after it had been extracted from them. Prodigious quantities of this ſalt are neceſſary for the purpoſes of war; and as Nature has not laid up great magazines of it as ſhe has of ſome other ſalts, this annual reproduction is the only ſource from which it can be procured. It became, therefore, of the utmoſt conſequence, if poſſible, to diſcover the means which Nature employed in forming it, in order to enable us to imitate her proceſſes by art, or at leaſt to accelerate and facilitate them at pleaſure. Numerous attempts accordingly have been made to explain and to imitate theſe proceſſes.

Stahl, ſetting out on the principle that there is only one acid in nature, ſuppoſed that nitric acid is merely ſulphuric acid combined with phlogiſton; and that this combination is produced by putrefaction: he affirmed accordingly, that nitre is compoſed by uniting together potaſs, ſulphuric acid, and phlogiſton. But this opinion, which was merely ſupported by very far-fetched analogies, could not ſtand the teſt of a rigorous examination.

Lemery the Younger accordingly advanced another; affirming, that all the nitre obtained exiſts previouſly in animals and vegetables, and that it is formed in theſe ſubſtances by the proceſſes of vegetation and animalization. But it was ſoon diſcovered that nitre exiſts, and is actually formed, in many places where no animal nor vegetable ſubſtance has been decompoſed; and conſequently this theory was as untenable as the former. So far indeed is it from being true that nitre is formed alone by theſe proceſſes, that the quantity of nitre in plants has been found to depend entirely on the ſoil in which they grow ‡.

At

* Ibid.

† Ann de Chim. ibid.

‡ Fourcroy and Vauquelin.

§ Ibid.

|| Fourcroy and Vauquelin.

¶ Fourcroy and Vauquelin.

* Ann. de Chim. ii. 58.

* Bergman.

† Mineral. ii. 27.

‡ Bouillon

At laſt by the numerous experiments of ſeveral French philoſophers, particularly by thoſe of Thouvenel, it was diſcovered that nothing elſe is neceſſary for the production of nitre but a baſis of lime, heat, and an open but not too free communication with dry atmoſpheric air. When theſe circumſtances combine, the acid is firſt formed, and afterwards the alkali makes its appearance. How the air furniſhes materials for this production is eaſily explained, now that the component parts of the nitric acid are known to be oxygen and azot. But how lime contributes to their union it is not ſo eaſy to ſee. It is a diſpoſing affinity, which, like moſt others referred to that ſingular claſs, our preſent knowledge of the nature of affinity does not enable us to explain. The appearance of the potaſs is equally extraordinary. If any thing can give countenance to the hypotheſis, that potaſs is compoſed of lime and azot, it is this ſingular fact.

669 Nitrat of ſoda. 2. Nitrat of ſoda. This ſalt was called formerly *cubic nitre.*

It forms rhomboidal cryſtals. Its ſpecific gravity is 1,870.

It has a cool ſharp taſte, and is ſomewhat more bitter than nitre.

It is ſoluble in about three parts of water at the temperature of 60°, and is ſcarcely more ſoluble in boiling water.

It is compoſed, according to Bergman, of 43 parts of acid, 32 of ſoda, and 25 of water. From an experiment formerly deſcribed, Mr Kirwan concludes, that it contains 57,65 of acid, and 42,35 of alkali; but perhaps the proportion of acid may be ſomewhat over-rated, as no direct proof has been brought that the ſalt contains no water.

When expoſed to the air it rather attracts moiſture.

Its phenomena in the fire are the ſame with thoſe of nitre, only it does not melt ſo eaſily.

It is decompoſed by compound affinity by the following ſalts:

Sulphat of barytes,
——— potaſs,
——— alumina,
Muriat of barytes,
——— potaſs,
——— lime,

Muriat of ammonia,
Acetite of barytes,
——— potaſs,
Carbonat of barytes,
——— potaſs.

670 Nitrat of ammonia. 3. Nitrat of ammonia. This ſalt cryſtallizes with difficulty into regular needles. It was formerly called *nitrum ſemivolatile*, and *nitrum flammans.*

It has a ſharp, acrid, ſomewhat urinous taſte.

It is ſoluble in about half its weight of boiling water.

It is compoſed of 58 parts of acid, about 26 of alkali, and 16 of water*.

When expoſed to the air it deliqueſces.

When expoſed to heat, it firſt undergoes the watery fuſion, afterwards detonates, and is completely decompoſed. Berthollet has ſhewn, that this phenomenon is owing to the hydrogen of the alkali entering into combination with the oxygen of the acid, and forming water, while the acid flies off in a gaſeous form.

By compound affinity it is decompoſed by the following ſubſtances:

Sulphat of barytes,
——— potaſs,
——— alumina,

Acetite of barytes,
——— potaſs,
——— ſoda,

Acetite of lime
——— magneſia,
——— alumina,
Muriat of barytes,
——— potaſs,
——— ſoda,

Muriat of lime,
——— magneſia,
——— alumina,
Carbonat of barytes,
——— potaſs,
——— ſoda.

671 Nitrat of barytes. 4. Nitrat of barytes. This ſalt may be formed into hexagonal cryſtals, but it requires great addreſs to produce them.

It attracts moiſture from the atmoſphere.

Heat decompoſes it, and leaves pure barytes. The decompoſition of this ſalt by heat is the moſt convenient method of procuring pure barytes yet known. It was firſt propoſed by Mr Vauquelin.

By compound affinity it is decompoſed by
Alkaline carbonats,
Oxalat of ammonia*.

672 Nitrat of lime. 5. Nitrat of lime. This ſalt forms by cryſtallization ſix-ſided priſms, terminated by dehedral pyramids, but more commonly ſmall regular octahedral needles.

It has a ſharp bitteriſh taſte.

It is ſoluble in two parts of cold water, and in its own weight of boiling water.

Boiling alcohol diſſolves its own weight of it †.

According to Bergman, it is compoſed of 43 parts of acid, 32 of lime, and 25 of water. Kirwan has found, that 100 parts of lime require for ſaturation 180 parts of acid ‡.

Nitrat of lime deliqueſces when expoſed to the air.

Heat decompoſes it like all other nitrats.

By compound affinity it is decompoſed by

Sulphat of barytes,
——— potaſs,
——— ſoda,
——— ammonia,
——— alumina,
Muriat of barytes,
——— potaſs,
Acetite of barytes,

Acetite of potaſs,
Carbonat of barytes,
——— potaſs,
——— ſoda,
——— ammonia,
——— alumina,
——— magneſia,
Tungſtat of ammonia §.

673 Nitrat of ſtrontites. 6. Nitrat of ſtrontites. This ſalt, firſt formed by Dr Hope, cryſtallizes readily, but the cryſtals are very irregular in their ſhape: ſometimes they are hexagonal truncated pyramids; ſometimes octahedrons, conſiſting of two four-ſided pyramids united at their baſes.

It is ſoluble in its own weight of water, at the temperature of 60°, and in little more than half its weight of boiling water. It has a ſtrong pungent taſte.

In a dry air it effloreſces, but in a moiſt air it deliqueſces.

It deflagrates on hot coals. Subjected to heat in a crucible, it decrepitates gently, and then melts. In a red heat it boils, and the acid is diſſipated. If a combuſtible ſubſtance be at this time brought into contact with it, a deflagration with a very vivid red flame is produced ||.

674 Nitrat of magneſia. 7. Nitrat of magneſia. The compoſition of this ſalt was firſt aſcertained by Dr Black.

Its cryſtals are quadrangular priſms. It has a very bitter taſte. It is very ſoluble in water. Alcohol diſſolves $\frac{1}{9}$th of its own weight of it ¶.

One hundred parts of magneſia require 255 of nitric acid for ſaturation *.

It deliqueſces in the air, according to Bergman; but Dijonval affirms, that he has procured it in cryſtals which rather effloreſce.

It

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* Kirwan.

* Bergman.

† Bergman.

‡ Miner. ii. 29.

§ Scheele.

|| Hope, *Tranſ. Edin* iv. 12.

¶ Bergman, ii. 381.

* Kirwan.

It is decompoſed by heat.

By compound affinity it is decompoſed by

Sulphat of barytes,
——— potaſs,
——— ſoda,
——— ammonia,
——— alumina,
Muriat of barytes,
——— potaſs,
——— ſoda,

Muriat of lime,
Acetite of barytes,
——— potaſs,
——— ſoda,
——— lime,
Carbonat of barytes,
——— potaſs,
——— lime.

675 Nitrat of ammonia and magneſia. 8. Nitrat of ammonia and magneſia. This triple ſalt was diſcovered by Mr Fourcroy. Into a ſaturated ſolution of nitrat of magneſia, containing 73 grains of magneſia, he poured ammonia as long as any precipitate could be obtained. Twenty-one grains of magneſia were precipitated, 52 grains remained combined with the acid and the ammonia. He found that 52 grains of magneſia produced, when ſaturated with nitric acid, 288 grains of nitrat; and that the quantity of nitric acid neceſſary to ſaturate 21 grains of magneſia, when ſaturated with ammonia, produced 84 grains of nitrat of ammonia. He concludes, therefore, though the data are not quite ſatisfactory, that the triple ſalt is compoſed of 288 grains of nitrat of magneſia, and 84 of nitrat of ammonia *.

676 Nitrat of alumina. 9. Nitrat of alumina. This ſeems to have been firſt attended to by Beaumé.

Its cryſtals are pyramidal. It has a very aſtringent taſte. It is ſoluble in water, and deliqueſces in the air.

677 Nitrat of jargonia. 10. Nitrat of jargonia. This ſalt may be eaſily formed by pouring nitric acid on newly precipitated jargonia.

It always contains an exceſs of acid. By evaporation a yellowiſh tranſparent matter is obtained, exceedingly tenacious and viſcid, and which dries with difficulty. It has an aſtringent taſte, and leaves on the tongue a viſcid matter, owing to its being decompoſed by the ſaliva. It is only very ſparingly ſoluble in water; the greateſt part remains under the form of gelatinous and tranſparent flakes. Like all the other ſalts into which jargonia enters, it is decompoſed by heat. It is decompoſed alſo by ſulphuric acid, which occaſions a white precipitate, ſoluble in exceſs of acid; by carbonat of ammonia, which produces a precipitate ſoluble by adding more carbonat; and by an infuſion of nut-galls in alcohol, which produces a white precipitate, ſoluble in an exceſs of the infuſion; unleſs the jargonia contains iron; in which caſe the precipitate is a greyiſh blue, and part of it remains inſoluble, giving the liquor a blue colour. This liquor, mixed with carbonat of ammonia, produces a matter purple by tranſmitted light, but violet by reflected light. Gallic acid alſo precipitates nitrat of jargonia of a greyiſh blue, but the colour is not ſo fine. Moſt of the other vegetable acids decompoſe this ſalt, and form combinations inſoluble in water †.

678 Nitrat of iron. 11. Nitrat of iron. The green oxide of iron decompoſes, but does not combine with nitric acid. The brown oxide forms with it a red or brown ſolution, which by evaporation may be reduced to a jelly, but will not cryſtallize.

679 Nitrat of zinc. 12. Nitrat of zinc. The oxide of zinc combines with nitric acid, and forms with it a ſalt which cryſtallizes in compreſſed and ſtriated tetrahedral priſms, terminated by four-ſided pyramids.

Its ſolution is exceedingly cauſtic. When placed on burning coals it melts and detonates as it dries. It can ſcarcely be dried without being in ſome meaſure decompoſed.

It deliqueſces in the air *.

680 Nitrat of mangancſe. 13. Nitrat of mangancſe. This ſalt, compoſed of oxide of manganeſe and nitric acid, was firſt examined by Scheele. Its cryſtals are ſmall and ſhining, of a very bitter taſte, and ſoluble in water †.

681 Nitrat of cobalt. 14. Nitrat of cobalt. It is of a pale red colour, and cryſtallizes in needles. It deliqueſces when expoſed to the air. Heat decompoſes it. When nickel is preſent, this ſalt aſſumes a green colour.

682 Of nickel. 15. Nitrat of nickel. Its cryſtals are of a green colour, and in the form of rhomboidal cubes. They are deliqueſcent, and are gradually decompoſed when expoſed to the air, the acid leaving them ‡.

683 Of lead. 16. Nitrat of lead. Nitric acid combines with the white oxide of lead. The cryſtals of this ſalt are of a white colour; their form an irregular octagon, or rather truncated hexahedral pyramid. When expoſed to heat it decrepitates, and melts with a yellowiſh flame. By compound affinity it is decompoſed by

Muriat of potaſs,
——— ſoda,
——— ammonia,
Carbonat of ſoda §.

684 Of tin. 17. Nitrat of tin. Tin is converted into an acid by nitric acid: it is not probable, therefore, that any permanent nitrat of tin can be formed.

685 Of copper. 18. Nitrat of copper. This ſalt appears to have been firſt obtained by Macquer.

Its form, when properly cryſtallized, is an oblong parallelogram. It is of a fine blue colour. It is exceedingly cauſtic. It melts at 77° ||.

It is deliqueſcent in a moiſt air, but in a dry place is covered with a green effloreſcence. It is very ſoluble in water. Heat decompoſes it.

686 Of biſmuth. 19. Nitrat of biſmuth. This ſalt cryſtallizes in various forms. Fourcroy obtained it in flattened rhomboids. It effloreſces in the air. Water decompoſes it. It detonates in the fire.

687 Of antimony. 20. Nitrat of antimony. Little is known concerning this ſalt, except that it is very deliqueſcent, and is decompoſed by heat.

688 Of arſenic. 21. Nitrat of arſenic. With white oxide of arſenic nitric acid forms a ſalt which cryſtallizes. It is very deliqueſcent. It does not detonate.

689 Of mercury. 22. Nitrat of mercury. This ſalt may be formed by diſſolving mercury in nitric acid. It cryſtallizes in the cold in regular flat 14-ſided figures; but their form differs according to the manner in which the cryſtallization has been performed.

It is ſoluble in water.

This ſalt is exceedingly cauſtic. It detonates on coals. When heated in a crucible it melts, and is decompoſed. The oxide attracts oxygen from the acid, which flies off in the form of nitrous gas, and red oxide of mercury remains behind.

It is ſlowly decompoſed alſo in the air. It is decompoſed by compound affinity by

Sulphat of copper, and a great many other ſulphats,
Phoſphat of ſoda,
Borax.

690 Of ammonia and mercury, 23. Nitrat of ammonia and mercury. This triple ſalt may be formed by pouring ammonia into a ſolution

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* *Ann. de Chim.* iv. 215.

† *Vauquelin, Ann. de Chim.* xxii. 199.

* *Fourcroy.*

† *Scheele on Manganeſe.*

‡ *Bergman,* ii. 268.

§ *Bergman.*

|| *Sage.*

Muriats.

of nitrat of mercury. If only enough of ammonia to ſaturate the acid be uſed, the triple ſalt precipitates in the form of a white powder; but with an exceſs of ammonia it remains diſſolved, and forms by evaporation very bright polyhedral cryſtals.

It has a very ſharp taſte. It is ſoluble in 1200 parts of water at the temperature of 55°. Hot water ſeparates a little ammonia, which renders it ſtill more inſoluble. It turns vegetable blues green. Muriatic acid diſſolves it.

According to Fourcroy's analyſis, it is compoſed of 68,20 parts of oxide of mercury, 16 of ammonia, and 15,80 of nitric acid and water.

When diſtilled it yields ammonia, azotic gas, oxygen gas, yellow oxide of mercury, and pure mercury *.

691 Nitrat of ſilver,

24. Nitrat of ſilver. This ſalt may be formed by diſſolving ſilver in nitric acid.

It forms flat tranſparent cryſtals compoſed of needles. It is exceedingly cauſtic. When melted it forms a grey maſs called *lapis infernalis*, from its great corroſiveneſs

It is very ſoluble in water. It is not altered by expoſure to the air. Light decompoſes it.

By compound affinity it is decompoſed by

The ſulphats,

The muriats.

692 Nitrat of uranium,

25. Nitrat of uranium. This ſalt was firſt formed by Klaproth. Its cryſtals are hexagonal plates of a greeniſh yellow colour. The largeſt were $\frac{1}{4}$ths of an inch in length and $\frac{1}{4}$th in breadth †.

693 Titanium,

26. Nitrat of titanium. It is capable of cryſtallizing.

694 Tellurium.

27. Nitrat of tellurium. The ſolution of tellurium in nitric acid is tranſparent and colourleſs. When concentrated, it produces in time ſmall white light cryſtals in the form of needles, which exhibit a dendritic aggregation ‡.

Sect. IV. *Of Nitrites.*

The ſalts which the nitrous acid forms with alkalies, earths, and metallic oxides, are denominated *nitrites*. Very few of them have been examined; we ſhall not therefore attempt a deſcription of them.

Sect. V. *Of Muriats.*

Salts into which the muriatic acid enters are called *muriats*.

695 Muriat of potaſs.

1. Muriat of potaſs. This ſalt was formerly called *febrifuge* or *digeſtive ſalt of Sylvius*, and *regenerated ſea ſalt*.

Its cryſtals are cubes, but rather irregular.

It has a diſagreeable bitter taſte. Its ſpecific gravity is 1,836 §.

It is ſoluble in three times its weight of water at the temperature of 60°, and in double its weight of boiling water ‖.

It is compoſed, according to Bergman, of 31 parts of acid, 61 of potaſs, and 8 of water. Kirwan has found it to contain 36 of acid, 46 of alkali, and 18 of water ¶.

It ſuffers little alteration from expoſure to the air.

When expoſed to heat, it firſt decrepitates, then melts, and at laſt is volatilized, but without decompoſition.

The following ſalts decompoſe it by compound affinity:

Sulphat of ſoda,
——— ammonia,
——— alumina,
Nitrat of ſoda,
——— lime,
Nitrat of ammonia,
——— magneſia,
——— alumina,
——— lead.

Muriats.

696 Muriat of ſoda.

2. Muriat of ſoda, common or ſea ſalt. This ſalt has been known, and in common uſe, from the earlieſt ages. It is ſometimes called alſo *ſal gem.*

Its cryſtals are cubes, but they often aſſume other forms. Its ſpecific gravity is 2,120 *.

Its taſte is univerſally known, and is what is ſtrictly ſpeaking denominated *ſalt*.

It is ſoluble in $2\frac{14}{17}$ times its weight of water at the temperature of 60°, and in $2\frac{13}{17}$ its weight of boiling water †.

According to Bergman, it is compoſed of 52 parts of acid, 42 of alkali, and 6 of water. According to the late experiments of Mr Kirwan, of 40 parts of acid, 35 of alkali, and 25 of water.

It is not affected by expoſure to the air. It ought to be obſerved, however, that the muriat of ſoda in common uſe contains, beſides other impurities, a quantity of muriat of magneſia, which renders it deliqueſcent.

When heated it decrepitates. Heat volatilizes, but does not decompoſe it.

The following ſalts decompoſe it by compound affinity:

Sulphat of ammonia,
——— alumina,
——— potaſs *,
——— iron †,
Nitrat of ammonia,
——— magneſia,
——— alumina,
——— lead ‡,
Nitrat of ſilver §,
Aceſite of barytes,
Pyrolignite of barytes ‖,
——— lead ‖,
Carbonat of potaſs (*a*),
Alum (*b*),
Red oxide of lead (*c*).

697 How decompoſed by red oxide of lead.

That the red oxide of lead decompoſes this ſalt is a well known fact, and it has been conſidered as contrary to the laws of affinity. Mr Haſſenfratz endeavoured to account for it by ſuppoſing that the oxide is combined with carbonic acid, and that therefore it is a caſe of compound affinity. Mr Curaudau has proved that carbonic acid, inſtead of promoting, impedes the decompoſition; and that, in fact, carbonat of lead is incapable of decompoſing muriat of ſoda. He concludes, therefore, that the phenomenon cannot be accounted for by the commonly received laws of affinity * We cannot, however, think that the phenomenon is ſo unaccountable as Mr Curaudau ſuppoſes; for muriatic acid is capable of decompoſing the red oxide of lead, of combining with part of its oxygen, and of being converted into oxy-muriatic acid. Now if oxy-muriatic and nitro-muriatic acids be merely the ſame ſubſtance in a different form, as there is the ſtrongeſt reaſon for ſuppoſing, the white oxide of lead has a ſtronger affinity for it than ſoda has, and ought therefore to decompoſe it.

698 Muriat of ammonia.

3. Muriat of ammonia, or ſal ammoniac. This ſalt was known to the ancients, and was called by them *ſal ammoniac*, becauſe it was found in great quantities near the temple of Jupiter Ammon in Africa †.

It aſſumes the form of plumoſe cryſtals. The individual cryſtals are long hexahedral pyramids. Its ſpecific gravity is 1,420 ‡.

It has an acrid, poignant, urinous taſte.

It diſſolves in about three times its weight of water at the temperature of 60°, and in a much ſmaller quantity of boiling water.

It is compoſed, according to Kirwan, of 35 parts of acid, 30 of alkali, and 45 of water §.

In its common form (which is an opaque maſs) it is not affected by the air, but its cryſtals are liable to deliqueſce.

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* Fourcroy, *Ann. de Chim.* xiv. 37.

† *Klaproth, Journ. de Phyſ.* xxxvii. 158

‡ *Klaproth, Phil. Mag.* i. 80.

§ *Kirwan.*

‖ *Bergman.*

¶ *Kirwan's Mineral.* ii. 30.

* *Kirwan.*

† *Bergman.*

* *Fuchs, Ann. de Chim.* vi. 29.

† *Bullen, ibid.* xi. 320.

‡ *Morveau.*

§ *Bergman.*

‖ *Morveau, Ann de Chim.* xix. 109.

(*a*) *Bergman*

(*b*) *Crell, Ann. de Chim.* xxvi. 217.

(*c*) *Scheele.*

* *Ann. de Chim.* xiv. 15.

† *Pliny*, lib. xxxi. c. 7. See *Sal Ammoniac*, Encyc.

‡ *Kirwan.*

§ *Kirwan's Mineral.* ii. 34.

Heat volatilizes without decompoſing it.

The following ſalts decompoſe it by compound affinity :

Sulphat of alumina,
Nitrat of ſoda,
——— lead,
Acetite of barytes,
——— potaſs,
——— ſoda,
——— lime,
Acetite of magneſia,
——— alumina,
——— lead,
Carbonat of barytes,
——— potaſs,
——— magneſia (Y)

When this ſalt is ſublimed with gold leaf, there is found in the neck of the retort an amethyſt coloured matter, bordering on purple, ſoluble in water, and forming a purple ſolution. When filtered there remains behind a purple powder. This ſalt ſeems from this to be capable of oxidating gold *.

099 Muriat of barytes, 4. Muriat of barytes. This ſalt was firſt deſcribed by Bergman, but it has been moſt particularly attended to by Dr Crawford.

It affords oblong ſquare cryſtals.

It has an unpleaſant aſtringent taſte.

It is not very ſoluble in water. It is ſoluble in alcohol.

It is not altered by expoſure to the air, nor does heat in all probability decompoſe it.

Dr Crawford wrote a treatiſe on it in 1790, in which he recommended its uſe internally for ſcrofulous complaints. Care ought to be taken not to give it in too large quantities, as, like the other compounds of barytes, it is poiſonous.

The following ſalts decompoſe it by compound affinity (Z) :

Sulphat of ſoda
——— ammonia,
——— magneſia,
——— alumina,
Nitrat of ſoda,
Nitrat of lime,
——— ammonia,
——— magneſia,
——— alumina,
Phoſphat of lime †.

700 Muriat of ammonia and barytes, 5. Muriat of ammonia and barytes. This triple ſalt was firſt diſcovered by Fourcroy. It may be formed by pouring a carbonat of ammonia into a ſolution of muriat of barytes. It is eaſily decompoſed by heat, but none of the alkalies nor their carbonats are capable of altering it ‡.

701 Muriat of lime, 6. Muriat of lime. This ſalt was formerly called *fixed ammoniac*, becauſe it was commonly obtained by decompoſing ſal ammoniac by means of lime.

Its cryſtals are four-ſided ſtriated priſms, terminated by a very ſharp pyramid ; but it is not eaſily cryſtallized.

Its taſte is very bitter.

It is ſoluble in about $1\frac{1}{2}$ parts of cold water, and in leſs than its own weight of boiling water. Alcohol diſſolves its own weight of it.

According to Bergman, it is compoſed of 31 parts of acid, 44 of lime, and 25 of water. According to Kirwan, 100 parts of lime require for ſaturation 86 parts of muriatic acid.

It very ſpeedily deliqueſces when expoſed to the air. By heat it melts into a very hard vitreform ſubſtance.

The following ſalts decompoſe it by compound affinity :

Sulphat of ſoda,
——— ammonia,
——— magneſia,
——— alumina,
Nitrat of ſoda,
——— ammonia,
——— magneſia,
——— alumina,
Carbonat of potaſs,
——— ſoda,
——— ammonia *,
——— barytes,
——— magneſia,
——— alumina,
Acetite of barytes,
——— potaſs,
——— ſoda.

702 Muriat of ſtrontites, 7. Muriat of ſtrontites. This ſalt was firſt formed by Dr Hope. Its cryſtals are very long, ſlender, hexagonal priſms. It has a peculiar, ſharp, penetrating taſte.

Three parts of theſe cryſtals are ſoluble in two parts of water at the temperature of 60°. Boiling water diſſolves any quantity of them whatever.

They contain 42 *per cent.* of water of cryſtallization.

They ſuffer no change when expoſed to the air except it be very moiſt ; in which caſe they deliqueſce.

When heated, they firſt undergo the watery fuſion, and are then reduced to a white powder. A very violent heat decompoſes this ſalt.

Muriatic acid precipitates this ſalt from its ſolution in water. That acid, therefore, has a ſtronger affinity for water than the ſalt has †.

703 Muriat of magneſia, 8. Muriat of magneſia. This ſalt abounds in ſea water.

It is not eaſily cryſtallized. Bergman's method was to evaporate it by a conſiderable heat to the proper degree of concentration, and then to expoſe it to a ſudden cold. By this method he obtained it in ſmall needles ‡.

It has a very bitter taſte. It is ſoluble in its own weight of water §, and in five parts of alcohol ||.

A ſaturated ſolution of it quickly forms a jelly ; on which if hot water be poured ſpongy maſſes are formed not even ſoluble in muriatic acid ¶.

It is compoſed, according to Bergman, of 34 parts of acid, 41 of earth, and 25 of water. According to Kirwan, 100 parts of magneſia require for ſaturation 104,275 of acid *.

It deliqueſces very ſpeedily when expoſed to the air.

A ſtrong heat decompoſes it. When dried in a high temperature, it is very cauſtic †.

The following ſubſtances decompoſe it by compound affinity :

Sulphat of ſoda,
——— ammonia,
——— alumina,
Nitrat of ammonia,
Acetite of potaſs,
——— ſoda,
——— ſilver ‡.

Carbonat

* Storr, Crell's New Diſcoveries, &c. Part ii. p. 45.

† Dr Pearſon.

‡ Ann. de Chim. iv. 8.

* Bergman.

† Hope, Tranſ. Edin. iv. 12.

‡ Bergman, ii 383.

§ Fourcroy.

|| Bergman, ii. 383.

¶ Bergman, ibid.

* Iriſh Tranſ. iv.

† Weſtrum, Ann. de Chim. ii. 135.

‡ Bergman.

(Y) Only at the common temperature. At a high temperature carbonat of ammonia decompoſes muriat of magneſia. See *Weſtrum*, *Ann. de Chim.* ii. 118.

(Z) Bergman affirmed, that this ſalt decompoſed all the ſulphats, and propoſed it therefore as a certain means of diſcovering the preſence of ſulphuric acid, however combined in any ſolution ; for the ſulphat of barytes is almoſt entirely inſoluble in water. But Mr Piſſis has obſerved, that it does not decompoſe ſulphat of lime nor of potaſs. See *Ann. de Chim.* xv. 317.

Carbonat of barytes,
——— potaſs,

Carbonat of ſoda
——— ammonia (y).

704 Muriat of ammonia and magneſia,

9. Muriat of ammonia and magneſia. This triple ſalt was firſt mentioned, we believe, by Bergman. It may be formed by pouring ammonia into a ſolution of muriat of magneſia. Part of the magneſia is precipitated, but great part of it remains diſſolved, and combined with the acid and the ammonia. This triple ſalt is compoſed, according to Fourcroy, of 73 parts of muriat of magneſia and 27 of muriat of ammonia *.

* Ann. de Chim. iv. 222.

705 Muriat of alumina,

10. Muriat of alumina.—This ſalt cryſtallizes with difficulty. It has an aſtringent taſte. Its ſolution is gelatinous, and cannot be filtrated without much dilution in water. It is deliqueſcent. When evaporated to dryneſs, it forms a gummy maſs: in a ſtrong heat it is decompoſed.

The following ſalts decompoſe it by compound affinity:

Nitrat of ammonia,
Acetite of barytes,
——— potaſs,
——— ſoda,
——— lime,

Acetite of magneſia,
Carbonat of barytes,
——— potaſs,
——— ſoda,
——— ammonia.

706 Muriat of jargonia,

11. Muriat of jargonia.—This ſalt is eaſily formed by pouring muriatic acid on newly precipitated jargonia. It is colourleſs; its taſte is very aſtringent: by evaporation it furniſhes ſmall tranſparent cryſtals in needles, which loſe their tranſparence in the air. Muriat of jargonia is very ſoluble in water and in alcohol; to the flame of which it does not communicate any particular colour. Heat decompoſes it; and it is decompoſed likewiſe by the ſaliva when taken into the mouth.

When muriat of jargonia contains a little ſilica, it forms cubic cryſtals without conſiſtence, and reſembling a jelly. Theſe cryſtals, when expoſed to the air, gradually loſe their tranſparency, and diminiſh in volume, and there are formed in the middle of the ſalt white ſilky needle-ſhaped cryſtals.

Muriat of jargonia is decompoſed by ſulphuric acid; part of the ſulphat precipitates, and part remains diſſolved in the muriatic acid. When this acid is driven off by heat, the remainder of the ſulphat is gradually depoſited: if the evaporation be ſtopped before the maſs be reduced to dryneſs, it forms a kind of jelly when cold. It is alſo decompoſed by the phoſphoric, citric, tartarous, oxalic, and ſaccholactic acids, which form with jargonia inſoluble compounds that precipitate in white flakes.

The gallic acid poured into muriat of jargonia produces a white precipitate; but a green, bordering on grey, if the jargonia contain iron; and this laſt precipitate becomes, when dry, of a bright black colour, and reſembles China ink. The liquid preſerves a greeniſh colour; new portions of gallic acid produce no farther precipitation; but carbonat of ammonia ſeparates in great abundance a flaky matter of a purpliſh colour, not unlike that of the leys of wine. From theſe experiments it follows, that gallic acid has a greater affinity for jargonia than muriatic acid has; and that the gallats of jargonia and iron are ſoluble in muriatic acid.

Carbonat of potaſs decompoſes muriat of jargonia, and part of the carbonic acid combines with the earth, and renders it eaſily ſoluble in acids though dried.

Carbonat of ammonia occaſions a precipitate, which is moſtly diſſolved by adding more carbonat.

Pruſſiat of mercury produces an abundant precipitate, which is ſoluble in muriatic acid; and which conſequently is not muriat of mercury.

A plate of zinc, introduced into a ſolution of muriat of jargonia, occaſions a ſlight effervelcence; the liquor becomes milky, and in a few days becomes a white ſemitranſparent jelly.

Alumina decompoſes muriat of jargonia with the aſſiſtance of a ſlight heat: the alumina diſſolves, the liquor becomes milky, and aſſumes the form of a jelly. When the muriat contains iron, it remains in the ſolution, and the precipitated jargonia is quite pure. Here, then, is a method of freeing jargonia from iron *.

* Vauquelin, Ann. de Chim. xxii. 201.

707 Muriat of iron,

12. Muriat of iron.—Muriatic acid forms with the green oxide of iron a ſalt which cryſtallizes in flat needles. When expoſed to the air, they deliqueſce, and the green oxide attracts oxygen, and is gradually converted into a brown oxide. Heat decompoſes this ſalt.

708 Muriat of zinc,

13. Muriat of zinc.—This ſalt, procured by diſſolving zinc or its oxide in muriatic acid, does not cryſtallize. Its ſolution is colourleſs. When heated, it becomes of a blackiſh brown. By diſtillation, a part of the acid is ſeparated, and muriat of zinc remains behind of a milk-white colour, ſolid, and formed of ſmall radiated needles. It attracts moiſture in the air.

709 Muriat of mangaueſe,

14. Muriat of manganeſe.—Muriatic acid diſſolves the white oxide of manganeſe. Its ſolution affords by evaporation angular ſhining cryſtals †: They are deliqueſcent and ſoluble in alcohol ‡.

† Scheele on Manganeſe.

‡ Kirwan's Mineral. ii. 37.

710 Cobalt,

14. Muriat of cobalt.—The ſolution of oxide of cobalt in muriatic acid is of a pale red, except it be contaminated with nickel or iron, when it is greeniſh. It cryſtallizes in ſmall needles, which are very deliqueſcent. Heat decompoſes it.

711 Nickel,

16. Muriat of nickel.—This ſalt is deliqueſcent, and loſes its acid when expoſed to the air §.

§ Bergman, ii. 268.

712 Lead,

17. Muriat of lead.—Muriatic acid combines with oxide of lead eaſily enough: but this ſalt is more readily procured by pouring muriatic acid into a ſolution of nitrat of lead; the muriat immediately precipitates in the form of a white powder. It is ſoluble in 30 times its weight of boiling water; and the ſolution yields by evaporation ſmall, ſlender, brilliant needles in bundles.

It is ſomewhat deliqueſcent. When expoſed to heat, it melts into a brown maſs, formerly called *corneous lead*.

It is decompoſed by compound affinity by
Sulphat of ſilver ||,
Carbonat of ſoda.

|| Bergman

713 Tin,

18. Muriat of tin.—This ſalt may be formed by diſſolving tin in hot muriatic acid. By evaporation it affords needle-ſhaped cryſtals, which are deliqueſcent.

This ſalt has a ſtrong affinity for oxygen. It decompoſes oxy-muriatic, nitric, ſulphurous, arſenic, molybdic, and tungſtic acids, the red oxide of mercury, black oxide of manganeſe, oxide of antimony, zinc, ſilver,

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(y) Only at a high temperature. See *Muriat of Ammonia*.

ver, and gold; and by that means is converted into oxy-muriat of tin. It even abſorbs oxygen when expoſed to the air *. Theſe compoſitions are doubtleſs produced by *diſpoſing affinity*.

714 Muriat of copper,

19. Muriat of copper.—This ſalt may be formed by diſſolving copper or its oxide in muriatic acid.

Its cryſtals are priſmatic. It is of a beautiful graſs green colour. It has a very aſtringent and cauſtic taſte. It deliqueſces when expoſed to the air. A moderate heat is ſufficient to melt it; and when cooled it congeals into a maſs. It requires a ſtrong heat to volatilize it.

It is decompoſed by nitrat of ſilver †.

715 Muriat of biſmuth,

20. Muriat of biſmuth.—This ſalt cryſtallizes with difficulty. By ſublimation it forms a ſoft fuſible ſubſtance, formerly called *butter of biſmuth*.

716 Antimony,

21. Muriat of antimony.—This ſalt is found native. It cryſtallizes in priſms. When heated it evaporates.

717 Arſenic,

22. Muriat of arſenic.—This ſalt cryſtallizes; it is very volatile, and not very ſoluble, in water ‡.

718 Mercury,

23. Muriat of mercury.—This ſalt may be prepared by pouring diluted muriatic acid into a diluted ſolution of nitrat of mercury: the muriat of mercury is immediately precipitated in the form of a white powder. Common ſalt may be uſed inſtead of muriatic acid. This ſalt was formerly called *white mercurial precipitate* and *calomel*.

It cryſtallizes; but the form of the cryſtals, which are very ſmall, has not been determined.

It has little taſte. It is almoſt inſoluble in water. It is uſed as a medicine.

It is decompoſed by ſulphat of ammonia §.

719 Muriat of ammonia and mercury,

24. Muriat of ammonia and mercury.—This triple ſalt was firſt diſcovered by Fourcroy. It may be formed by pouring ammonia into a ſolution of corroſive muriat of mercury. It has the appearance of a white powder. Its taſte is at firſt earthy, afterwards metallic. It is nearly inſoluble in water. According to Fourcroy's analyſis, it is compoſed of 81 parts of oxide of mercury, 16 of muriatic acid, and 3 of ammonia.

Heat decompoſes it; producing ammonia, azotic gas, and muriat of mercury.

Sulphuric, nitric, and muriatic acids decompoſe it ‖.

720 Muriat of ſilver,

25. Muriat of ſilver.—This ſalt may be formed by diſſolving oxide of ſilver in muriatic acid, or, which is better, by pouring muriatic acid into nitrat of ſilver; muriat of ſilver immediately precipitates. It is very little ſoluble in water; according to Monnet, one part of it requires 3072 parts of water.

When expoſed to a ſmall heat, it melts into a grey ſemitranſparent maſs, not unlike horn; hence it was formerly called *luna cornea*. A long continued heat decompoſes it. This ſalt is very cauſtic: it is employed as an eſcharotic under the name of *lunar cauſtic*.

721 Muriat of titanium.

26. Muriat of titanium has been formed by Mr Klaproth.

Sect. VI. *Of Oxy-muriats.*

Those ſalts, into which the oxy-muriatic acid enters as an ingredient, are called *oxy-muriats*. As we conſider the nitro-muriatic acid to be preciſely the ſame with the oxy-muriatic, its combinations of courſe muſt receive the ſame name.

722 Oxy-muriat of potaſs.

1. Oxy-muriat of potaſs.—This ſingular ſalt was diſcovered by Mr Berthollet in 1786. It may be formed by ſaturating a ſolution of potaſs with oxy-muriatic acid gas. By evaporating this ſolution in the dark, common muriat of potaſs is firſt obtained: When it is ſeparated, and the liquor allowed to cool, oxy-muriat of potaſs cryſtallizes.

Its cryſtals are rhomboids, of a ſilvery brilliancy.

It has an inſipid cooling taſte, reſembling that of nitre. It is ſoluble in 17 parts of water at the temperature of 60, and in 2½ parts of boiling water *. It does not deliqueſce in the air; but light converts it into common muriat by ſeparating oxygen. When heated, it melts, and gives out oxygen gas; and this is the beſt method hitherto diſcovered of obtaining that gas in a ſtate of purity. According to Mr Hoyle, it contains about half its weight of concrete oxygen †.

When mixed with charcoal, iron, and many other combuſtibles, and heated, it detonates with aſtoniſhing violence. This property induced the French chemiſts to propoſe it as a ſubſtitute for nitre in the preparation of gunpowder. The attempt was made at Eſſons in 1788; but no ſooner had the workmen begun to triturate the mixture of charcoal, ſulphur, and oxy-muriat, than it exploded with violence, and proved fatal to Mr Letors and Mademoiſelle Chevraud. The force of this gunpowder when it is prepared is much greater than that of the common ſort of powder; but the danger of preparing it, and even of uſing it after it is prepared, is ſo great, that it can hardly ever be ſubſtituted with advantage for common gunpowder.

Fourcroy and Vauquelin aſcertained by experiment, that this ſalt exploded when triturated with ſulphur, charcoal, antimony, arſenic, cinnabar, ſugar, gums, oils, alcohol, ether, and ſulphuret of iron. When theſe ſubſtances were mixed, and ſtruck with a hammer, the exploſion took place. The theory of theſe exploſions was firſt pointed out by Mr Berthollet. The oxygen of the oxy-muriatic acid combines with the combuſtible, and at the ſame time lets go a quantity of caloric; and trituration or percuſſion acts merely by bringing the particles which combine within the ſphere of each others attraction.

723 Oxy-muriat of ſoda,

2. Oxy-muriat of ſoda. This ſalt was diſcovered at the ſame time by Mr Berthollet. Its properties are the ſame with the laſt, except that it is too deliqueſcent to be uſed.

3. Oxy-muriat of ammonia.—This combination is impoſſible. The oxy-muriatic acid and ammonia decompoſe each other.

724 Oxy-muriat of barytes, lime, magneſia,

4. Oxy-muriat of barytes.
5. ——— ——— lime.
6. ——— ——— magneſia.

} Theſe ſalts were diſcovered by Berthollet alſo. They all poſſeſs the property of detonating with combuſtibles, and of being reduced by that means to the ſtate of common muriats. Mr Tennant has lately propoſed the oxy-muriat of lime as a ſubſtitute for the other ſubſtances formerly uſed in the new mode of bleaching; particularly for bleaching printed cottons: And, as far as we can learn, it anſwers the purpoſe remarkably well (z).

725 Oxy-muriat of mercury,

7. Oxy-muriat of mercury.—This ſalt was formerly called *corroſive ſublimate*, and afterwards *corroſive muriat of*

(z) We have been informed, that this ſalt had been uſed by bleachers in Scotland ſome years before Mr Tennant propoſed it.

* *Pelletier, Ann. de Chim.* xii. 225.

† *Bergman.*

‡ *Bergman,* ii. 293.

§ *Bergman.*

‖ *Fourcroy, Ann de Chim.* xiv. 47.

* *Hoyle, Nicholſon's Journal,* ii. 292.

† *Ibid.*

Oxy-muriat.

of mercury. Berthollet firſt pointed out the nature of its compoſition.

This ſalt was mentioned by Rhaſes in the 10th century; and it ſeems to have been known in the eaſt at a much earlier period (A). The methods of preparing it uſed by the older chemiſts were numerous, complicated, and generally concealed as ſecrets. We ſhall not attempt, therefore, to give any account of them; and the methods uſed by later chemiſts have been deſcribed at conſiderable length in the article CHEMISTRY (*Encycl.* n° 815.)

It may be prepared by diſſolving mercury in a ſufficient quantity of oxy-muriatic acid, or by diſſolving red oxide of mercury in common muriatic acid.

When carefully cryſtallized, this ſalt aſſumes the form of cubes or oblique parallelopipeds, or rather quadrangular priſms, with ſides alternately narrower, and terminated by two inclined planes meeting together.

It has an exceedingly diſagreeable metallic taſte.

It is ſoluble in 19 times its weight of water at the temperature of 50°*. Boiling water, according to Macquer, diſſolves half its weight of it. Alcohol, at the temperature of 70°, diſſolves $\frac{3}{8}$ths of its weight of this ſalt †.

* *Spielman.*

† *Macquer.*

It does not attract moiſture from the air.

It is ſoluble in ſulphuric, nitric, and muriatic acids.

When triturated with $\frac{3}{4}$ths of its weight of mercury and a little water, and then ſublimed, it forms a white inſipid ſalt, called formerly *calomel* or *ſweet mercury*: This, as Scheele has proved, is preciſely the ſame with common muriat of mercury.

The theory of theſe two preparations is now pretty obvious. The experiments of Adet and Pelletier have ſhewn, that oxy-muriatic acid may be obtained from corroſive muriat of mercury ‡. We may conclude, therefore, with confidence, that the ſalt is an oxy-muriat. It cannot be prepared by means of common muriatic acid, except with red oxide of mercury, or ſome other ſubſtance from which it may abſorb oxygen. When pure mercury is added to oxy-muriat, it ſeizes the oxygen from the oxy-muriat, and the whole is converted into common muriat.

‡ *Ann. de Chim.* i. 1. and xii. 225.

It is decompoſed by

Tartar,
Moſt metals.

726 Oxy-muriat of tin.

8. Oxy-muriat of tin. When an amalgam of tin is triturated with its own weight of corroſive muriat of mercury, and the mixture is diſtilled in a glaſs retort by means of a very gentle heat, there paſſes over a thick white ſmoke, which condenſes into a colourleſs liquor that emits copious fumes, and has been called, in conſequence, *ſmoking liquor of Libavius*. This liquor was examined by Mr Adet. He found, that when about $\frac{1}{3}$d part of water was added to this liquor, it ceaſed to fume, and aſſumed a cryſtalline form; that then it might even be made red hot without ſubliming. It therefore owes its volatility to want of water, or rather to a ſtrong attraction for water. He found that this ſubſtance was capable of diſſolving, and therefore of oxidating more tin, without the emiſſion of any hydrogen, and conſequently without the decompoſition of water; he concluded from this, that it was compoſed of oxy-muriatic acid and tin *. This has been completely proved by Mr Pelletier, who found that when oxide of tin was combined with oxy-muriatic acid, it formed a compound preciſely the ſame with the ſmoking liquor of Libavius †.

Phoſphats.

* *Ann. de Chim.* i. 3.

† *Ann. de Chim.* xiii. 225.

This ſalt may be prepared, as Pelletier has proved, by diſſolving tin in muriatic acid, and then ſaturating it with oxy-muriatic acid gas.

It is uſed in dyeing.

727 Oxy-muriat of iron.

9. Oxy-muriat of iron. This ſalt is deliqueſcent; colourleſs; of a pure bitter taſte, without any of the ſweet aſtringency of the common ſalts of iron ‡.

‡ *Lambe, Mancheſter Mem.* v. p. 1.

Few of the other oxy-muriats have been hitherto examined with attention: Many of the metals, indeed, have been diſſolved in aqua-regia; but in moſt of theſe ſolutions the ſalt produced is a common muriat. The nitric acid ſupplies oxygen, and the muriatic acid diſſolves the oxide.

SECT. VII. *Of Phoſphats.*

THOSE ſalts, into which phoſphoric acid enters as an ingredient, are called *phoſphats*. This claſs of ſalts was firſt diſcovered by Margraf.

728 Phoſphat of potaſs,

1. Phoſphat of potaſs. This ſalt cryſtallizes in ſhort tetrahedral priſms, terminated by quadrangular pyramids.

It is very ſoluble in cold water, and ſtill more ſo in hot water.

It decrepitates on ignited coals like common ſalt. When a very ſtrong heat is applied, it melts into an opaque vitreous maſs, ſtill ſoluble in water.

The following ſalts decompoſe it by compound affinity:

Sulphat of lime,
Nitrat of mercury,
Muriat of mercury,
Acetite of lead.

729 Phoſphat of ſoda,

2. Phoſphat of ſoda.—Dr Pearſon, who firſt formed this ſalt, gives the following proceſs for preparing it;

Diſſolve in a long-necked matraſs 1400 grains of cryſtallized carbonat of ſoda in 2100 grains of water at the temperature of 150°. Add gradually 500 grains of phoſphoric acid of the ſpecific gravity 1,85. Boil the liquor for ſome minutes; and while it is boiling hot, filtrate it, and pour it into a ſhallow veſſel. Let it remain in a cool place, and cryſtals will continue to form for ſeveral days. From the above quantities of materials he has obtained from 1450 to 1550 grains of cryſtals.

Its cryſtals are rhomboidal priſms, of which the acute angles are 60°, and the obtuſe angles 120°, terminated by a three-ſided pyramid.

Its taſte is almoſt the ſame with that of common ſalt.

It is ſoluble in water. When expoſed to the air it effloreſces.

This ſalt has been introduced into medicine as a purgative, and on account of its pleaſant taſte has of late been much uſed. It is uſually taken in broth, which it is employed to ſeaſon inſtead of common ſalt.

Hellot remarked a particular ſalt in urine, different from thoſe that had uſually been obſerved, in 1737. Haupt deſcribed it in 1740 under the name of *ſal mirabile*

(A) If we liſten to Junker, the ancients applied the name *mercurium* to this ſalt; mercury they called *argentum vivum*.

rabile perlatum, or *wonderful perlated ſalt*. It was called *perlated* from the grey, opaque, pearl-like colour which it aſſumed when melted by the blow-pipe. Margraf deſcribed it in 1745, and found it would not yield phoſphorus when treated with charcoal, as the other ſalts of urine did. Rouelle the Younger analyſed it in 1776, and concluded from his experiments that it was a compound of phoſphoric acid and ſoda; but Mr Prouſt, being unable to obtain phoſphorus from it, concluded, that it did not contain phoſphoric acid, but another acid analogous to the boracic. To this ſubſtance, which Mr Prouſt actually obtained, Bergman gave the name of *perlated acid*, and Morveau afterwards called it *ouretic acid*. But Mr Klaproth ſoon afterwards analyſed it, and proved that it conſiſted of ſoda ſuperſaturated with phoſphoric acid. Scheele ſoon after made the ſame diſcovery. This acid of Mr Prouſt, then, is merely phoſphat of ſoda combined with phoſphoric acid, or *acidulous phoſphat of ſoda*.

730 Phoſphat of ammonia,

3. Phoſphat of ammonia.—This ſalt forms oblong-pointed cryſtals, or, as Mr Lavoiſier affirms, cryſtals reſembling thoſe of alum.

It is ſoluble in water. Heat evaporates it ſo eaſily, that it is difficult to obtain it in cryſtals except by adding an exceſs of alkali.

Microcoſmic ſalt, or ſalt of urine, is merely a mixture of theſe two laſt deſcribed ſalts.

731 Of barytes,

4. Phoſphat of barytes.—This ſalt is inſoluble in water[*].

732 Of lime,

5. Phoſphat of lime.—This ſalt is taſteleſs, and almoſt perfectly inſoluble in water. It forms the baſis of bones, and is therefore often called *earth of bones*. Wenzel obſerved it cryſtallize when held in ſolution by phoſphoric acid.

It is decompoſed by ſulphat of ammonia[†].
Carbonat of potaſs[‡],
——— ſoda[§].

733 Of ſtrontites,

6. Phoſphat of ſtrontites.—This ſalt was firſt formed by Dr Hope. It is a white powder ſoluble in 1920 parts of boiling water[||].

734 Of magneſia,

7. Phoſphat of magneſia.—This ſalt does not cryſtallize except with exceſs of acid, and then the cryſtals are very ſmall. Somewhat longer cryſtals may be formed by dropping phoſphoric acid into acetite of magneſia. It moſt commonly forms by evaporation a gummy maſs. It is ſoluble in alcohol[¶].

It is inſoluble in nitric acid. It melts by a ſtrong heat into a porcelain-like ſubſtance[*].

735 Of alumina,

8. Phoſphat of alumina.—This is a ſaline powder, inſoluble in water. Diſſolved in phoſphoric acid, it yields a gritty powder, and a gummy ſolution, which by heat is converted into a tranſparent glaſs.

736 Of iron,

9. Phoſphat of iron.—This ſalt is merely a dry adheſive maſs, inſoluble in water, but ſoluble in acids. With exceſs of acid, it forms cryſtals which do not deliqueſce, and by heat are converted into a garnet-coloured glaſs[†].

737 Of zinc,

10. Phoſphat of zinc.—It does not cryſtallize, but when evaporated becomes a gummy maſs, which may be melted into a tranſparent glaſs[‡].

738 Of mangancſe,

11. Phoſphat of mangancſe.—The ſolution of the oxide of mangancſe in phoſphoric acid is reddiſh, but becomes white on expoſure to the air.

739 Of nickel,

12. Phoſphat of nickel.—It is greeniſh, and does not cryſtallize[§].

740 Of arſenic,

13. Phoſphat of arſenic.—It cryſtallizes in ſmall grains hardly ſoluble in water[*].

741 Of uranium,

14. Phoſphat of uranium.—Firſt formed by Klaproth. It does not cryſtallize, but aſſumes the appearance of yellowiſh white flakes, difficultly ſoluble in water.

742 James's powder.

15. Phoſphat of antimony and lime.—Dr Pearſon has diſcovered, that the well known medicine called *James's Powder* is a triple ſalt, compoſed of phoſphoric acid, oxide of antimony, and lime. It is very inſoluble in water.

The remaining phoſphats are ſcarcely known.

SECT. VIII. *Of Borats.*

THE compounds into which the boracic acid enters are called *borats*.

743 Borat of potaſs,

1. Borat of potaſs.—This ſalt, formed by combining boracic acid and potaſs, is very little known. Baron firſt formed it. Borat of potaſs cryſtallizes, is ſoluble in water, and may be melted into a vitreous maſs, ſoluble in water.

744 Of ſoda,

2. Borat of ſoda or borax.—This ſalt is brought from the Eaſt Indies in an impure ſtate under the name of *tinkal*. When purified in Europe, it takes the name of *borax*.

Its cryſtals are hexangular priſms, of which two ſides are much broader than the remainder, terminated by triangular pyramids. It is of a white colour. Its ſpecific gravity is 1,740.

Its taſte is ſtyptic and alkaline.

It is ſoluble in 18 times its weight of water of the temperature of 60°, and 6 times its weight of boiling water.

It is compoſed, according to Bergman, of 17 parts of ſoda, 39 of acid, and 44 of water.

When expoſed to the air, it effloreſces ſlowly and ſlightly.

When heated, it ſwells, loſes about four-tenths of its weight, becomes ropy, and then aſſumes the form of a light, porous, and very friable maſs, known by the name of *calcined borax*; it then melts into a tranſparent glaſs, ſtill ſoluble in water.

By compound affinity it is decompoſed by
Nitrat of mercury[†].

When two pieces of borax are ſtruck together in the dark, a flaſh of light is emitted[‡].

Borax has the property of facilitating the fuſion of a great number of bodies. This property renders it uſeful in glaſs-making, in aſſaying ores, and in ſoldering metals.

Borax turns ſyrup of violets green; it appears therefore to be ſuperſaturated with alkali.

The real borat of ſoda, or the ſalt in which boracic acid and ſoda ſaturate each other, has not yet been examined with attention. According to Dr Withering, ſoda requires twice its weight of boracic acid to ſaturate it.

745 Of ammonia,

3. Borat of ammonia.—This ſalt has been examined only by Mr Fourcroy.

Its cryſtals are polyhedral pyramids.

It has a poignant urinous taſte, and turns ſyrup of violets green. It diſſolves readily enough in water. When expoſed to the air, it gradually loſes its cryſtalline form and becomes brown[§].

4. Borat

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[*] Morveau.

[†] Dellefskamp Ann. de Chim. vi. 37.

[‡] Bergman.

[§] Id.

[||] Dr Hope, Tranſ. Edin. iv. 16.

[¶] Bergman, ii. 390.

[*] Wenzel.

[†] Id.

[‡] Id.

[§] Bergman, ii. 268.

[*] Bergman, ii. 290.

[†] Bergman.

[‡] Accum, Nicholſon's Journal, ii. 28.

[§] Fourcroy's Chemiſtry, Part ii. ch. 4.

Borats.

4. Borat of barytes.—Unknown.

746 Of lime,
5. Borat of lime.—It is difficultly ſoluble in water, and did not cryſtallize with Beaumé.

747 Of ſtrontites,
6. Borat of ſtrontites.—This ſalt was firſt formed by Dr Hope.—It is a white powder, ſoluble in about 130 parts of boiling water. The ſolution turns the ſyrup of violets green *.

* *Hope, Tranſ. Edin.* iv. 17.

748 Of magneſia,
7. Borat of magneſia.—It aſſumes the appearance of ſmall irregular cryſtals. It is ſoluble in acetous and formic acids. Alcohol decompoſes it. It melts eaſily in the fire without being decompoſed †.

† *Bergman*, ii. 386.

749 Of alumina,
8. Borat of alumina.—It does not cryſtallize, and is ſcarcely ſoluble in water.

750 Of iron,
9. Borat of iron.—Its cryſtals are of a yellow colour, but the ſalt has never been examined with attention.

751 Of zinc,
10. Borat of zinc.—This ſalt does not appear to be capable of cryſtallizing. By heat, it melts into a light green inſoluble ſlag ‡.

‡ *Reuſs.*

752 Cobalt,
11. Borat of cobalt.—When oxide of cobalt is melted with boracic acid, a bluiſh grey ſlag is produced. This, by lixiviation and evaporation, yields cryſtals of a reddiſh white colour and ramified form §.

§ *Id.*

753 Nickel,
12. Borat of nickel.—A ſaline ſubſtance difficultly ſoluble ‖.

‖ *Bergman.*

754 Lead,
13. Borat of lead.—When boracic acid and red oxide of lead are melted together, the product is a fine greeniſh yellow, tranſparent, hard, inſoluble glaſs ¶.

¶ *Reuſs.*

755 Tin,
14. Borat of tin.—When equal parts of boracic acid and tin filings are melted together, the product diſſolved in water yields by evaporation tranſparent white polygonous cryſtals.

756 Copper,
15. Borat of copper.—When borax is poured into a ſolution of ſulphat of copper, borat of copper is precipitated in the form of a pale light green jelly, which when dried is with great difficulty ſoluble in water. It eaſily melts into a dark red vitreous ſubſtance *. According to Palm, by long trituration of filings of copper and boracic acid in water, and then digeſting the mixture, it diſſolves, and cryſtals may be obtained from it.

* *Bergman.*

757 Biſmuth,
16. Borat of biſmuth.—A white powder, which melts into a white tranſparent permanent glaſs †.

† *Wenzel.*

758 Arſenic,
17. Borat of arſenic.—White oxide of arſenic and boracic acid form a ſalt ſoluble in water and cryſtallizable ‡.

‡ *Reuſs.*

Sect. IX. *Of Fluats.*

Those ſalts into which fluoric acid enters are called *fluats*. They were firſt formed by Scheele.

759 Fluat of potaſs,
1. Fluat of potaſs. It forms a gelatinous maſs almoſt without taſte.

It diſſolves readily in water. When expoſed to the fire it melts without any ebulition §.

§ *Scheele* on *Fluor.*

760 Soda,
2. Fluat of ſoda. This ſalt reſembles exactly the fluat of potaſs ‖.

‖ *Ibid.*

761 Ammonia,
3. Fluat of ammonia. It cryſtallizes in ſmall priſms. It is deliqueſcent, and is partly decompoſed by heat ¶. It is decompoſed by

Nitrat of mercury,
——— — ſilver,
——— — lead.

¶ *Wiegleb.*

762 Barytes,
4. Fluat of barytes. A powder which requires a large quantity of water to diſſolve it *.

* *Bergman.*

763 Lime,
5. Fluat of lime. This ſalt abounds in nature. It is known by the name of fluor ſpar.

It cryſtallizes moſt commonly in the form of cubes. It is taſteleſs and nearly inſoluble in water.

It is not altered by the air. Its ſpecific gravity is about 3,1.

When expoſed to a ſudden heat it decrepitates. A very violent heat melts it into a white opaque maſs.

When reduced to powder and heated it becomes phoſphoreſcent; but it loſes this quality altogether if it be heated red hot.

6. Fluat of ſtrontites. This ſalt was formed by Dr Hope: but its properties have not been examined.

764 Magneſia,
7. Fluat of magneſia.—It is not ſoluble in water except there be an exceſs of acid. In that caſe, by ſpontaneous evaporation, it forms hexagonal priſms, terminated by a low pyramid compoſed of three rhomboidal ſides.

These cryſtals are hardly ſoluble in water. Alcohol diſſolves a ſmall portion of them. Heat does not decompoſe them *.

* *Bergman*, ii. 384.

765 Alumina,
8. Fluat of alumina. A ſaline maſs; which is ſweetiſh, clammy, and gelatinous.

766 Silica,
9. Fluat of ſilica. Little is known concerning this ſingular combination, except that it can exiſt in a gaſeous form, and that it depoſites ſilica in cryſtals after a certain time.

10. Fluat of ſilica and potaſs or ſoda. This triple ſalt may be formed by pouring fixed alkali into a ſolution of fluat of ſilica. It contains an exceſs of acid. On evaporation it yields a kind of jelly, which when dry ſeparates into gritty particles like ſand. It is ſoluble in 96 parts of hot water. In the fire it readily melts into a white maſs. If the heat be continued the acid ſeparates, and there remains a tranſparent glaſs, which is ſoluble in water, and forms a *liquor ſilicum* †.

† *Scheele, Crell's Journal*, i. 207. Eng. Tranſl.

11. Fluat of iron. It is incryſtallizable; but when evaporated leaves a hard maſs.

12. Fluat of zinc. It reſembles that of iron.

767 Metallic fluats.
13. Fluat of manganeſe. It may be formed by pouring fluat of ammonia into a ſolution of oxide of zinc in any of the three mineral acids. It cryſtallizes.

14. Fluat of cobalt. A yellow gelatinous maſs.

15. Fluat of nickel. It affords green cryſtals.

16. Fluat of lead. A ſweet taſted powder.

17. Fluat of tin. A nauſeous taſted jelly.

18. Fluat of copper. Blue cryſtals; ſome of them oblong, others cubic.

19. Fluat of arſenic. Small cryſtals.

20. Fluat of mercury. A powder. Before the blowpipe it melts into a yellow glaſs, moſt of which evaporates by a continued heat ‡.

‡ *Scheele* on *Fluor.*

Sect. X. *Of Carbonats.*

The compounds into which the carbonic acid enters are called *carbonats*. They were firſt analyſed by Dr Black.

768 Carbonat of potaſs.
1. Carbonat of potaſs. This ſalt is formed by ſaturating potaſs with carbonic acid, which is beſt done by expoſing a ſolution of potaſs for a conſiderable time to carbonic acid gas.

It cryſtallizes, according to Bergman, in quadrangular priſms; the apexes of which are compoſed of two inverted triangles, converging like the roof of a houſe ‖. According to Pelletier they are tetrahedral rhomboidal priſms, with dihedral ſummits. The complete cryſtal has eight faces, two hexagons, two rectangles, and four rhombs ¶.

‖ *Bergman.*

* *Ann. de Chim.* xv. 39.

It

It has an alkaline, but not a cauſtic taſte.

It is ſoluble at the common temperature in about four times its weight in water *. Boiling water diſſolves $\frac{5}{6}$ths of its weight †. Alcohol, even when hot, does not diſſolve above $\frac{1}{1200}$ parts of it.

According to Bergman, it is compoſed of 48 parts of potaſs, 20 of acid, and 32 of water. According to Pelletier, of 43 parts of acid, 40 of potaſs, and 17 of water. Bergman under-rated the quantity of acid from not obſerving that the ſalt loſes part of its acid when heated. Even ſolution in hot water produces a ſeparation of ſome acid ‡.

It is not altered by expoſure to the air.

Heat deprives it of its water and part of its acid, but does not decompoſe it completely. The following ſalts decompoſe it by compound affinity :

Sulphat of lime,
——— barytes,
——— ſoda,
——— ammonia,
——— magneſia,
——— alumina,
Muriat of barytes,
——— lime,
——— ammonia,
——— magneſia,
——— alumina,
——— ſoda §,
Nitrat of lime,
Nitrat of barytes,
——— ſoda,
——— ammonia,
——— magneſia,
——— alumina,
Acetite of barytes,
——— lime,
——— ammonia,
——— magneſia,
——— alumina,
Oxy-muriat of mercury,
Phoſphat of lime ‖.

When potaſs is ſaturated with carbonic acid it always lets fall a quantity of ſilica. Mr Pelletier has propoſed this ſaturation as the beſt method of purifying potaſs from that earth.

769 Carbonat of ſoda,

2 Carbonat of ſoda. This ſalt may be formed in the ſame manner with carbonat of potaſs.

Its cryſtals are five-ſided priſms, with one of the angles frequently truncated, ſurmounted by dihedral pyramids with rhomboidal faces.

Its taſte is preciſely the ſame with that of carbonat of potaſs.

It is ſoluble in double its weight of cold water.

It is compoſed, according to Bergman, of 16 parts of acid, 20 of alkali, and 64 of water.

It effloreſces when expoſed to the air. Heat is incapable of decompoſing it completely ¶.

The following ſalts decompoſe it by compound affinity :

Sulphat of ammonia,
——— barytes,
——— lime,
——— magneſia‡,
——— alumina,
Muriat of barytes,
——— ammonia,
——— lime,
——— magneſia,
——— alumina,
Acetite of barytes,
——— ammonia,
——— lime,
——— magneſia,
——— alumina,
Nitrat of ammonia,
——— magneſia,
——— alumina,
——— lead*,
Phoſphat of lime †.

770 Carbonat of ammonia,

3. Carbonat of ammonia. This ſalt forms octahedral cryſtals, having for the moſt part their two oppoſite apexes truncated ‡.

Its taſte and ſmell, though much weaker, are the ſame with thoſe of pure ammonia. Like all the alkaline carbonats it converts vegetable blues to green, preciſely as pure alkalies do.

It is ſoluble in rather leſs than twice its weight of cold water. Hot water diſſolves its own weight of it.

According to Bergman it is compoſed of 43 parts of alkali, 45 of acid, and 12 of water.

When expoſed to the air it becomes ſomewhat moiſt.

The ſmalleſt heat is ſufficient to evaporate it.

The following ſalts decompoſe it by compound affinity:

Sulphat of alumina,
Nitrat of lime,
Muriat of lime,
——— magneſia,
——— alumina,
Acetite of barytes,
——— lime,
——— magneſia,
——— alumina.

771 Carbonat of barytes,

4. Carbonat of barytes. This ſalt has been found native.

Its cryſtals have been obſerved to aſſume four different forms; double ſix-ſided and double four-ſided pyramids, ſix-ſided columns terminated by a pyramid with the ſame number of faces, and ſmall radiated cryſtals $\frac{1}{2}$ an inch in length, and very thin, appearing to be hexagonal priſms, rounded towards the point.

Cold water diſſolves $\frac{1}{2304}$ part, and boiling water $\frac{1}{1304}$ part of this ſalt. Water ſaturated with carbonic acid diſſolves $\frac{1}{830}$th part*.

According to Dr Withering, who firſt diſcovered it native, it is compoſed of 80 parts of barytes and 20 of acid. Bergman informs us, that artificial carbonat is compoſed of 7 parts of acid, 28 of water, and 65 of earth †.

It is not altered by expoſure to the air.

It is decompoſed by the application of a very violent heat ‡.

By compound affinity it is decompoſed by the following ſalts :

Sulphat of ſoda,
——— lime,
——— ammonia,
——— magneſia,
——— alumina,
Nitrat of ſoda,
——— lime,
——— ammonia,
——— magneſia,
Nitrat of alumina,
Muriat of lime,
——— ammonia,
——— magneſia,
——— alumina,
Acetite of lime,
——— magneſia,
——— alumina.

772 Carbonat of lime.

5. Carbonat of lime. This ſubſtance, under the names of marble, chalk, lime ſtone, &c. exiſts in great abundance in nature, variouſly mixed with other bodies.

When pure, it is of a white colour, and has very little taſte.

It is inſoluble in pure water; but water ſaturated with carbonic acid diſſolves $\frac{1}{1500}$ part of it ; from this ſolution it gradually precipitates as the acid leaves it in the form of ſmall rhomboidal cryſtals §.

It is compoſed, according to Bergman, of 34 parts of acid, 11 of water, and 55 of lime.

It ſuffers little or no alteration by being expoſed to the air.

When expoſed to heat, it firſt loſes its water, and afterwards its acid ſeparates as the heat is increaſed : But to ſeparate the acid completely, a very ſtrong heat is required.

The following ſalts decompoſe it by compound affinity :

Sulphat of alumina,
——— copper.

773 Carbonat of ſtrontites,

6. Carbonat of ſtrontites. This ſalt, which was firſt examined by Dr Hope, is inſipid, and ſoluble in 1536

parts

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* Bergman, i. 13.

† Pelletier.

‡ Id.

§ Bergman.

‖ Id.

¶ Bergman, i. 18.

‡ Bergman.

* Id.

† Id.

‡ Bergman, i. 21.

* Fourcroy, Ann. de Chim. iv. 64.

† Bergman, i. 21.

‡ Dr Hope.

§ Bergman, i. 21.

parts of boiling water. It is compoſed of 30,2 parts of acid, 69,8 of ſtrontites. A violent heat decompoſes it *.

774 Carbonat of magneſia. 7. Carbonat of magneſia. This ſalt may be formed by ſaturating the common magneſia of the ſhops with carbonic acid gas.

It diſſolves in water ſaturated with carbonic acid; and forms by evaporation cryſtals, which are tranſparent hexagonal priſms, terminated by a hexagonal plane; theſe are partly in groups and partly ſolitary: their length is about ſix lines, their breadth two †. They were diſcovered by Mr Butini of Geneva.

Water at the temperature of 50 diſſolves $\frac{1}{18}$ part of its weight of this ſalt ‡. When in the ſtate of powder, and of courſe deprived of its water of cryſtallization, it is much more inſoluble; and what is very remarkable, it is more ſoluble in cold than in hot water, impregnated with carbonic acid §.

It is compoſed, according to Fourcroy, of 50 parts of acid, 25 of magneſia, and 25 of water.

When expoſed to the air, it effloreſces, and falls into powder ||.

When heated, it decrepitates, falls into powder, and is decompoſed ¶.

The following ſalts decompoſe it by compound affinity:

Sulphat of lime,
——— ammonia,
——— alumina,

Nitrat of lime,
Muriat of lime,
Acetite of lime.

775 Carbonat of alumina. 8. Carbonat of alumina. Carbonic acid is capable of diſſolving alumina; for if alum be decompoſed by an alkaline carbonat, ſome alumina remains diſſolved in the liquor, and may be precipitated by a heat ſufficient to drive off the carbonic acid *. It cannot be doubted, then, that there may be produced a carbonat of alumina; but the ſalt has never been examined with accuracy.

776 Metallic carbonats. 9. Carbonat of iron. Water ſaturated with carbonic acid diſſolves $\frac{1}{10500}$ part of its weight of iron, which gradually precipitates by expoſure to the air †. Ruſt of iron is a kind of carbonat, at leaſt it always contains carbonic acid.

10. Carbonat of zinc. Zinc is copiouſly diſſolved by water ſaturated with carbonic acid ‡. As the metallic oxides, when ſaturated with carbonic acid, do not differ materially in their appearance from pure oxides, we ſhall not attempt to deſcribe any of the metallic carbonats. We ſhall, however, preſent our readers with the following Table, exhibiting a view of the weight which metallic oxides gain by being ſaturated with this acid.

	By Bergman.	By Wenzel.
	Precipitated by	
	Carb. of Soda.	Carb. of Potaſs.
100 parts of	Weight.	Weight.
Oxide of zinc,	100,930	100,774
iron,	100,250	100,863
mangaueſe,	100,800	
cobalt,	100,600	
nickel,	100,350	
lead,	100,320	100,304
tin,	100,310	100,345
copper,	100,940	100,884
biſmuth,	100,300	100,224
antimony,	100,400	100,395
mercury,	100,100	100,062
ſilver,	100,290	100,288
gold,	100,060	100,326

* Hope, Tranſ. Edin. iv. 5.

† Butini ſur la Magneſie.

‡ Fourcroy, Ann. de Chim. ii. 298.

§ Butini.

|| Fourcroy, ibid.

¶ Id. ibid.

* Bergman, i. 11.

† Bergman, i. 33.

‡ Ibid.

Quantity of loſs by driving off the gas by ſolution according to Wenzel:

Zinc,	0,137
Iron,	0,009
Cobalt,	0,352
Lead,	0,157
Tin,	0,000
Copper,	0,174
Biſmuth,	0,056
Antimony,	0,000
Mercury,	0,038
Silver,	0,158
Gold,	0,144

Theſe determinations differ too widely from each other to be exact. It is obvious that part of the weight muſt be owing to adhering water, and very probably triple ſalts are formed, which muſt render the determination ſtill more erroneous.

Sect. XI. *Of Acetites.*

The compounds which the acetous acid forms are called *acetites*.

777 Acetite of potaſs. 1. Acetite of potaſs. Pliny is ſuppoſed, but probably without any reaſon, to have been acquainted with this ſalt, becauſe he recommends a mixture of vinegar and vine aſhes as a cure for a particular ſpecies of tumor *. It was firſt clearly deſcribed by Raymond Lully. It has received a great number of names; as, for inſtance, *arcanum tartari*, *ſecret foliated earth of tartar*, *eſſential ſalt of wine*, *regenerated tartar*, *diuretic ſalt*, *digeſtive ſalt of Sylvius*.

Its cryſtals are very white, and aſſume the form of thin plates.

It has a ſharp warm taſte.

It is ſoluble in about ten times its weight of water at the temperature of 60° †. It is ſoluble alſo in alcohol.

According to Wenzel, 240 parts of acetous acid require for ſaturation $241\frac{4}{9}$ths of potaſs. And from the experiments of Dr Higgins, it appears that acetite of potaſs is compoſed of 61,5 parts of alkali and 38,5 of acetous acid and water ‡.

When expoſed to the air it is very deliqueſcent.—When heated, it melts as readily as wax; and if a very ſtrong heat be applied, the acid is decompoſed.

The following ſalts decompoſe it by compound affinity:

Sulphat of ſoda,
——— lime,
——— ammonia,
——— magneſia,
——— alumina,
Nitrat of ſoda,
——— lime,

Nitrat of ammonia,
——— magneſia,
——— alumina,
——— biſmuth,
——— mercury,
Muriat of ammonia,
——— alumina.

778 Acetite of ſoda. 2. Acetite of ſoda. This ſalt was firſt deſcribed by Mr Baron.

Its cryſtals are ſtriated priſms, not unlike thoſe of ſulphat of ſoda.

It has a ſharp taſte, approaching to bitter.

It is ſoluble in 2,86 parts of water at the temperature of 60° §.

According to Wenzel, 440 parts of acetous acid require for ſaturation $157\frac{1}{7}$ths of ſoda.

It is not affected by expoſure to the air.

When heated, it firſt loſes its water of cryſtallization;

* Plinii, l. xxiii. præmium.

† Bergman, v. 78.

‡ On Acetous Acid, p. 8.

§ Bergman, ibid.

in a ſtrong heat it melts; and in a ſtill ſtronger, its acid is deſtroyed. This ſalt can only be obtained in cryſtals when there is an exceſs of alkali in the ſolution.

The following ſalts decompoſe it by compound affinity :

Sulphat of ammonia,
——— alumina,
Nitrat of ammonia,
——— magneſia,
Nitrat of alumina,
Muriat of lime,
——— ammonia,
——— magneſia.

779
Acetite of ammonia.

3. Acetite of ammonia. This ſalt was formerly called *ſpirit of Mindererus*.

It is too volatile to be eaſily cryſtallized : It may, however, by gentle evaporation, be made to depoſite needle-ſhaped cryſtals. Mr de Laſſone cryſtallized it by ſublimation *. When the ſublimation is ſlow, it forms long, ſlender, flatted cryſtals, terminating in ſharp points, of a pearl white colour, and about an inch and eight-tenths in length †.

It impreſſes the tongue at firſt with a ſenſe of coldneſs, and then of ſweetneſs, which is followed by a taſte reſembling that of a mixture of ſugar and nitre, in which the ſweet does not predominate over the mawkiſh taſte of the nitre ‡.

According to Wenzel, 240 parts of acetous acid ſaturate 244 of ammonia.

It is very deliqueſcent. It melts at 170°, and ſublimes at about 250° §.

When a watery ſolution of this ſalt is diſtilled, there comes over firſt a quantity of ammonia, next a quantity of acetous acid, and at laſt of the neutral ſalt itſelf. No ſuch decompoſition takes place when the cryſtals are diſtilled by a moderate heat ‖.

The following ſalts decompoſe acetite of ammonia by compound affinity :

Sulphat of alumina,
Carbonat of potaſs,
Carbonat of ſoda,
Nitrat of ſilver ¶.

780
Acetite of barytes.

4. Acetite of barytes. This ſalt was firſt formed by Mr Morveau.

It is not eaſily cryſtallized. Morveau procured it in long priſms in groups.

It has a pleaſant, ſomewhat acid taſte, and always contains an exceſs of acid.

It is ſoluble in water, and does not deliqueſce when expoſed to the air *.

The following ſalts decompoſe it by compound affinity :

Sulphat of potaſs,
——— ſoda,
——— lime,
——— ammonia,
——— magneſia,
——— alumina,
Nitrat of potaſs,
——— ſoda,
——— lime,
——— ammonia,
——— magneſia,
Nitrat of alumina,
Muriat of potaſs,
——— ſoda,
——— lime,
——— ammonia,
——— magneſia,
——— alumina,
Carbonat of potaſs,
——— ſoda,
——— ammonia.

781
Acetite of lime.

5. Acetite of lime. This ſalt was firſt deſcribed accurately by Crollius. The ancients, however, uſed a mixture of lime and vinegar in ſurgery †.

It cryſtallizes in fine needles, of a gloſſy appearance like ſatin.

Its taſte is bitter and ſour, becauſe it has an exceſs of acid.

It is ſoluble in water.

According to Wenzel, 240 parts of acetous acid require for ſaturation 125 of lime : according to Maret, 100 parts of acetite of lime contain 50 of lime *. From the experiments of Dr Higgins, it follows, that acetite of lime is compoſed of 35,7 parts of lime and 64,3 of acetous acid and water †.

It is not altered by expoſure to the air ; at leaſt Morveau kept ſome of it for a whole year merely covered with paper, and even quite uncovered for a month, without its undergoing any alteration ‡.

Heat decompoſes it, and at the ſame time partly decompoſes its acid.

The following ſalts decompoſe it by compound affinity :

Sulphat of ſoda,
——— ammonia,
——— magneſia,
——— alumina,
Nitrat of ammonia,
——— magneſia,
——— alumina,
Muriat of ammonia,
Muriat of alumina,
Carbonat of barytes,
——— potaſs,
——— ſoda,
——— ammonia,
——— magneſia,
——— alumina.

782
Acetite of ſtrontites.

6. Acetite of ſtrontites. This ſalt was firſt formed by Dr Hope. It forms ſmall cryſtals, which are not affected by expoſure to the atmoſphere. 49 parts of it are ſoluble in 120 parts of boiling water : It ſeems to be nearly as ſoluble in cold water. It renders vegetable colours green §.

783
Acetite of magneſia.

7. Acetite of magneſia. This ſalt was firſt mentioned by Mr Wenzel.

It is not cryſtallizable ; but forms by evaporation a viſcid maſs ‖.

It has a ſweetiſh taſte ; leaving, however, a ſenſe of bitterneſs ¶.

It is very ſoluble both in water and alcohol *.

According to Wenzel, 240 parts of acetous acid require for ſaturation $123\frac{3}{4}$ths of magneſia.

When expoſed to the air, it deliqueſces. Heat decompoſes it.

The following ſalts decompoſe it by compound affinity :

Sulphat of ammonia,
——— alumina,
Nitrat of ammonia,
——— alumina,
Muriat of ammonia,
——— alumina,
Carbonat of barytes,
——— potaſs,
——— ſoda,
——— ammonia,
——— alumina.

784
Acetite of alumina.

8. Acetite of alumina. This ſalt can only be formed by digeſting acetous acid on alumina recently precipitated.

By evaporation needle-ſhaped cryſtals are obtained, which are very deliqueſcent. According to Wenzel, 240 parts of acetous acid require $20\frac{5}{7}$ths of alumina for ſaturation.

This ſalt is decompoſed by compound affinity by the following ſalts :

Nitrat of ammonia,
Muriat of ammonia,
Carbonat of barytes,
Carbonat of potaſs,
——— ſoda,
——— ammonia.

785
Acetite of jargonia.

9. Acetite of jargonia. This ſalt may be formed by pouring acetous acid on newly precipitated jargonia. It has an aſtringent taſte. It does not cryſtallize ; but when evaporated to dryneſs, it forms a powder, which does not attract moiſture from the air as acetite of alumina does †. It is very ſoluble in water and in alcohol.

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* *Mem. Par.* i. 775.

† *Higgins on Acetous Acid*, p. 188.

‡ *Higgins, ibid*, p. 192.

§ *Ibid.*

‖ *Ibid.*

¶ *Ibid.* p. 193.

* *Morveau, Encyc. Method. Chim.* i. 8.

† *Plinii*, l. xxxvi. c. 24.

* *Encyc. Method. Chim.* i. 9.

† *On Acetous Acid*, p. 47.

‡ *Ibid. Encyc. Method.*

§ *Dr Hope, Tranſ. Edin.* iv. 14.

‖ *Bergman*, ii. 388.

¶ *Morveau, ibid.*

* *Bergman*, ii. 358.

† *Klaproth, Journ. de Phyſ.* xxxvi. 188.

hol. It is not ſo eaſily decompoſed by heat as nitrat of jargonia, probably becauſe it does not adhere ſo ſtrongly to water *.

786 Acetite of iron.

10. Acetite of iron.—This ſalt was mentioned by Schrœder and Juncker. It is compoſed of acetous acid and brown oxide of iron.

Its ſolution forms by gentle evaporation ſmall oblong cryſtals; but the greateſt part of the ſalt aſſumes the form of a gelatinous maſs †.

It has a ſweetiſh ſtyptic taſte.

According to Wenzel, 240 parts of acetous acid require for ſaturation $186\frac{1}{2}$ of iron.

Heat decompoſes this ſalt; and it ſeems alſo to be gradually decompoſed by expoſure to the air.

787 Acetite of zinc.

11. Acetite of zinc.—This ſalt was firſt mentioned by Glauber.

Its cryſtals are rhomboidal, and ſometimes hexagonal plates, of a white colour, and the appearance of talk.

It is ſoluble in water. According to Wenzel, 240 parts of acetous acid require for ſaturation $195\frac{5}{6}$ths of zinc.

It is not altered by expoſure to the air. Heat decompoſes it. When thrown upon burning coals, it explodes with a blue flame.

12. Acetite of mangaueſe.—This ſalt is not cryſtallizable; and when evaporated to dryneſs, it deliqueſces. Is it not an acetat?

788 Acetite of cobalt.

13. Acetite of cobalt.—This ſalt is deliqueſcent. Its ſolution is of a fine red colour while cold; but becomes blue by being heated, and it recovers its former colour on cooling. According to Wenzel, 240 parts of acetous acid require for ſaturation $241\frac{5}{7}$ths of cobalt.

789 Acetite of nickle.

14. Acetite of nickel.—This ſalt forms rhomboidal cubes of a green colour ‡: They are not deliqueſcent: Their taſte is ſweet §.

790 Acetite of lead.

15. Acetite of lead.—This ſalt is mentioned by Iſaac Hollandus and Raymond Lully. It is compoſed of acetous acid and white oxide of lead.

It was formerly called *ſugar of lead*, *ſugar of Saturn*, *ſalt of Saturn*, *vinegar of Saturn*, *extract of Saturn*, &c.

Its cryſtals are flat parallelopipeds, terminated by two inclined planes approaching each other.

It has a ſweet and ſomewhat aſtringent taſte.

It is not very ſoluble in water; but acetous acid diſſolves it abundantly.

According to Wenzel, 240 parts of acetous acid require for ſaturation 503 of lead.

When expoſed to the air it becomes yellow, but undergoes no other alteration.

Heat decompoſes it by deſtroying the acid. When diſtilled, the reſiduum takes fire ſpontaneouſly on expoſure to the air. Paper dipped into acetite of lead forms excellent matches, which are not ſubject to go out, and which burn very ſlowly.

The following ſalts decompoſe it by compound affinity:

Muriat of ammonia,	Phoſphat of ammonia,
Sulphat of copper,	Oxalat of potaſs ‖,
Phoſphat of ſoda,	Malat of potaſs ¶.

791 Acetite of tin.

16. Acetite of tin.—This ſalt was firſt deſcribed by Lemery.

Its cryſtals are priſmatic needles in groups *. According to Wenzel, 240 parts of acetous acid require for ſaturation $3\frac{5}{11}$ of tin.

792 Acetite of copper.

17. Acetite of copper.—This ſalt was known to the ancients, and various ways of preparing it are deſcribed by Pliny *. It was formerly known by the names of *cryſtals of Venus and verdigriſe*.

It is of a deep green colour. Its cryſtals are rhomboids.

It has a diſagreeable coppery taſte.

It is ſoluble in water and in alcohol.

According to Wenzel, 240 parts of acetous acid require $16\frac{1}{8}$th of copper for ſaturation.

It effloreſces when expoſed to the air. Heat decompoſes it. It is uſed in painting.

793 Acetite of biſmuth.

18. Acetite of biſmuth.—This ſalt ſeems to have been firſt mentioned by Geoffroi. He called it *ſugar of biſmuth*.

It is moſt eaſily procured by mixing together the ſolutions of nitrat of biſmuth and acetite of potaſs. It forms brilliant, talky, ſilvery cryſtals.

It has a ſweetiſh taſte. According to Wenzel, 240 parts of acetous acid require for ſaturation $15\frac{5}{7}$ths of biſmuth.

It does not deliqueſce when expoſed to the air. Heat decompoſes it.

794 Acetite of antimony.

19. Acetite of antimony.—It yields with difficulty ſmall cryſtals †. According to Wenzel, 240 parts of acetous acid require for ſaturation $1\frac{1}{3}$d of antimony.

795 Acetite of arſenic.

20. Acetite of arſenic.—This ſalt forms ſmall cryſtals in grains, hardly ſoluble in water ‡.

796 Acetite of mercury.

21. Acetite of mercury.—This ſalt is mentioned by Schrœder.

Its cryſtals are ſmall thin plates.

It has a diſagreeable taſte, and excites coughing.

It is hardly ſoluble in water. According to Wenzel, 240 parts of acetous acid require for ſaturation $240\frac{1}{7}$ths of mercury.

When expoſed to the air it becomes black, owing to the reduction of the oxide of mercury. Heat decompoſes it.

797 Acetite of ſilver.

22. Acetite of ſilver.—This ſalt was perhaps firſt deſcribed by Margraf.

It is beſt formed by dropping acetite of ſoda or potaſs into a ſaturated ſolution of nitrat of ſilver §.

It forms ſmall oblong cryſtals, eaſily diſſolved in water †. It has a ſharp taſte.

According to Wenzel, 240 parts of acetous acid require for ſaturation $101\frac{4}{9}$ths of ſilver.

Heat decompoſes it. It is decompoſed by muriat of magneſia ¶.

798 Acetite of gold.

23. Acetite of gold.—This ſalt is mentioned by Schrœder and Juncker.

799 Acetite of uranium.

24. Acetite of uranium.—This ſalt was firſt formed by Klaproth.

Its cryſtals are regular four-ſided ſlender priſms, terminated at both ends by regular quadrilateral pyramids: they are tranſparent, and of a beautiful topaz yellow colour.

Heat decompoſes them: and what is ſingular, if they be heated gradually red hot, the oxide which remains retains nearly the form of the cryſtals *.

800 Acetats.

The compounds into which the acetic acid enters are called *acetats*. They are ſo imperfectly known at preſent, that we ſhall not attempt a deſcription of them.

Sect. XII. *Of Oxalats.*

The compounds of which oxalic acid forms a part are

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* *Vauquelin, Ann. de Chim.* xxii. 206.

† *Wenzel.*

‡ *Bergman.*

§ *Monnet.*

‖ *Scheele.*

¶ *Id.*

* *Morveau.*

* Lib. xxxiv. c. 11.

† *Wenzel.*

‡ *Bergman.*

§ *Maret, ibid.*

† *Margraf.*

¶ *Bergman.*

* *Klaproth on Uranium.*

are known by the name of *oxalats*. They were firſt deſcribed by Bergman.

801 Oxalat of potaſs.

1. Oxalat of potaſs.—This ſalt cryſtallizes with difficulty. It is very ſoluble in water. When heated it falls to powder *.

802 Acidulous oxalat of potaſs.

2. Acidulous oxalat of potaſs.—The oxalic acid is alſo capable of combining with potaſs in exceſs, and forming another ſalt, called *acidulous oxalat* from its acid taſte; or, to ſpeak more accurately, this ſalt is formed by the combination of oxalat of potaſs with oxalic acid. This ſalt exiſts ready formed in *oxalis acetoſella* or woodſorrel; from which it is extracted in ſome parts of Europe in great quantities. Hence it was formerly called ſalt of wood ſorrel. It is mentioned by Duclos in the Memoirs of the French Academy for 1668. Margraf firſt proved that it contained potaſs; and Scheele diſcovered that its acid is the oxalic. A great many intereſting experiments had been previouſly made on it by Wenzel and Wiegleb.

It may be formed, as Scheele has ſhown, by dropping potaſs very gradually into a ſaturated ſolution of oxalic acid and water: as ſoon as the proper quantity of alkali is added, acidulous oxalat is precipitated. But care muſt be taken not to add too much alkali, otherwiſe no precipitation will take place at all.

Its cryſtals are ſmall opaque parallelopipeds †.

It has an acid, poignant, bitteriſh taſte.

It is ſoluble in about ten times its weight of boiling water, but much leſs ſoluble in cold water.

It is not altered by expoſure to the air. Heat decompoſes it.

This ſalt is ſold in this country under the name of *eſſential ſalt of lemons*.

803 Oxalat of ſoda.

3. Oxalat of ſoda.—This ſalt agrees very much with oxalat of potaſs. Its cryſtals are ſmall, and ſoluble in water.

From Bergman's deſcription, oxalic acid appears alſo capable of combining in exceſs with ſoda, and forming an acidulous oxalat.

804 Oxalat of ammonia.

4. Oxalat of ammonia.—Its cryſtals are four-ſided priſms, generally diverging from various points. They redden the infuſion of turnſole.

They are eaſily ſoluble in water, but not in alcohol ‡.

It is decompoſed by nitrat of barytes §.

805 Earthy oxalats.

5. Oxalat of barytes.—This ſalt does not cryſtallize except with exceſs of acid. The addition of potaſs, or even of water, deprives it of this exceſs, and then it crumbles into powder. It is inſoluble in water ‖.

6. Oxalat of lime.—This ſalt does not cryſtallize. It is inſoluble in water, but ſomewhat ſoluble in acids. It is compoſed of 48 parts of acid, 46 of lime, and 6 of water. Heat decompoſes it ¶.

7. Oxalat of ſtrontites.—This ſalt was firſt formed by Dr Hope. It is a white inſipid powder; ſoluble in 1920 parts of boiling water. Heat decompoſes it by deſtroying the acid *.

8. Oxalat of magneſia.—This ſalt is in the form of a white powder. It is ſcarcely ſoluble either in water or alcohol. It is compoſed of 35 parts of magneſia and 65 of acid and water. Heat decompoſes it †.

9. Oxalat of alumina.—It is uncryſtallizable; but furniſhes on evaporation a yellowiſh pellucid maſs. It is ſparingly ſoluble in alcohol. It has a ſweet aſtringent taſte. It is compoſed of 44 parts of alumina and 56 of acid and water. When expoſed to the air it deliqueſces; and if it has been previouſly well dried, its weight is increaſed by $\frac{2}{3}$. It reddens turnſole *.

806 Metallic oxalats.

10. Oxalat of iron.—This ſalt forms priſmatic cryſtals of a yellowiſh green colour.

It has an aſtringent and ſweet taſte. It is very ſoluble in water.

It is compoſed of 45 parts of green oxide, and 55 of acid and water. When expoſed to heat it falls to powder †.

From Bergman's deſcription, the brown oxide of iron appears alſo capable of combining with oxalic acid. The compound does not cryſtallize, and is nearly inſoluble in water ‡.

11. Oxalat of zinc.—It is hardly ſoluble in water.

It is compoſed of 75 parts of oxide and 25 of acid.

12. Oxalat of manganeſe.—It is compoſed of oxalic acid and white oxide of manganeſe. It appears capable of cryſtallizing §.

13. Oxalat of cobalt.—This is a roſe-coloured powder, inſoluble in water, but ſoluble in oxalic acid; and capable, by that means, of cryſtallizing ‖.

14. Oxalat of nickel.—This is a green coloured powder, hardly ſoluble in water. It is compoſed of two parts of acid and one of oxide ¶.

15. Oxalat of lead.—It forms ſmall cryſtalline grains. They are inſoluble in alcohol, and nearly inſoluble in water. They contain 55 parts of oxide and 45 of acid *.

16. Oxalat of tin.—This ſalt forms priſmatic cryſtals. It has an auſtere taſte. If the ſolution of this ſalt be quickly evaporated, it affords a maſs reſembling horn, and ſoluble in water †.

17. Oxalat of copper.—This ſalt is uncryſtallizable. It is a bluiſh powder, inſoluble in water, except with exceſs of acid. It is compoſed of 21 parts of copper and 29 of acid ‡.

18. Oxalat of biſmuth.—This ſalt may be formed by dropping oxalic acid into a ſolution of nitrat of biſmuth. It forms pellucid polygonous cryſtals. When oxide of biſmuth is diſſolved by oxalic acid, the reſult is a white powder, ſcarcely ſoluble in water §.

19. Oxalat of antimony.—This ſalt forms cryſtalline grains, with difficulty ſoluble in water †.

20. Oxalat of arſenic.—This ſalt is compoſed of oxalic acid and white oxide of arſenic. Its cryſtals are priſms very ſoluble in water and alcohol. It reddens turnſole.

Heat ſublimes it; and by a ſtrong heat it may be decompoſed ¶.

21. Oxalat of mercury.—A white powder, hardly ſoluble in water, except with exceſs of acid *.

22. Oxalat of ſilver.—This ſalt may be formed by pouring oxalic acid into a ſolution of nitrat of ſilver. It is a white powder, ſcarcely ſoluble in water, and not at all in alcohol; but ſoluble in nitric acid. It becomes black by being expoſed to the air, owing to the reduction of the oxide †.

23. Oxalat of platinum.—This ſalt affords yellow cryſtals.

SECT. XIII. *Of Tartrites.*

THE ſalts into which tartarous acid enters as an ingredient are known by the name of *tartrites*.

807 Tartar.

1. Acidulous oxalat of potaſs or tartar.—This ſalt, which is compoſed of potaſs and an exceſs of tartarous acid, or rather of tartrite of potaſs and tartarous acid, has

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* *Bergman*, i. 262.

† *De Liſle.*

‡ *Bergman.*

§ *Bergman, ibid.*

‖ *Bergman, ibid.*

¶ *Bergman, ibid.*

* *Hope, Tranſ. Edin.* iv. 14.

† *Bergman, ibid.* and ii. 387.

* *Bergman, ibid.*

† *Ibid.*

‡ *Ibid.*

§ *Ibid.*

‖ *Ibid.*

¶ *Ibid.*

* *Ibid.*

† *Ibid.*

‡ *Ibid.*

§ *Ibid.*

† *Ibid.*

¶ *Ibid.*

* *Ibid.*

† *Ibid.*

Tartrites. has been long known. It is obtained in a ſtate of impurity at the bottom, and adhering to the ſides of caſks in which wine has fermented. It is called *tartar*, ſays Paracelſus, becauſe it produces the oil, water, limeſtone, and ſalt, which burn the patient as *Hell* does. According to him, it was the principle of every diſeaſe and every remedy, and all things contain the germ of it.

Margraf and Rouelle firſt demonſtrated that it contained potaſs ready formed: and Scheele firſt obtained tartarous acid from it in a ſtate of purity.

Its cryſtals are very ſmall and irregular. According to Montet, they are priſms, ſomewhat flat, and moſtly with ſix ſides. It has a ſtrong acid taſte. It is ſoluble in about 30 times its weight of boiling water*. According to Bergman, it contains 23 parts of alkali and 77 of acid.

It is not altered by expoſure to the air. Heat decompoſes it, and at the ſame time deſtroys the acid. It is capable of forming a great many compounds.

808 Tartrite of potaſs.

2. Tartrite of potaſs. This ſalt may be formed by ſaturating the laſt deſcribed ſalt with potaſs. It was formerly called *ſoluble tartar*, becauſe it is much more ſoluble in water than the acidulous tartrite of potaſs. It cryſtallizes moſt readily when there is a ſmall exceſs of alkali in the ſolution. Its cryſtals are ſmall oblongs.

It has an unpleaſant bitter taſte. It is ſoluble in 4 parts of water at the temperature of 40°.

3. Tartrite of ſoda. This ſalt has never been accurately examined.

809 Tartrite of potaſs and ſoda.

4. Tartrite of potaſs and ſoda. This triple ſalt, formerly known by the name of *ſalt of Seignette*, becauſe firſt formed by Mr Seignette apothecary at Rochelle, is made by ſaturating tartar with ſoda.

Its cryſtals are priſms of eight or ten unequal ſides, having their ends truncated at right angles. They are generally divided into two in the direction of their axes, and the baſe on which they ſtand is marked with two diagonal lines, ſo as to divide it into four triangles.

It has a bitter taſte. It is almoſt as ſoluble as tartrite of potaſs.

It effloreſces when expoſed to the air. Heat decompoſes it.

810 Tartrite of ammonia.

4. Tartrite of ammonia. The cryſtals of this ſalt are polygonous priſms, not unlike thoſe of the laſt deſcribed ſalt.

It has a cooling bitter taſte like that of nitre. It is eaſily ſoluble in water. Heat decompoſes it.

5. Acidulous tartrite of ammonia. This ſalt may be formed by pouring tartarous acid into a ſolution of tartrite of ammonia. Like acidulous tartrite of potaſs, it is very inſoluble in water.

6. Tartrite of potaſs and ammonia. This triple ſalt may be formed by pouring ammonia into acidulous tartrite of potaſs.

Its cryſtals, according to Macquer, are priſms with four, five, or ſix ſides: according to the Dijon academicians, parallelopipeds, with two alternate ſloping ſides.

It has a cooling taſte. It is ſoluble enough in water. It effloreſces in the air. Heat decompoſes it.

811 Earthy tartrites.

7. Tartrite of barytes. Unknown.

8. Tartrite of lime. This ſalt, firſt formed by Scheele, is a taſteleſs and almoſt inſoluble powder. By heat the acid is decompoſed, and the pure lime remains behind.

9. Tartrite of ſtrontites. This ſalt was firſt formed by Dr Hope. Its cryſtals are ſmall regular triangular tables, having the edges and angles ſharp and well defined. It is inſipid. It diſſolves in 320 parts of boiling water.

It is not altered by expoſure to the air. Heat decompoſes it by deſtroying the acid *.

10. Tartrite of magneſia. This ſalt is inſoluble in water except there be an exceſs of acid preſent. It then affords by evaporation ſmall cryſtals in the form of hexangular truncated priſms †.

It has a more ſaline taſte, and is more fuſible, than tartrite of lime ‡.

Heat firſt melts and afterwards decompoſes it.

11. Tartrite of alumina. This ſalt does not cryſtallize, but forms by evaporation a clear tranſparent gummy maſs. Its taſte is aſtringent. It is ſoluble in water. It does not deliqueſce in the air §.

12. Tartrite of potaſs and alumina. This triple ſalt is formed by ſaturating tartar with alumina. It bears a very ſtriking reſemblance to the laſt deſcribed ſalt.

812 Metallic tartrites.

13. Tartrite of iron. This is a grey powder. When tartarous acid is poured into a ſolution of ſulphat of iron, ſcaly cryſtals are formed by evaporation. Theſe cryſtals are doubtleſs compoſed of tartarous acid combined with ſulphat of iron. This triple ſalt might be called *tartro-ſulphat of iron*.

14. Tartrite of potaſs and iron. This triple ſalt was formerly called *tartariſed tincture of Mars*, *chalybeated tartar*, and *tartariſed iron*. It may be formed by boiling two parts of tartar and one of iron filings, previouſly made up into a paſte, in a proper quantity of water. The liquor by evaporation depoſites cryſtals, which form the ſalt wanted.

15. Tartrite of zinc. This ſalt is not eaſily ſoluble in water.

16. Tartrite of potaſs and zinc. This triple ſalt, formed by combining tartar and oxide of zinc, is very ſoluble in water ‖.

17. Tartrite of lead. This ſalt, which is compoſed of tartarous acid and white oxide of lead, is almoſt inſoluble in water. Nitric acid diſſolves it.

18. Tartrite of potaſs and lead. This ſalt, formed by combining white oxide of lead with tartar, is very ſoluble in water ¶.

19. Tartrite of tin. Unknown. The tartrite of potaſs and tin, compoſed of tartar and oxide of tin, is capable of cryſtallizing.

20. Tartrite of copper. This ſalt is beſt formed by pouring tartarous acid into the ſolutions of muriat or ſulphat of copper; it precipitates in the form of blue cryſtals *.

This ſalt forms the beſt kind of the pigment called *Brunſwick green* †.

21. Tartrite of potaſs and copper. This triple ſalt is alſo in the form of blue cryſtals.

22. Tartrite of biſmuth. Small cryſtalline grains ‡.

23. Tartrite of antimony. This ſalt has never been examined with attention.

24. Tartrite of potaſs and antimony, or tartar emetic. To this ſalt, which is perhaps the moſt powerful emetic known, a great deal of attention has been paid, and a vaſt number of methods have been tried to prepare it. Theſe methods have been already deſcribed in the Encyclopædia. It appears from the experiments of Mr Bindheim,

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* *Wenzel.*

* *Hope, Edin. Tranſ.* iv. 15.

† *Bergman*, ii. 283.

‡ *Von Packen ae Sale eſſent. acid. Tartar.*

§ *Von Packen.*

‖ *Elemens de Chim. Dijon.*

¶ *Wenzel.*

* *Bergman.*

† *Leonhardi.*

‡ *Bergman.*

Bindheim, that if this ſalt be carefully prepared, the difference that reſults from the uſe of different oxides is not ſo great as might have been expected *.

It was firſt made known by Adrian in 1631. It is a triple ſalt, compoſed of tartar and white oxide of antimony.

It is of a white colour and tranſparent. Its cryſtals are trihedral pyramids.

It diſſolves in 60 parts of cold water, and in a ſmaller proportion of hot water. It is decompoſed by lime and alkalies, iron, &c. Care ought therefore to be taken to uſe only diſtilled water when it is adminiſtered as a medicine.

25. Tartrite of arſenic. This ſalt forms priſmatic cryſtals very like thoſe of oxalat of arſenic †.

26. Tartrite of mercury. A yellow powder.

27. Tartrite of potaſs and mercury. This triple ſalt cryſtallizes ‡.

Sect. XIV. *Of Citrats.*

The compounds into which the citric acid enters have been denominated *citrats*.

Theſe ſalts are at preſent very imperfectly known. Mr Dizé has promiſed ſoon to ſupply this defect §.

813 Alkaline citrats. 1. Citrat of potaſs. This ſalt does not cryſtallize. It has a cooling ſaline taſte, and deliqueſces when expoſed to the air.

2. Citrat of ſoda. This ſalt does not deliqueſce. It has a mild, pleaſant, cooling taſte ||. According to Scheele, it does not cryſtallize.

3. Citrat of ammonia. This ſalt cryſtallizes in thin needles. It has a cooling and moderately ſaline taſte ¶. The ammonia is ſeparated by the application of heat *.

814 Earthy citrats. 4. Citrat of barytes. This ſalt is ſcarcely ſoluble in water. It aſſumes the form of a white powder †. It is ſoluble in citric acid.

5. Citrat of lime. This is a white powder, ſcarcely ſoluble in water ‡.

6. Citrat of magneſia. Does not cryſtallize. It forms a gummy ſaline maſs very ſoluble in water §.

7. Citrat of alumina. This ſalt is ſcarcely ſoluble in water.

815 Metallic citrats. 8. Citrat of iron. A ſolution of a brown colour.

9. Citrat of copper. A green gummy maſs.

10. Citrat of mercury. This ſalt may be formed by pouring citric acid into nitrat or acetite of mercury. It is a flaky ſalt, of a brick-duſt colour, more or leſs red ||.

Sect. XV. *Of Malats.*

816 Malats. The compounds into which the malic acid enters are called *malats*. This claſs of ſalts was firſt diſcovered by Scheele. They are no better known than the citrats.

1. Malat of potaſs.
2. Malat of ſoda. } Theſe ſalts are deliqueſcent ¶.
3. Malat of ammonia.

4. Malat of lime. Small irregular cryſtals. They require a large quantity of boiling water for their ſolution. With exceſs of acid they are readily ſoluble in cold water †. They are inſoluble in alcohol ‡.

5. Malat of barytes. The properties of this ſalt reſemble pretty much thoſe of malat of lime §.

6. Malat of magneſia. Deliqueſcent ||.

7. Malat of iron. A brown ſolution, not cryſtallizable *.

8. Malat of zinc. This ſalt forms beautiful cryſtals †.

Sect. XVI. *Of Lactats.*

817 Lactats. The neutral ſalts formed by the combination of the lactic acid with various baſes are called *lactats*. They were firſt diſcovered by Scheele.

1. Lactat of potaſs. A deliqueſcent ſalt, ſoluble in alcohol ‡.

2. Lactat of ſoda. This ſalt does not cryſtallize. It is ſoluble in alcohol §.

3. Lactat of ammonia. Cryſtals which deliqueſce. Heat ſeparates a great part of the ammonia before deſtroying the acid.

4. Lactat of barytes.
5. Lactat of lime. } Theſe ſalts deliqueſce ||. The lactat of lime is ſoluble in alcohol ¶.
6. Lactat of alumina.
7. Lactat of magneſia. Small deliqueſcent cryſtals *.
8. Lactat of iron. A brown ſolution.
9. Lactat of zinc. Cryſtals †.

Theſe ſalts have a very ſtrong reſemblance to malats. The only difference which Scheele obſerved was, that the malat of lime was inſoluble in alcohol, while alcohol diſſolved lactat of lime.

Sect. XVII. *Of Saccholats.*

818 Saccholats. The compounds into which the ſaccholactic acid enters are called *ſaccholats*. They alſo were firſt diſcovered by Scheele.

1. Saccholat of potaſs. Small cryſtals, ſoluble in eight times their weight of boiling water ‡.

2. Saccholat of ſoda. The ſame; ſoluble in five times their weight of boiling water §.

3. Saccholat of ammonia. A ſalt which has a ſouriſh taſte. Heat ſeparates the ammonia ¶.

4. Saccholat of barytes.
5. Saccholat of lime. } Theſe ſalts are inſoluble
6. Saccholat of magneſia. } in water *.
7. Saccholat of alumina.

Sect. XVIII. *Of Gallats.*

819 Gallats. The compounds into which the gallic acid enters are denominated *gallats*. They were firſt attended to by the Dijon academicians and by Scheele.

1. Gallat of potaſs.
2. Gallat of ſoda. } We only know that theſe compoſitions are poſſible, and that their properties
3. Gallat of ammonia.

are different from thoſe of all other ſalts.

4. Gallat of barytes. } Theſe ſalts are ſoluble in wa-
5. Gallat of lime. } ter, eſpecially when there is

exceſs of acid.

6. Gallat of magneſia. This ſalt is a yellow powder, ſoluble in water and in alcohol *.

7. Gallat of alumina. This ſalt, according to Bartholdi, exiſts ready formed in nut galls. It is very ſoluble in water.

8. Gallat of iron. This ſalt, which Mr Prouſt has diſcovered to be formed of gallic acid and brown oxide of iron, is of a black colour, and does not ſeem capable of cryſtallizing. It is ſoluble in the three mineral acids, and by that means is deprived of its black colour. It is to this ſalt that ink partly owes its black colour. Gallat of iron is decompoſed by alkalies.

We ſhall not attempt any farther account of this claſs of

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* Ann. de Chim. xiii. 218.

† Bergman, ii. 295.

‡ Monnet.

§ Journ. de Phyſ. 1794, Supplement.

|| Dr Donald Monro, Phil. Tranſ. 57.

¶ Dobſon.

* Scheele.

† Id.

‡ Id.

§ Id.

|| Dizé.

¶ Scheele.

† Id.

‡ Id.

§ Id.

|| Id.

* Scheele.

† Id.

‡ Scheele on Milk.

§ Ibid.

|| Ibid.

¶ Ibid.

* Ibid.

† Ibid.

‡ Scheele on Sugar of Milk.

§ Ibid.

¶ Ibid.

* Ibid.

* Bartholdi Ann. de Chim. xii. 305.

of ſalts. Scarcely any addition has yet been made to the experiments of Scheele which have been given already in the article Chemistry, *Encycl.*

Sect. XIX. *Of Benzoats.*

820 Alkaline benzoats.

The compounds into which the benzoic acid enters have been called *benzoats*.

1. Benzoat of potaſs. This ſalt forms pointed feathery cryſtals. It has a ſaline ſharp taſte. It is very ſoluble in water. It deliqueſces when expoſed to the air *.

2. Benzoat of ſoda. The cryſtals of this ſalt are larger, but its taſte is the ſame with that of benzoat of potaſs. It is alſo very ſoluble in water. It effloreſces in the air †.

3. Benzoat of ammonia. This ſalt cryſtallizes with difficulty. Its cryſtals are feather-ſhaped. It deliqueſces ‡.

821 Earthy benzoats.

4. Benzoat of lime. This ſalt forms white, ſhining, pointed cryſtals, of a ſweetiſh taſte, and not eaſily ſoluble in water §.

5. Benzoat of magneſia. Feather-ſhaped cryſtals, of a ſharp bitter taſte, and eaſily ſoluble in water †.

6. Benzoat of alumina, an aſtringent ſalt.

822 Metalline benzoats.

7. Benzoat of iron. This ſalt forms yellow cryſtals. It has a ſweet taſte. It is ſoluble in water and alcohol. It effloreſces in the air. Heat diſengages the acid ¶.

8. Benzoat of zinc. This ſalt forms arboreſcent cryſtals. It is ſoluble in water and alcohol. When expoſed to the air it is diſſipated. Heat decompoſes it *.

9. Benzoat of mangaueſe. This ſalt, which is formed of benzoic acid and white oxide of mangaueſe, cryſtallizes in ſmall ſcales. It diſſolves readily in water; with difficulty in alcohol. It is not altered by expoſure to the air †.

10. Benzoat of cobalt. Flat cryſtals ‡.

11. Benzoat of lead. Very white cryſtals, ſoluble in water and alcohol. They are not altered by expoſure to the air. Heat diſengages the acid §.

12. Benzoat of tin. This ſalt may be formed by pouring benzoat of potaſs into a ſolution of tin in the nitro-muriatic acid. The benzoat of tin is precipitated. It is ſoluble in hot water, but inſoluble in alcohol. Heat decompoſes it ‖.

13. Benzoat of copper. Small cryſtals of a deep green colour. They are with difficulty ſoluble in water, and not at all in alcohol ¶.

14. Benzoat of biſmuth. This ſalt forms white needle-ſhaped cryſtals. They are ſoluble in water, and in a very ſmall proportion in alcohol. They are not altered by expoſure to the air. Heat decompoſes them *.

15. Benzoat of antimony. Cryſtals which effloreſce in the air, and are decompoſed by heat †.

16. Benzoat of arſenic. Small feather-ſhaped cryſtals. It is ſoluble in hot water, but cryſtallizes in the cooling. A moderate heat ſublimes it; a ſtrong heat decompoſes it. Sulphur decompoſes it. It is not decompoſed by alkalies ‡.

17. Benzoat of mercury. A white powder. It is inſoluble in water, but diſſolves in a ſmall quantity in alcohol. It is not altered by expoſure to the air. A ſmall heat ſublimes it; a greater decompoſes it. It is decompoſed by ſulphur §.

18. Benzoat of ſilver. This ſalt is ſoluble in water, and alſo in a very ſmall proportion in alcohol. It is not altered by expoſure to the air, but the rays of the ſun render it brown. Heat diſengages its acid *.

19. Benzoat of gold. Small irregular cryſtals, not eaſily ſoluble in water; inſoluble in alcohol. It is not altered by expoſure to the air. Heat decompoſes it †.

20. Benzoat of platinum. This ſalt forms ſmall browniſh cryſtals, with difficulty ſoluble in water; not ſoluble in alcohol. When expoſed to heat, it is decompoſed, and there remains behind a brown powder ‡.

Sect. XX. *Of Succinats.*

The neutral ſalts, formed by the combination of the ſuccinic acid with various baſes, have been called *ſuccinats*.

We ſhall not deſcribe theſe ſalts, as we could not add much to the account given in the Appendix to the article Chemistry in the *Encycl.* That account was taken from Mr Kier's Chemical Dictionary, and that gentleman borrowed it from Leonhardi.

Sect. XXI. *Of Camphorats.*

The neutral ſalts into the compoſition of which camphoric acid enters, have been denominated *camphorats*. The only chemiſt who has hitherto examined them is Bouillon la Grange: his experiments have been publiſhed in the 27th volume of the *Annales de Chimie*.

823 Camphorat of potaſs.

1. Camphorat of potaſs. To prepare this ſalt, carbonat of potaſs is to be diſſolved in water, and the ſolution ſaturated with camphoric acid. When the efferveſcence is over, the liquor is to be evaporated by a gentle heat to the proper conſiſtence, and cryſtals of camphorat of potaſs will be depoſited when the liquor cools.

Camphorat of potaſs is white and tranſparent; its cryſtals are regular hexagons. Its taſte is bitteriſh and ſlightly aromatic.

Water at the temperature of 60° diſſolves $\frac{1}{102}$th part of its weight of this ſalt; boiling water diſſolves $\frac{1}{4}$th part of its weight.

It is ſoluble in alcohol, and the ſolution burns with a deep blue flame.

When expoſed to moiſt air, it loſes a little of its tranſparency, but in dry air it ſuffers no change.

When expoſed to heat it melts, ſwells, and the acid is volatilized in a thick ſmoke, which has an aromatic odour. Before the blow-pipe it burns with a blue flame, and the potaſs remains behind in a ſtate of purity.

By compound affinity this ſalt is decompoſed by

Nitrat of barytes,
All the ſalts whoſe baſe is lime,
Nitrat of ſilver,
Sulphat of iron,
Muriat of tin,
——— lead §.

824 Camphorat of ſoda.

2. Camphorat of ſoda. This ſalt may be formed preciſely in the ſame manner with the camphorat of potaſs.

It is white and tranſparent; its taſte is ſomewhat bitter; its cryſtals are irregular.

Water at the temperature of 60° diſſolves leſs than $\frac{1}{200}$th part of its weight of this ſalt; boiling water diſſolves $\frac{1}{8}$th of its weight.

It is alſo ſoluble in alcohol.

When expoſed to the air it loſes its tranſparency, and effloreſces

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* *Keir's Dictionary.*

† *Ibid.*

‡ *Ibid.*

§ *Ibid.*

† *Ibid.*

¶ *Trommſdorf, Ann de Chim.* xi. 314.

* *Id. ibid.*

† *Id. ibid.*

‡ *Id. ibid.*

§ *Id. ibid.*

‖ *Id. ibid.*

¶ *Id. ibid.*

* *Id. ibid.*

† *Id. ibid.*

‡ *Id. ibid.*

§ *Id. ibid.*

* *Id. ibid.*

† *Id. ibid.*

‡ *Id. ibid.*

§ *Bouillon La Grange, Ann. de Chim.* xxvii. 24.

effloreſces ſlightly, but is never completely reduced to powder.

Heat produces the ſame effect upon it as on camphorat of potaſs: the acid burns with a blue flame, which becomes reddiſh towards the end.

By compound affinity it is decompoſed by

Nitrat of lime,
——— ſilver,
Muriat of magneſia,
——— barytes,
——— alumina,
Muriat of lime,
——— iron,
Sulphat of alumina,
——— iron: and many other ſalts with metallic baſes *.

825 Camphorat of ammonia.

3. Camphorat of ammonia. This ſalt may be prepared by diſſolving carbonat of ammonia in hot water, and adding camphoric acid ſlowly till the alkali is ſaturated. It muſt then be evaporated with a very moderate heat, to prevent the diſengaging of ammonia.

It is very difficult to obtain this ſalt in regular cryſtals. When evaporated to dryneſs, there is obtained a ſolid opaque maſs of a ſharp and bitteriſh taſte.

Water at the temperature of about 60° diſſolves nearly $\frac{1}{100}$th part of its weight of this ſalt; boiling water diſſolves $\frac{1}{3}$d of its weight: But this and the two ſalts above deſcribed are a good deal more ſoluble when there is exceſs of baſe.

It is entirely ſoluble in alcohol.

When expoſed to the air it attracts moiſture, but not in ſufficient quantity to enable it to aſſume a liquid form.

When expoſed to heat it ſwells, melts, and is converted into vapour; before the blow-pipe it burns with a blue and red flame, and is entirely volatilized.

Moſt of the calcareous ſalts form triple ſalts with camphorat of ammonia.

It decompoſes in part all the aluminous ſalts except the ſulphat of alumina †.

826 Camphorat of barytes.

4. Camphorat of barytes. In order to prepare this ſalt, barytes is to be diſſolved in water, and camphoric acid added to the ſolution; the mixture is then to be boiled, and afterwards filtered and evaporated to dryneſs.

Camphorat of barytes does not cryſtallize; when the evaporation is conducted ſlowly, the ſalt is depoſited in thin plates one above another, which appear tranſparent while immerſed in the liquor, but become opaque whenever they come into contact with the air.

It has very little taſte, though it leaves at laſt upon the tongue a ſlight impreſſion of acidity mixed with bitterneſs.

Water diſſolves only a very ſmall quantity of this ſalt, boiling water being capable of taking up only $\frac{1}{600}$th part of it.

It is not altered by expoſure to the air.

When expoſed to heat it melts eaſily, and the acid is volatilized. When the heat is conſiderable, the acid burns with a lively blue flame, which becomes red and at laſt white.

It is decompoſed by

Nitrat of potaſs, ſoda, lime, ammonia, and magneſia.
Muriat of lime, potaſs, alumina, and magneſia.
All the ſulphats.
Carbonat of potaſs and ſoda.
Phoſphat of potaſs, ſoda, and ammonia ‡.

827 Camphorat of lime.

5. Camphorat of lime. This ſalt may be prepared by dropping into lime-water cryſtallized camphoric acid. The mixture is then to be made boiling hot, paſſed through a filter, and evaporated to about $\frac{3}{4}$ths of its volume. On cooling, camphorat of lime is depoſited.

It has no regular ſhape; but if the evaporation has been properly conducted, it is in plates lying one above another. It is of a white colour, and has a taſte ſlightly bitter.

Water at the temperature of 60° diſſolves very little of this ſalt; boiling water is capable of diſſolving about $\frac{1}{200}$th part of its weight of it. It is inſoluble in alcohol.

It is compoſed of 43 parts of lime, 50 of acid, and 7 of water.

When expoſed to the air it dries and falls into powder.

When expoſed to a moderate heat it melts and ſwells up: when placed on burning coals, or when heated in cloſe veſſels, the acid is decompoſed and volatilized, and the lime remains pure.

When ſulphuric acid is poured into a ſolution of this ſalt, it produces an inſoluble precipitate; nitric and muriatic acids precipitate the camphoric acid.

It is decompoſed by compound affinity by

Carbonat of potaſs,
Nitrat of barytes,
Muriat of alumina,
Sulphat of alumina,
Phoſphat of ſoda *.

828 Camphorat of magneſia.

6. Camphorat of magneſia. This ſalt may be prepared by pouring water on carbonat of magneſia, and then adding cryſtallized camphoric acid: heat is then applied, the ſolution is filtrated, and evaporated to dryneſs. The ſalt obtained is diſſolved in hot water, paſſed through a filter, and evaporated by means of a moderate heat till a pellicle forms on the ſurface of the ſolution. On cooling, the ſalt is depoſited in thin plates. The ſecond ſolution is to remove any exceſs of magneſia that may happen to be preſent.

This ſalt does not cryſtallize. It is white, opaque, and has a bitter taſte.

It is ſcarcely more ſoluble in water than camphorat of lime.

Alcohol has no action on it while cold, but when hot it diſſolves the acid and leaves the magneſia; and the acid precipitates again as the alcohol cools.

When expoſed to the air it dries and becomes covered with a little powder; but this effect is produced ſlowly, and only in a warm place.

When this ſalt is placed on burning coals, the acid is volatilized, and the magneſia remains pure. Before the blow-pipe it burns like the other camphorats with a blue flame.

The nitrats, muriats, and ſulphats, do not completely decompoſe this ſalt, if we except the nitrat of lime and muriat of alumina †.

829 Camphorat of alumina.

7. Camphorat of alumina. To prepare this ſalt, alumina, precipitated by means of ammonia, and well waſhed, is to be mixed with water, and cryſtals of camphoric acid added. The mixture is then to be heated, filtered, and concentrated by evaporation.

This ſalt is a white powder, of an acid bitteriſh taſte, leaving on the tongue, like moſt of the aluminous ſalts, a ſenſation of aſtringency.

Water at the temperature of 60° diſſolves about $\frac{1}{200}$th part of its weight of this ſalt. Boiling water diſſolves it

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* *Bouillon La Grange, Ann. de Chim.* xxvii. 26.

† *Ibid.*

‡ *Bouillon La Grange, ibid.* p. 28.

* *Bouillon La Grange, Ann. de Chim.* xxvii. 21.

† *Id. ibid.*

it in conſiderable quantities; but it precipitates again as the ſolution cools.

Alcohol, while cold, diſſolves it very ſparingly; but when hot it diſſolves a conſiderable quantity of it, which precipitates alſo as the ſolution cools.

This ſalt undergoes very little alteration in the air; but it rather parts with than attracts moiſture.

Heat volatilizes the acid; and when the ſalt is thrown on burning coals it burns with a blue flame.

It is decompoſed by the nitrats of lime and barytes *.

Sect. XXII. *Of Suberats.*

The ſalts formed by the ſuberic acid have obtained the appellation of *ſuberats*. They have hitherto been examined only by Bouillon la Grange.

830 Suberat of potaſs.

1. Suberat of potaſs.—This ſalt ought to be formed by means of cryſtallized carbonat of potaſs.

It cryſtallizes in priſms, having four unequal ſides. It has a bitter ſaltiſh taſte, and it reddens vegetable blues. It is very ſoluble in water. Caloric melts it, and at laſt volatilizes the acid.

It is decompoſed by moſt of the metallic ſalts, and by ſulphat of alumina, muriat of alumina, and of lime; nitrat of alumina and of lime; and phoſphat of alumina †.

831 Suberat of ſoda.

2. Suberat of ſoda.—This ſalt does not cryſtallize. It reddens the tincture of turnſole. Its taſte is ſlightly bitter. It is very ſoluble in water and in alcohol. It attracts moiſture from the air. Caloric produces the ſame effect on it that it does on ſuberat of potaſs.

It is decompoſed by the calcareous, aluminous, and magneſian ſalts ‡.

832 Suberat of ammonia.

3. Suberat of ammonia.—This ſalt cryſtallizes in parallelopipeds. Its taſte is ſaltiſh, and it leaves an impreſſion of bitterneſs: It reddens vegetable blues.

It is very ſoluble in water. It attracts moiſture from the air. When placed upon burning coals, it loſes its water of cryſtallization, and ſwells up; and before the blow-pipe it evaporates entirely.

It is decompoſed by the aluminous and magneſian ſalts §.

833 Suberat of barytes.

4. Suberat of barytes.—This ſalt does not cryſtallize. Heat makes it ſwell up, and melts it. It is ſcarcely ſoluble in water except there be an exceſs of acid.

It is decompoſed by moſt of the neutral ſalts, except the barytic ſalts and the fluat of lime ‖.

834 Suberat of lime.

5. Suberat of lime.—This ſalt does not cryſtallize. It is perfectly white: It has a ſaltiſh taſte: It does not redden the tincture of turnſole.

It is very ſparingly ſoluble in water except when hot; and as the ſolution cools moſt of the ſalt precipitates again.

When placed upon burning coals it ſwells up, the acid is decompoſed, and there remains only the lime in the ſtate of powder.

It is decompoſed by
The muriat of alumina,
The carbonats of potaſs and ſoda,
The fluat of magneſia,
The phoſphats of alumina and ſoda,
The borat of potaſs,
All the metallic ſolutions ¶.

835 Suberat of magneſia.

6. Suberat of magneſia.—This ſalt is in the form of a powder:. It reddens the tincture of turnſole. It has a bitter taſte: It is ſoluble in water, and attracts ſome moiſture when expoſed to the air.

When heated it ſwells up and melts: before the blow-pipe the acid is decompoſed, and the magneſia remains in a ſtate of purity.

It is decompoſed by
Muriat of alumina,
Nitrat of lime and alumina,
Borat of potaſs,
Fluat of ſoda,
Phoſphat of alumina *.

836 Suberat of alumina.

7. Suberat of alumina.—This ſalt does not cryſtallize. When its ſolution is evaporated by a moderate heat in a wide veſſel, the ſalt obtained is of a yellow colour, tranſparent, having a ſtyptic taſte, and leaving an impreſſion of bitterneſs on the tongue. When too much heat is employed it melts and blackens. It reddens the tincture of turnſole, and attracts moiſture from the air. Before the blow-pipe it ſwells up, the acid is volatilized and decompoſed, and nothing remains but the alumina.

It is decompoſed by
The carbonats of potaſs and ſoda,
The ſulphat of iron,
The muriat of iron,
The nitrats of ſilver, mercury, and lead †.

Suberic acid forms alſo compounds with the oxides of ſilver, mercury, lead, copper, tin, iron, biſmuth, arſenic, cobalt, zinc, antimony, manganeſe, and molybdenum; moſt of which are incryſtallizable, and have an exceſs of acid ‡.

Sect. XXIII. *Of Pruſſiats.*

The compounds into which the pruſſic acid enters are called *Pruſſiats*.

Theſe ſubſtances, the moſt important of which are triple ſalts, have ſomething very peculiar in their affinities. The pruſſic acid appears to have a ſtronger affinity for alkalies and earths than for metals, at leaſt theſe ſubſtances are capable of decompoſing metallic pruſſiats; yet acids ſcarcely decompoſe the metallic pruſſiats, while the weakeſt acid known decompoſes the pruſſiats of alkalies and earths. Theſe phenomena have not yet been ſatisfactorily accounted for.

837 Alkaline pruſſiats.

1. Pruſſiat of potaſs. }
2. Pruſſiat of ſoda. } Theſe ſalts were firſt obtained pure by Mr Scheele. They are ſoluble in water; but they are of little uſe, as mere expoſure to the air decompoſes them.

3. Pruſſiat of ammonia.—This ſalt has the ſmell of ammonia. It is very volatile and as eaſily decompoſed as the other two.

838 Earthy pruſſiats.

4. Pruſſiat of lime.—This ſalt is ſoluble in water. It is alſo decompoſed by expoſure to the air.

5. Pruſſiat of barytes. }
6. Pruſſiat of magneſia. } Theſe ſalts are alſo ſoluble in water, and decompoſed by all acids.

Pruſſic acid does not combine with alumina.

839 Pruſſian blue.

7. Pruſſiat of iron, or Pruſſian blue.—This ſubſtance is compoſed, as Mr Prouſt has ſhewn, of the pruſſic acid and brown oxide of iron. With the green oxide the pruſſic acid forms a white compound, which, however, becomes gradually blue when expoſed to the atmoſphere, becauſe the oxide abſorbs oxygen, and is converted into brown oxide §.

Pruſſiat of iron is a deep blue coloured powder. It

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* Bouillon La Grange, Ann. de Chim. xxvii. 34.

† Id. ibid. xxiii. 52.

‡ Id. ibid. p. 53.

§ Id. ibid. p. 55.

‖ Id. ibid. p. 52.

¶ Id. ibid. p. 54.

* Bouillon La Grange, Ann. de Chim. xxiii. 55.

† Id. ibid.

‡ Id. ibid. p. 57.

§ Nicholſon's Jour. i. 453.

is inſoluble in water, and ſcarcely ſoluble in acids. It is compoſed, according to the moſt accurate experiments hitherto made, of equal parts of oxide of iron and pruſſic acid. It is not affected by expoſure to the air. Heat decompoſes it by deſtroying the acid, and the oxide of iron remains behind.

The Pruſſian blue of commerce, beſides other impurities, contains mixed with it a great quantity of alumina. Its uſe as a pigment, and the attempts which have been made to introduce it as a dye, are well known.

Pruſſiat of iron may alſo exiſt in another ſtate: It may have a ſuperabundance of oxide; its colour is then more or leſs yellow. To this ſtate it may be reduced by digeſting it with alkalies or any of the alkaline earths. Theſe ſubſtances deprive it of part of its acid, but not of the whole.

This yellow pruſſiat is ſoluble in acids.

840 Affinities of the pruſſic acid explained.

Were we to attempt an explanation of this, and the other phenomena which the pruſſic acid diſplays in its combinations, we would conjecture, that this yellow pruſſiat is the ſubſtance formed by the direct combination of brown oxide of iron and pruſſic acid, and that the blue pruſſiat is formed of the yellow pruſſiat combined as an integrant with pruſſic acid: That the affinity between the pruſſic acid and oxide of iron is much ſtronger than that between yellow pruſſiat of iron and pruſſic acid; that therefore alkalies and earths have a ſtronger affinity for pruſſic acid than the yellow pruſſiat has, but a much weaker affinity than oxide of iron, and perhaps every other oxide;—hence the apparent ſuperiority of alkalies and earths in ſome caſes, while in others they appear very inferior. We would ſuppoſe, then, that the pruſſic acid has a much ſtronger affinity for oxide of iron, and perhaps for all other oxides, than for other bodies; that the pruſſiats, thus formed, are capable of combining with pruſſic acid; but that their affinity for it is much leſs than that of the alkalies and earths. This conjecture is ſupported by all the phenomena at preſent known; it would remove all the apparent anomalies which the combinations of this ſingular acid preſent, and reduce the whole of them under the known laws of affinity.

841 Properties of Pruſſian alkali,

8. Pruſſiat of potaſs and iron, commonly called *Pruſſian alkali*, or *Pruſſian teſt*. This ſubſtance is a triple ſalt, compoſed of pruſſic acid, potaſs, and oxide of iron combined together. To chemiſts and mineralogiſts it is one of the moſt important inſtruments ever invented; as, when properly prepared, it is capable of indicating whether any metallic ſubſtance (platinum excepted) be preſent in any ſolution whatever, and even of pointing out the particular metal, and of aſcertaining its quantity: This it does by means of a compound affinity, which, after what has been ſaid above, may be eaſily underſtood. The Pruſſian alkali may be conceived to be a combination of two ſubſtances, pruſſiat of potaſs and blue pruſſiat of iron. Now every metallic oxide has a ſtronger affinity for pruſſic acid than potaſs has (and, in fact, ſeems to have a ſtronger affinity for it than for any other ſubſtance). If, therefore, there happen to be any oxide in the ſolution, it immediately ſeizes the pruſſic acid with which the potaſs is combined, and by that means decompoſes the triple ſalt. A pruſſiat of the particular metal is formed, and, as moſt pruſſiats of metals are inſoluble, it is precipitated; and it indicates by its colour the particular metal, and by its weight the quantity of metal that happens to be preſent. At the ſame time the blue pruſſiat of iron is alſo precipitated, and its weight muſt be deducted from the quantity of the precipitate.

In order to be certain of the accuracy of theſe reſults, it is neceſſary to have a Pruſſian alkali perfectly pure, and to be certain before hand of the quantity, or rather of the proportions of its ingredients. To obtain a teſt of this kind has been the object of chemiſts ever ſince the diſcoveries of Macquer pointed out its importance. It is to the uſe of impure teſts that a great part of the contradictory reſults of mineralogical analyſes by different chemiſts is to be aſcribed.

842 Liable to impurities.

There are two * ways in which this teſt may be rendered impure, beſides the introduction of foreign ingredients, which we do not mention, becauſe it is obvious that it muſt be guarded againſt. 1. There may be a ſuperabundance of alkali preſent, or, which is the ſame thing, there may be mixed with the Pruſſian teſt a quantity of pure alkali; or, 2. There may be contained in it a quantity of yellow pruſſiat of iron, for which pruſſiat of potaſs has alſo a conſiderable affinity.

If the Pruſſian teſt contain a ſuperabundance of alkali, two inconveniences follow. This ſuperabundant quantity will precipitate thoſe earthy ſalts which are liable to contain an exceſs of acid, and which are only ſoluble by that exceſs: Hence alumina and barytes will be precipitated. It is to the uſe of impure teſts of this kind that we owe the opinion, that barytes and alumina are precipitated by the Pruſſian alkali, and the conſequent theories of the metallic nature of theſe earths. This miſtake was firſt corrected, we believe, by Mr Klaproth.

Another inconvenience ariſing from the ſuperabundance of alkali in the Pruſſian teſt is, that it gradually decompoſes the blue pruſſiat which the teſt contains, and converts it into yellow pruſſiat. In what manner it does this will be underſtood, after what has been ſaid, without any explanation.

On the other hand, when the Pruſſian alkali contains a quantity of yellow pruſſiat of iron, as great inconveniences follow. This yellow pruſſiat has an affinity for pruſſic acid, which, though inferior to that of the potaſs, is ſtill conſiderable; and, on the other hand, the potaſs has a ſtronger affinity for every other acid than for the pruſſic. When, therefore, the teſt is expoſed to the air, the carbonic acid, which the atmoſphere always contains, aſſiſted by the affinity between the yellow pruſſiat and the pruſſic acid, decompoſes the pruſſiat of potaſs in the teſt; and the yellow pruſſiat is precipitated in the form of Pruſſian blue: And every other acid produces the ſame effect. A teſt of this kind, therefore, would indicate the preſence of iron in every mixture which contains an acid (for a precipitation of Pruſſian blue would appear); and could not, therefore, be truſted to with any confidence.

843 Klaproth's method of forming it.

We will not attempt to deſcribe the various methods which different chemiſts have adopted of preparing this teſt; but ſhall ſatisfy ourſelves with deſcribing the method of Klaproth, which anſwers the purpoſe completely. This we ſhall do nearly in the words of Mr Kirwan.

Prepare a pure potaſs, by gradually projecting into a large crucible heated to whiteneſs a mixture of equal parts of purified nitre and cryſtals of tartar; when the whole

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* See *Kirwan's Min.* i. 487.

is injected, let it be kept at a white heat for half an hour, to burn off the coal.

Detach the alkali thus obtained from the crucible, reduce it to powder, ſpread it on a muffle, and expoſe it to a white heat for half an hour.

Diſſolve it in ſix times its weight of water, and filter the ſolution while warm.

Pour this ſolution into a glaſs receiver, placed in a ſand furnace, heated to 170° or 180°, and then gradually add the beſt Pruſſian blue in powder, injecting new portions according as the former becomes grey, and ſupplying water as faſt as it evaporates; continue until the added portions are no longer diſcoloured, then increaſe the heat to 212° for half an hour.

Filter the ley thus obtained, and ſaturate it with ſulphuric acid moderately diluted; a precipitate will appear; when this ceaſes, filter off the whole, and waſh the precipitate.

Evaporate the filtered liquor to about one quarter, and ſet it by to cryſtallize: after a few days, yellowiſh cryſtals of a cubic or quadrangular form will be found mixed with ſome ſulphat of potaſs and oxide of iron; pick out the yellowiſh cryſtals, lay them on blotting paper, and rediſſolve them in four times their weight of cold water, to exclude the ſulphat of potaſs.

7. Eſſay a few drops of this ſolution with barytic water, to ſee whether it contains any ſulphuric acid, and add ſome barytic water to the remainder if neceſſary: filter off the ſolution from the ſulphat of barytes, which will have precipitated, and ſet it by to cryſtallize for a few days; that the barytes, if any ſhould remain, may be precipitated. If the cryſtals now obtained be of a pale yellow colour, and diſcover no bluiſh ſtreaks when ſprinkled over with muriatic acid, they are fit for uſe; but if they ſtill diſcover bluiſh or green ſtreaks, the ſolutions and cryſtallizations muſt be repeated.

Theſe cryſtals muſt be kept in a well-ſtopped bottle, which to preſerve them from the air ſhould be filled with alcohol, as they are inſoluble in it.

Before they are uſed, the quantity of iron they contain ſhould be aſcertained, by heating 100 grains to redneſs for half an hour in an *open* crucible: the pruſſic acid will be conſumed, and the iron will remain in the ſtate of a reddiſh brown magnetic oxide, which ſhould be weighed and noted: This oxide is half the weight of the Pruſſian blue afforded by the Pruſſian alkali; its weight muſt therefore be ſubtracted from that of metallic precipitates formed by this teſt. Hence the weight of the cryſtals, in a given quantity of the ſolution, ſhould be noted, that the quantity employed in precipitation may be known. Care muſt be taken to continue the calcination till the oxide of iron becomes brown; for while it is black it weighs conſiderably more than it ſhould *.

9. Pruſſiat of ſoda and iron. The only diſcernible difference between this ſalt and the laſt is, that it cryſtallizes differently †.

844
Pruſſiat of ammonia and iron.

10. Pruſſiat of ammonia and iron. This triple ſalt has alſo been employed as a teſt; but it is not ſo eaſy to obtain it in a ſtate of purity as the other two. It was diſcovered by Macquer, and firſt recommended by Meyer.

It forms flat hexangular cryſtals, ſoluble in water, and deliqueſces in the air. Heat decompoſes it like the other pruſſiats ‡.

We ſhall not give any deſcription of the triple ſalts formed by digeſting the alkaline earths on pruſſiat of iron; they are ſufficiently known, and are not of any uſe except as teſts; and in that reſpect they are inferior to that above deſcribed. They are all ſoluble in water, and are moſt of them capable of cryſtallizing.

845
Pruſſiat of mercury.

11. Pruſſiat of mercury. This ſalt, which was firſt formed by Scheele, is compoſed of the pruſſic acid combined with the red oxide of mercury. It may be formed by boiling the red oxide of mercury with Pruſſian blue. It cryſtallizes in tetrahedral priſms, terminated by quadrangular pyramids, the ſides of which correſpond with the angles of the priſm.

This ſalt is capable of combining with ſulphuric and muriatic acids, and forming triple ſalts, which have not yet been examined *.

Sect. XXIV. *Of Formats.*

The compounds into which the formic acid enters are called *formats*. We ſhall not deſcribe them, as little has been added to the account already given in the Appendix to the article Chemistry in the Encyclopædia.

Sect. XXV. *Of Sebats.*

The compounds into which the ſebacic acid enters are called *ſebats*. For our knowledge of this claſs of ſalts we are chiefly indebted to the celebrated Crell, who publiſhed a diſſertation on the ſebacic acid and its combinations in the Philoſophical Tranſactions for 1780 and 1782.

846
Alkaline ſebats.

1. Sebat of potaſs. This ſalt is of a white colour. Its cryſtals are quadrangular pyramids, of which two oppoſite ſides are narrower than the others. It has a ſharp ſaline taſte like muriat of ammonia, but milder. It is ſoluble in water, inſoluble in alcohol, and does not deliqueſce when expoſed to the air. Heat decompoſes it.

2. Sebat of ſoda. This ſalt is white. Its cryſtals are pyramids, with three or four ſides: a very moderate heat melts them.

3. Sebat of ammonia. This ſalt in taſte and ſolubility reſembles muriat of ammonia, but it differs from it in not being capable of ſubliming iron.

847
Earthy ſebats.

4. Sebat of lime. The cryſtals of this ſalt are hexagons, terminated by a plane ſurface: they have a ſharp acrid taſte; are very ſoluble in water, but not in alcohol: they do not deliqueſce.

5. Sebat of magneſia. A gummy, ſaline, uncryſtallizable maſs.

6. Sebat of alumina. A gummy ſaline maſs, which does not cryſtallize, and has an auſtere aſtringent taſte.

848
Metallic ſebats.

7. Sebat of iron. Needle-ſhaped cryſtals, which deliqueſce.

8. Sebat of lead. Needle-ſhaped cryſtals, very ſoluble in water.

9. Sebat of tin. A white deliqueſcent ſalt.

10. Sebat of copper. This ſalt is capable of cryſtallizing, but is very deliqueſcent.

11. Sebat of antimony. A cryſtallizable ſalt, which does not deliqueſce.

12. Sebat of arſenic. Small cryſtals.

13. Sebat of mercury. A white powder, very difficultly ſoluble in water.

14. Sebat of gold. Yellow cryſtals.

15. Sebat of platinum. Browniſh yellow cryſtals.

The bombats or compounds which the bombic acid forms are ſtill unknown.

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* *Kirwan's Mineral.* i. 494.

† *Berthollet.*

‡ *Woulfe, Journ. de Phyſ.* xxxiv. 101.

* *Berthollet.*

Sect. XXVI. *Of Arſeniats.*

The compounds formed by the combination of the arſenic acid with baſes are called *arſeniats*. This claſs of ſalts was firſt diſcovered by Macquer; but little accurate was known concerning it till Scheele made known the arſenic acid.

An abſtract of Scheele's experiments has been given in the article Chemistry, *Encycl.*

To his deſcription of arſeniats ſeveral additions might be made, but not of ſufficient conſequence to warrant a repetition of what has been given in that article; and without ſuch a repetition theſe additions would ſcarcely be intelligible.

Sect. XXVII. *Of Metallic Acid Salts.*

It has been conjectured that all metals may be converted into acids by combining them with a ſufficient quantity of oxygen. This conjecture has been verified in a conſiderable number of inſtances. We have ſeen the arſenic acid, the tungſtic acid, the molybdic acid, and the new metallic acid of Vauquelin. Berthollet has diſcovered that platinum becomes an acid; and the ſame thing has been aſcertained with regard to tin. Even thoſe metallic oxides which do not poſſeſs many of the characters of acids are capable of combining with alkalies and earths, and of forming peculiar neutral ſalts. Theſe oxides, therefore, perform the office of acids; and conſequently muſt be conſidered as partaking of their nature, or rather as a kind of intermediate ſubſtances between acids and thoſe bodies which unite only with acids.

Some of theſe neutral ſalts we ſhall proceed to enumerate.

849 Fulminating gold.

1. Aurat of ammonia, or fulminating gold. This ſalt is compoſed of the oxide of gold and ammonia. This compound may be formed by precipitating gold from nitro-muriatic acid by ammonia. The precipitate is fulminating gold. Bergman was the firſt who clearly demonſtrated that this powder is compoſed of oxide of gold and ammonia. When heated a little above the boiling temperature it explodes with aſtoniſhing violence. Chemiſts had made many attempts to explain the cauſe of this phenomenon, but without ſucceſs, till Mr Berthollet diſcovered the compoſition of ammonia. After making that diſcovery, he proved, by a number of delicate and hazardous experiments, that during the fulmination the ammonia is decompoſed, that its hydrogen combines with the oxygen of the oxide and forms water, while the azot flies off in a gaſeous form, and occaſions the exploſion.

850 Fulminating ſilver.

2. Argentat of ammonia, or fulminating ſilver. This ſubſtance was diſcovered by Mr Berthollet. It may be formed by diſſolving oxide of ſilver in ammonia. It is a black powder. It poſſeſſes the fulminating property much more powerfully than the laſt deſcribed ſubſtance. The ſlighteſt friction makes it explode with violence. This property, as Mr Berthollet has proved *, is owing to the ſame decompoſition of ammonia and formation of water that cauſes the exploſion of fulminating gold.

If a ſmall retort be filled with the liquor from which the fulminating ſilver has been precipitated, and be made to boil, ſome azot is diſengaged, and ſmall opaque cryſtals are formed conſiſting of the ſame ſubſtance; which explode when touched, though they be covered with water. Nitrat and muriat of barytes precipitate ſilver from this ſalt.

851 Mercuriat of lime and of ammonia.

3. Mercuriat of lime. Oxide of mercury boiled with lime-water forms, by evaporation, ſmall tranſparent yellow cryſtals *.

4. Mercuriat of ammonia. Oxide of mercury diſſolves in ammonia in large quantity; and by evaporation furniſhes a white ſalt †.

852 Cuprat of ammonia.

5. Cuprat of ammonia. Oxide of copper diſſolves in ammonia. Mr Sage has deſcribed its cryſtallization. It is decompoſed by lime and potaſs, and cuprat of lime and potaſs are formed.

853 Stannat of gold.

6. Stannat of gold. When gold is precipitated by tin it unites with it. Vogel and Beaumé firſt obſerved that the precipitate, which is purple, contained tin.

854 Plumbat of lime.

7. Plumbat of lime. Lime-water boiled on the red oxide of lead diſſolved it. This ſolution, evaporated in a retort, gave very ſmall tranſparent cryſtals, forming priſmatic colours, and not more ſoluble in water than lime. It is decompoſed by all the ſulphats of alkalies and by ſulphurated hydrogen gas. The ſulphuric and muriatic acids precipitate the lead. It blackens wool, the nails, the hair, white of eggs; but it does not affect the colour of ſilk, the ſkin, the yoke of eggs, nor animal oil. It is the lead which is precipitated on theſe coloured ſubſtances in the ſtate of oxide; for all acids can diſſolve it. The ſimple mixture of lime and oxide of lead blackens theſe ſubſtances; a proof that the ſalt is eaſily formed ‡.

855 Zincat of ammonia.

8. Zincat of ammonia. De Caſſone has publiſhed a great number of experiments on the property which ammonia has of diſſolving oxide of zinc. Lime-water and potaſs alſo diſſolve it §.

856 Antimoniat of potaſs.

9. Antimoniat of potaſs. When antimony is detonated with nitre in a crucible, part of its oxide unites with the potaſs of the nitre ‖.

Chap. III. *Of* Hydrosulphurets.

857 Properties of ſulphurated hydrogen gas.

Sulphurated hydrogen gas, which has been deſcribed in the firſt part of this article, poſſeſſes almoſt all the properties of acids. It combines with water, and the ſolution gives a red colour to vegetable blues. It decompoſes ſoaps and ſulphurets, and is capable of combining with alkalies, earths, and metallic oxides, and of forming compounds, to which Mr Berthollet, to whom we are indebted for diſcovering them, has given the name of *hydroſulphurets* ¶.

Before giving any account of theſe compounds, which we ſhall do from the paper of Berthollet juſt quoted, we beg leave to make a few previous obſervations, in order to rectify ſome inaccuracies into which we have fallen from not being acquainted with the experiments of that philoſopher.

858 Remarks on ſulphurets.

Sulphur is capable of combining with alkalies, earths, metals, and metallic oxides, and forming the compounds known by the name of *ſulphurets*. The alkaline, earthy, and even ſome of the metallic ſulphurets, can only exiſt in a ſtate of dryneſs: the inſtant they are moiſtened with water, a quantity of ſulphurated hydrogen gas is formed, which combines with the ſulphuret, and forms a new compound. To theſe triple compounds Mr Berthollet has given the name of *hydrogenous ſulphurets*. All ſolutions of ſulphurets in water are in fact hydrogenous ſulphurets. Were it not for the formation and combination of ſulphurated hydrogen, the alkaline ſulphurets would

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* *Berthollet, Ann. de Chim.* i.

* *Id. ibid.*

† *Lavoiſier, ibid.*

‡ *Berthollet, Ann. de Chim.* i. 37.

§ *Id. ibid.* p. 42.

‖ *Id. ibid.*

¶ *Ann. de Chim.* xxv. 233.

would be completely decompoſed by water, and their ſulphur precipitated; for water has a ſtronger affinity for the alkalies than ſulphur has. This Berthollet proved by the following experiment: To a ſolution of ſulphuret of potaſs in water (that is, to hydrogenous ſulphuret of potaſs), a quantity of oxy-muriatic acid ſuperſaturated with potaſs was added, and the ſulphur was immediately precipitated. In this experiment the ſulphurated hydrogen was deſtroyed by the oxygen of the oxy-muriatic acid; and the precipitation of the ſulphur ſhews that its affinity for potaſs was not ſufficient to keep it diſſolved, or, which is the ſame thing, that its affinity for potaſs was inferior to that of water.

859 Hydrogenous ſulphuret of mercury. The ſubſtance which we deſcribed in Part I. chap. iii. ſect. 4. of this article, under the name of *Black Sulphuret of Mercury*, is a hydrogenous ſulphuret of mercury, and therefore differs from the red ſulphuret of mercury or cinnabar by containing a quantity of ſulphurated hydrogen. Potaſs has a ſtronger affinity for this laſt ſubſtance than the ſulphuret; potaſs therefore, by the aſſiſtance of heat, deprives the black or hydrogenous ſulphuret of its ſulphurated hydrogen, and reduces it to the ſtate of red ſulphuret. This explains the method of forming cinnabar deſcribed in the ſection above referred to, and points out a much eaſier proceſs for obtaining that uſeful pigment.

860 Method of forming hydroſulphurets. We ſhall now proceed to the method of forming the hydroſulphurets. Berthollet obtained ſulphurated hydrogen gas from ſulphuret of iron in the uſual manner, by means of ſulphuric acid. It was made to paſs thro' a veſſel filled with water before it entered that in which the combination was to take place. By this method a ſolution of potaſs was impregnated with ſulphurated hydrogen; and in order to be certain of ſaturating the alkali completely, the gas was added in exceſs, and the exceſs was afterwards driven off by means of heat. By this method hydroſulphurets of potaſs, ſoda, and ammonia, may be formed.

In order to form hydroſulphuret of lime, that earth was mixed with diſtilled water, and ſulphurated hydrogen gas paſſed into this mixture till a ſufficient quantity of hydroſulphuret was judged to be formed; the liquid, which contained it in ſolution, was poured off the undiſſolved lime, and ſaturated to exceſs with ſulphurated hydrogen, and this exceſs was afterwards driven off by means of heat.

Hydroſulphuret of magneſia may be formed by diſſolving magneſia in water impregnated with ſulphurated hydrogen gas.

If a ſolution of ſulphuret of barytes in water, or, more properly, if hydrogenous ſulphuret of barytes be evaporated, a great number of confuſed cryſtals are formed; if theſe be ſeparated quickly by filtration, and placed upon blotting paper to dry, a white cryſtalline ſubſtance is obtained, which is hydroſulphuret of barytes.

861 Affinities of ſulphurated hydrogen. The affinities of the alkalies and earths for ſulphurated hydrogen appear, from the experiments of Berthollet, to be as follows:

Barytes,
Potaſs,
Soda,
Lime,
Ammonia,
Magneſia,
Jargonia.

Almoſt all the metallic oxides have a ſtronger affinity for ſulphurated hydrogen than the earths have.

862 Properties of hydroſulphurets. When the hydroſulphurats are prepared with the neceſſary precautions to prevent the contact of atmoſpherical air, they are colourleſs, but the action of the air renders them yellow.

If they be decompoſed while they are colourleſs, by pouring upon them ſulphuric acid, muriatic acid, or any other acid which does not act upon hydrogen, the ſulphurated hydrogen gas exhales without the depoſition of a ſingle particle of ſulphur; but if the hydroſulphuret has become yellow, ſome ſulphur is always depoſited during its decompoſition, and the quantity of ſulphur is proportional to the deepneſs of the colour.

The yellow colour, therefore, which hydroſulphurets acquire by expoſure to the atmoſphere is owing to a commencement of decompoſition. Part of the hydrogen of the ſulphurated hydrogen abandons the ſulphur, combines with the oxygen of the atmoſphere, and forms water. By degrees, however, a portion of the ſulphur is alſo converted into an acid; and when the proportion of ſulphurated hydrogen is diminiſhed, and that of the ſulphur increaſed to a certain point, the ſulphur and the hydrogen combine equally with oxygen.

If ſulphuric or muriatic acids be poured upon a hydroſulphuret after it has been for ſome time expoſed to the air, a quantity of ſulphurated hydrogen gas exhales, ſulphur is depoſited, and after an interval of time ſulphurous acid is diſengaged. It is therefore ſulphurous, and not ſulphuric acid, which is formed while the hydroſulphuret ſpontaneouſly abſorbs oxygen. This acid, however, is not perceptible till after a certain interval of time when ſeparated from the hydroſulphuret by means of an acid; becauſe as long as it meets with ſulphurated hydrogen a reciprocal decompoſition takes place. The oxygen of the acid combines with the hydrogen of the gas, and the ſulphur of both is precipitated.

863 Metalline hydroſulphurets. Sulphurated hydrogen is capable of combining with ſeveral of the metals, mercury, for inſtance, and ſilver: it combines with the greater number of the metallic oxides, and forms hydroſulphurets, on which the alkalies have no action at the temperature of the atmoſphere: But concentrated acids combine with the oxides of theſe hydroſulphurets, and ſeparate the ſulphurated hydrogen in the form of gas.

In the greater number of theſe metallic oxide hydroſulphurets, the tendency which oxygen and hydrogen have to combine occaſions a partial decompoſition of the ſulphurated hydrogen, and brings the oxides nearer to the metallic ſtate. In ſome of theſe hydroſulphurets part of the ſulphur alſo combines with oxygen, and forms ſulphuric acid.

The alkaline hydroſulphurets precipitate all the metals from their combination with acids; they are therefore very valuable teſts of the preſence of metals in any ſolution, as they do not precipitate any of the earths except alumina and jargonia. The following Table exhibits a view of the effect of hydroſulphuret of potaſs, hydrogenous ſulphuret of potaſs, and water impregnated with ſulphurated hydrogen gas, upon various metallic ſolutions.

Metallic

Hydroſulphurets.

Metallic Solutions.	Solution of Hydrogenous Sulphuret of Potaſs.	Water impregnated with Sulphurated Hydrogen Gas.	Hydroſulphuret of Potaſs.
Green ſulphat of iron.	A black precipitate, which becomes yellow by the contact of the air.		A black precipitate. The potaſs ſeparated.
Red oxide of iron.		Becomes black. The liquor remains very deep coloured if there be an exceſs of ſulphurated hydrogen.	Becomes black.
Sulphat of zinc.	A white precipitate.	A white precipitate.	A white precipitate.
Acetite of lead.	A white precipitate, which by an addition becomes black.	A black precipitate.	A black precipitate.
Red oxide of lead.		Becomes black.	The potaſs ſeparated.
Nitrat of biſmuth.		A black precipitate.	A black precipitate.
Oxide of biſmuth.		Becomes black.	
Nitrat of ſilver.	A black precipitate.	A black precipitate.	A black precipitate.
Sulphat of copper.	A brown precipitate.	A black precipitate.	A black precipitate.
Green oxide of copper.		Becomes black.	Separation of the potaſs.
Nitrat of mercury.	In a great deal of water, a brown colour.	A browniſh black precipitate.	A browniſh black precipitate.
Oxy-muriat of mercury.	A white precipitate, which becomes black by addition.	A white precipitate, becoming black by an addition.	White, becomes black by addition.
Red oxide of mercury.		Blackiſh.	A heat produced which cauſed the hydroſulphuret to boil. The alkali ſeparated (A).
Muriat of tin.			A black precipitate.
Oxy-muriat of tin.	A precipitation of ſulphur, and of the oxide.	No change.	A precipitate of white oxide of tin, and a diſengagement of ſulphurated hydrogen gas.
White oxide of tin.		No change.	Diſengagement of ſulphurated hydrogen gas.
Sulphat of manganeſe.		No change.	A white precipitate.
Black oxide of manganeſe.		The odour diſappears. An exceſs of the water diſſolves the oxide.	Ammonia diſengaged. Heat. The liquor boils (A).
Nitrat of antimony.			A reddiſh orange precipitate.
Tartrite of antimony.	A yellow orange precipitate.	An orange colour, but no precipitate.	An orange red precipitate, rediſſolved by an exceſs of hydroſulphuret.
White oxide of antimony.		Becomes yellow after ſome ſeconds.	The liquor loſes its colour (A).

Metallic

(A) In theſe, hydroſulphuret of ammonia was uſed inſtead of hydroſulphuret of potaſs.

Table continued.

Metallic Solutions.	Solution of Hydrogenous Sulphuret of Potaſs.	Water impregnated with Sulphurated Hydrogen Gas.	Hydrofulphuret of Potaſs.
Oxide of antimony ſublimed.		Scarcely changes colour.	
Solution of oxide of arſenic.	Sulphuret decompoſed as by an acid.	Becomes ſomewhat muddy, and of a yellow colour.	A yellow colour, but no precipitate.
Sulphat of titanium.			A precipitate of a deep green.
Molybdic acid.		A brown precipitate.	A brown precipitate.

Chap. IV. *Of* Cryſtallization.

864 Cryſtals. The word *cryſtal*, in its ſtrict and proper ſenſe, ſignifies a tranſparent body poſſeſſed of a regular figure. But it is now uſed to denote a body which has aſſumed a regular figure whether it be tranſparent or not. *Cryſtallization* is the *act* by which this regular figure is formed.

As the greater number of cryſtals belong to the claſs of neutral ſalts, it may not be improper, before we conclude this part of the article, to make a few obſervations on the phenomena of cryſtallization.

As cryſtallization is confeſſedly nothing elſe than the regular arrangement of the particles of bodies, it is evident that before it can take place the particles of the body to be cryſtallized muſt be at ſome diſtance from each other, and that they muſt be at liberty to obey the laws of attraction. They may be put into this ſituation by three methods, ſolution, ſuſpenſion, and fuſion.

865 Formed by ſolution, 1. Solution is the common method of cryſtallizing ſalts. They are diſſolved in water: The water is ſlowly evaporated, the ſaline particles gradually approach each other, combine together, and form ſmall cryſtals; which become conſtantly larger by the addition of other particles till at laſt they fall by their gravity to the bottom of the veſſel. It ought to be remarked, however, that there are two kinds of ſolution, each of which preſents different phenomena of cryſtallization. Some ſalts diſſolve in very ſmall proportions in cold water, but are very ſoluble in hot water; that is to ſay, water at the common temperature has little effect upon them, but water combined with caloric diſſolves them readily. When hot water ſaturated with any of theſe ſalts cools, it becomes incapable of holding them in ſolution: the conſequence of which is, that the ſaline particles gradually approach each other and cryſtallize. Sulphat of ſoda is a ſalt of this kind. To cryſtallize ſuch ſalts, nothing more is neceſſary than to ſaturate hot water with them, and ſet it by to cool. But were we to attempt to cryſtallize them by evaporating the hot water, we ſhould not ſucceed; nothing would be procured but a ſhapeleſs maſs. Many of the ſalts which follow this law of cryſtallization combine with a great deal of water; or, which is the ſame thing, many cryſtals formed in this manner contain a great deal of water of cryſtallization.

There are other ſalts again which are nearly equally ſoluble in hot and cold water; common ſalt for inſtance. It is evident that ſuch ſalts cannot be cryſtallized by cooling; but they cryſtallize very well by evaporating their ſolution while hot. Theſe ſalts generally contain but little water of cryſtallization.

866 Suſpenſion, 2. It appears, too, that ſome ſubſtances are capable of aſſuming a cryſtalline form merely by having their particles ſuſpended in water, without any regular ſolution; at leaſt it is not eaſy, on any other ſuppoſition, to explain the cryſtallizations of carbonat of lime ſometimes depoſited by waters that run over quantities of that mineral.

867 And fuſion. 3. There are many ſubſtances, however, neither ſoluble in water, nor capable of being ſo minutely divided as to continue long ſuſpended in that fluid; and which, notwithſtanding, are capable of aſſuming a cryſtalline form. This is the caſe with the metals, with glaſs, and ſome other bodies. The method employed to cryſtallize them is *fuſion*, which is a ſolution by means of caloric. By this method the particles are ſeparated from one another; and if the cooling goes on gradually, they are at liberty to arrange themſelves in regular cryſtals. There are many ſubſtances, however, which it has been hitherto impoſſible to reduce to a cryſtalline form, either by theſe or any other method. Whether this be owing to the nature of theſe bodies themſelves, or to our ignorance of the laws by which cryſtals are formed, as is much more likely, cannot be determined.

868 Cryſtallization explained. The phenomena of cryſtallization ſeem to have attracted but little of the attention of the ancient philoſophers. Their theory indeed, that the elements of bodies poſſeſs certain regular geometrical figures, may have been ſuggeſted by theſe phenomena; but we are ignorant of their having made any regular attempt to explain them. The ſchoolmen aſcribed the regular figure of cryſtals to their ſubſtantial forms, without giving themſelves much trouble about explaining the meaning of the term. This notion was attacked by Boyle; who proved that cryſtals were formed by the mere aggregation of particles *. But it ſtill remained to explain, why that aggregation took place? and why the particles united in ſuch a manner as to form regular figures? Theſe queſtions were anſwered by Newton. According to him, the aggregation is produced by the attraction which he had proved to exiſt between the particles of all bodies, and which acts as ſoon as theſe particles are brought within a certain diſtance of each other by the evaporation of the liquid in which they are diſſolved. The regularity of their figures he explained by ſuppoſing, that while in a ſtate of ſolution they were arranged in the liquid in regular rank and file; the conſequence

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* *Treatiſe on the Origin of Forms and Qualities.*

ſequence of which, as they are acted upon by a power which at equal diſtances is equal, at unequal diſtances unequal, will be cryſtals of determinate figures *.

This explanation, which is worthy of Newton, is now univerſally admitted as the true one, and has contributed much towards elucidating this important part of chemiſtry.

Still, however, there remain various phenomena relating to cryſtallization, which it is no eaſy matter to explain.

869 Salts do not eaſily cryſtallize in cloſe veſſels,

It has been obſerved, that thoſe ſalts which cryſtallize upon cooling, do not aſſume a cryſtalline form ſo readily if they are allowed to cool in cloſe veſſels. If a ſaturated ſolution of ſulphat of ſoda, for inſtance, in hot water be put into a phial, corked up cloſely, and allowed to cool without being moved, no cryſtals are formed at all; but the moment the glaſs is opened, the ſalt cryſtallizes with ſuch rapidity that the whole of the ſolution in a manner becomes ſolid. This phenomenon has been explained by ſuppoſing that there is an affinity between the ſalt and caloric, and that while the caloric continues combined with it the ſalt does not cryſtallize; that the caloric does not leave the ſalt ſo readily when external air is not admitted, as glaſs receives it very ſlowly and parts with it very ſlowly. In ſhort, the atmoſpherical air ſeems to be the agent employed to carry off the caloric; a taſk for which it is remarkably well fitted, on account of the change of denſity which it undergoes by every addition of caloric. This is confirmed by the quantity of caloric which always makes its appearance during theſe ſudden cryſtallizations. This explanation might be put to the teſt of experiment, by putting two ſolutions of ſulphat of ſoda in hot water in two ſimilar veſſels; one of glaſs, the other of metal, and both cloſed in the ſame manner. If the ſalt contained in the metallic veſſel cryſtallized, which ought to be the caſe on account of the great conducting power of metals, while that in the glaſs veſſel remained liquid, this would be a confirmation of the theory, amounting almoſt to demonſtration. On the contrary, if both ſolutions remained liquid, it would be a proof that the phenomenon was ſtill incompletely underſtood.

870 And why.

Not only ſalts, but water itſelf, which commonly cryſtallizes at 32°, may be made to exhibit the ſame phenomenon: it may be cooled much lower than 32° without freezing. This, as Dr Black has completely proved, depends entirely upon the retention of caloric.

871 Variety of forms in cryſtals accounted for.

If the regular form of cryſtals depends upon the aggregation of particles, and if during all cryſtallizations this aggregation goes on in the ſame manner, why have not all cryſtals the ſame form? Some have aſcribed theſe differences to a certain polarity which the particles of bodies are ſuppoſed to poſſeſs, and which diſpoſes each kind of particles to arrange themſelves according to a certain law. Sir Iſaac Newton appears rather to have aſcribed it to the forms of the particles themſelves †; and this ſeems to be the real ſolution of the problem. For ſuppoſing that all particles have the ſame form, they muſt of courſe poſſeſs the ſame polarity; and therefore every cryſtal muſt have the ſame form. It is impoſſible, then, to account for the different forms of cryſtals without ſuppoſing that the particles which compoſe them have alſo different forms. And if the particles of bodies have different forms, their regular aggregation muſt produce cryſtals of various ſhapes; and therefore their polarity, which is merely a ſuppoſition founded on this difference in the appearance of cryſtals, cannot be admitted. Suppoſe, for inſtance, that eight cubic particles were regularly arranged in water, and that by the gradual evaporation of the liquid were to approach, and at laſt to combine, it is evident that the cryſtal which they would produce would be a cube. Eight ſix-ſided priſms would alſo produce a ſix-ſided priſm; and eight tetrahedrons would form a very different figure.

But it will be aſked, if the figure of cryſtals depends entirely upon the form of the particles that compoſe them, how comes it that the ſame ſubſtance does not always cryſtallize in the ſame way, but preſents often ſuch a variety of forms that it is ſcarcely poſſible to reckon them? We anſwer, that theſe various forms are ſometimes owing to variations in the ingredients which compoſe the integrant particles of any particular body. Alum, for inſtance, cryſtallizes in octahedrons; but when a quantity of alumina is added, it cryſtallizes in cubes; and when there is an exceſs of alumina, it does not cryſtallize at all. If the proportion of alumina varies between that which produces octahedrons and what produces cubic cryſtals, the cryſtals become figures with fourteen ſides; ſix of which are parallel to thoſe of the cube and eight to thoſe of the octahedron; and according as the proportions approach nearer to thoſe which form cubes or octahedrons, the cryſtals aſſume more or leſs of the form of cubes or octahedrons. What is ſtill more, if a cubic cryſtal of alum be put into a ſolution that would afford octahedral cryſtals, it paſſes into an octahedron: and, on the other hand, an octahedral cryſtal put into a ſolution that would afford cubic cryſtals, becomes itſelf a cube *. Now, how difficult a matter it is to proportion the different ingredients with abſolute exactneſs, muſt appear evident to all.

Another circumſtance which contributes much to vary the form of cryſtals, is the different degree of concentration to which their ſolution has been reduced, and the rapidity or ſlowneſs with which they are formed. For it is too evident to require illuſtration, that when cryſtals are depoſited very rapidly they muſt obſtruct one another, and mix together ſo as very much to obſcure the natural regularity of their form.

Even the nature of the veſſel in which the cryſtallization is performed is not without ſome influence.

872 Hauy's theory of cryſtals.

But, independent of theſe accidental circumſtances, Mr Hauy has ſhewn that every particular ſpecies of cryſtals has a primitive figure, and that the variations are owing to the different ways in which the particles arrange themſelves. Of this theory, which is certainly exceedingly ingenious, and even ſatisfactory, we ſhall attempt to give a ſhort view.

Happening to take up a hexangular priſm of calcareous ſpar, or carbonat of lime, which had been detached from a group of the ſame kind of cryſtals, he obſerved that a ſmall portion of the cryſtal was wanting, and that the fracture preſented a very ſmooth ſurface. Let *abcde fgh* (fig. 8.) be the cryſtal; the fracture lay obliquely as the trapezium *psut*, and made an angle of 135°, both with the remainder of the baſe *abcsph* and with *tuef*, the remainder of the ſide *inef*. Obſerving that the ſegment *psutin* thus cut off had for its vertex *in*, one of the edges of the baſe *abcnih* of the priſm, he attempted to detach a

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* Optics, p. 363.

† Optics, p. 375.

* Le Blanc, Ann. de Chim. xiv. 149.

a ſimilar ſegment in the part to which the next edge *c n* belonged, employed for that purpoſe the blade of a knife, directed in the ſame degree of obliquity as the trapezium *p s u t*, and aſſiſted by the ſtrokes of a hammer. He could not ſucceed: But upon making the attempt upon the next edge *b c*, he detached another ſegment, preciſely ſimilar to the firſt, and which had for its vertex the edge *b c*. He could produce no effect on the next edge *a b*; but from the next following, *a h*, he cut a ſegment ſimilar to the other two. The ſixth edge likewiſe proved refractory. He then went to the other baſe of the priſm *d e f g h r*, and found, that the edges which admitted ſections ſimilar to the preceding ones were not the edges *e f*, *d r*, *g k*, correſponding with thoſe which had been found diviſible at the oppoſite baſe, but the intermediate edges *d e*, *k r*, *g f*. The trapezium *l q y v* repreſents the ſection of the ſegment, which had *k r* for its vertex. This ſection was evidently parallel to the ſection *p s u t*; and the other four ſections were alſo parallel two and two. Theſe ſections were, without doubt, the natural joinings of the layers of the cryſtal. And he eaſily ſucceeded in making others parallel to them, without its being poſſible for him to divide the cryſtal in any other direction. In this manner he detached layer after layer, approaching always nearer and nearer the axis of the priſm, till at laſt the baſes diſappeared altogether, and the priſm was converted into a ſolid OX (fig. 9.), terminated by twelve pentagons, parallel two and two; of which thoſe at the extremities, that is to ſay, ASRIO, IGEDO, BAODC at one end, and FKNPQ, MNPXU, ZQPXY at the other, were the reſults of mechanical diviſion, and had their common vertices O, P ſituated at the centre of the baſes of the original priſm. The ſix lateral pentagons RSUXY, ZYRIG, &c. were the remains of the ſix ſides of the original priſm.

By continuing ſections parallel to the former ones, the lateral pentagons diminiſhed in length; and at laſt the points R, G coinciding with the points Y, Z, the points S, R with the points U, Y, &c. there remained nothing of the lateral pentagons but the triangles YIZ, UXY, &c. (fig. 10.). By continuing the ſame ſections, theſe triangles at laſt diſappeared, and the priſm was converted into the rhomboid *a e* (fig. 11.).

So unexpected a reſult induced him to make the ſame attempt upon more of theſe cryſtals; and he found that all of them could be reduced to ſimilar rhomboids. He found alſo, that the cryſtals of other ſubſtances could be reduced in the ſame manner to certain primitive forms; always the ſame in the ſame ſubſtances, but every ſubſtance having its own peculiar form. The primitive form of fluat lime, for inſtance, was an octahedron; of ſulphat of barytes, a priſm with rhomboidal baſes; of field-ſpath, an oblique angled parallelopiped, but not rhomboidal; of adamantine ſpar, a rhomboid, ſomewhat acute; of blende, a dodecahedron, with rhomboidal ſides; and ſo on.

Theſe muſt be conſidered as the real *primitive forms* of the cryſtals; the other forms which they often aſſume may be called *ſecondary forms*.

The primitive cryſtals obtained by the above proceſs may be divided by ſections parallel to their different ſides: all the matter which ſurrounded this primitive cryſtal may alſo be divided by ſections parallel to the ſides of the primitive cryſtal. It follows from this, that the parts detached by means of theſe ſections are ſimilar, and differ from one another only in ſize, which diminiſhes in proportion to the length that the diviſion is carried. But the diviſion of the cryſtals into ſimilar ſolids has a term, beyond which we ſhould come to the ſmalleſt particles of the body, which could not be divided without chemical decompoſition. It is probable, therefore, that the form of the integrant particles of a body is the ſame with the primitive form of its cryſtals. Here, then, we have a method of diſcovering the form of the particles of bodies; and if this method could be applied to all ſubſtances whatever, it would enable us to aſcertain the affinity of all bodies for each other by accurate calculation. It muſt be allowed that ſeveral objections might be made to the concluſions of Mr Hauy; but his theory is, on the whole, ſo plauſible, that it would certainly be worth while to extend it, and apply it to the calculation of affinities as far as it is ſuſceptible of the application. If the cryſtals obtained by the above proceſs be the primitive forms, it becomes a queſtion of ſome conſequence to determine in what manner the ſecondary forms are produced.

According to Hauy, all the parts ſuperadded to the primitive cryſtals, in order to form the ſecondary cryſtal, conſiſt of plates, which decreaſe regularly by the ſubtraction of one or more rows of integrant particles, in ſuch a manner, that the number of theſe ranks, and conſequently the form of the ſecondary cryſtal, may be determined by theory (c).

To explain this, let us ſuppoſe that EP (fig. 12.) repreſents a dodecahedron, terminated by equal and ſimilar rhombs; that this dodecahedron is a ſecondary cryſtal, the primitive form of which is a cube: the ſituation of this cube in the dodecahedron may be conceived from fig. 13. The ſmaller diagonals DC, CG, GF, FD, of four ſides of the dodecahedron, united round the ſame ſolid angle L, form the ſquare CDFG. Now there are ſix ſolid angles, compoſed of four plains, to-wit, the angles L, O, E, N, R, P (fig. 12.); and conſequently, by making ſections through the ſmaller diagonals of the ſides that form theſe angles, ſix ſquares will be made apparent, which are the ſix ſides of the primitive cube, three of which are repreſented in fig. 13. CDFG, ABCD, BCGH.

This cube being compoſed of cubic integrant particles, each of the pyramids, LCDFG for inſtance (fig. 13.) which repoſe upon its ſides, muſt alſo, according to the theory, be compoſed of ſimilar cubic particles. To make this appear, let us ſuppoſe that ABFG (fig. 14.) is a cube compoſed of 729 ſmall cubes: Each of its ſides will conſiſt of 81 ſquares, being the external ſides of as many cubic particles, which together conſtitute the cube. Upon ABCD, one of the ſides of this cube, let us apply a ſquare lamina, compoſed of cubes equal to thoſe of which the primitive cryſtal conſiſts, but which has on each ſide a row of cubes leſs than the outermoſt layer of the primitive cube. It will of courſe be compoſed of 49 cubes, 7 on each ſide; ſo that its lower baſe *o n f g* (fig. 15.) will fall exactly on the ſquare marked with the ſame letters in fig. 14.

Above this lamina let us apply a ſecond *l m p u* (fig. 16.),

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(c) The explanation of Bergman is not very different. See his *Opuſc.* vol. ii. diſſ. 1.

16.), compoſed of 25 cubes; it will be ſituated exactly above the ſquare marked with the ſame letters (fig. 14.) Upon this ſecond let us apply a third lamina *v x y z* (fig. 17.) conſiſting only of 9 cubes; ſo that its baſe ſhall reſt upon the letters *v x y z* (fig. 14.). Laſtly, on the middle ſquare *r* let us place the ſmall cube *r* (fig. 18.), which will repreſent the laſt lamina.

It is evident, that by this proceſs a quadrangular pyramid has been formed upon the face ABCD (fig. 14.), the baſe of which is this face, and the vertex the cube *r* (fig. 18.). By continuing the ſame operation on the other five ſides of the cube, as many ſimilar pyramids will be formed; which will envelope the cube on every ſide.

It is evident, however, that the ſides of theſe pyramids will not form continued planes, but that, owing to the gradual diminution of the laminæ of the cubes which compoſe them, theſe ſides will reſemble the ſteps of a ſtair. We can ſuppoſe, however (what muſt certainly be the caſe), that the cubes of which the nucleus is formed are exceedingly ſmall, almoſt imperceptible; that therefore a vaſt number of laminæ are required to form the pyramids, and conſequently that the channels which they form are imperceptible. Now DCBE (fig. 19.) being the pyramid reſting upon the face ABCD (fig. 14.), and CBOG (fig. 19.) the pyramid applied to the next face BCGH (fig. 14.), if we conſider that every thing is uniform from E to O (fig. 19.) in the manner in which the edges of the *laminæ of ſuperpoſition* (as the Abbé Hauy calls the laminæ which compoſe the pyramids) mutually project beyond each other, it will readily be conceived, that the face CEB of the firſt pyramid ought to be exactly in the ſame plane with the face COB of the adjacent pyramid; and that therefore the two faces together will form one rhomb ECOB. But all the ſides of the ſix pyramids amount to 24 triangles ſimilar to CEB; conſequently they will form 12 rhombs, and the figure of the whole cryſtal will be a dodecahedron, ſimilar to that repreſented in fig. 12. and 13.

If the decreaſe of the laminæ of ſuperpoſition took place according to a more rapid law, if each lamina had on its circumference two, three, or four rows of cubes leſs than the inferior lamina—in that caſe, the pyramids produced being lower, their adjacent faces would no longer form one plane; and therefore the ſurface of the ſecondary cryſtal would conſiſt of 24 iſoſceles triangles, all inclined towards each other.

In this manner Mr Hauy has ſhewn, that a variety of ſecondary cryſtals are formed, and that their forms vary by means of ſlight variations in the ratio of the *decrement*. Dodecahedral ſulphuret of iron, for inſtance, is formed from a cubic nucleus, by the addition of laminæ, decreaſing, as in the example given above, with this difference, that from every lamina laid upon the face ABCD (fig. 14.) only one row of cubes are ſubtracted at the ſides AD and BC reſpectively; whereas two rows are ſubtracted at each of the ſides AB and CD. The conſequence of this more rapid decrement on two parallel ſides than on the other two will be, that the pyramid raiſed on the face ABCD (fig. 14.), inſtead of terminating in a ſingle cube as in the example given above, will terminate in a range of cubes; or (ſuppoſing the cubes infinitely ſmall) inſtead of terminating in a point, it will terminate in a ridge. The pyramid will therefore have for its two ſides, contiguous to AB and DC, two trapeziums, and for its ſides, contiguous to AD and BC, two triangles. Let us ſuppoſe alſo, that with regard to the laminæ of ſuperpoſition which ariſe on the face BCGH (fig. 14.), the decrements follow the ſame law, and that each lamina decreaſes by two rows of cubes towards the lines BC and HG, and only by one row towards the lines CG, BH: The pyramid, in that caſe, will be placed in a direction oppoſite to the pyramid on ABCD, the ridge at the vertex of it running parallel to BC: the vertex of the pyramid raiſed upon CDFG muſt be parallel to CG: the pyramids on the three other ſides of the cube ought to ſtand each like that which ariſes on the oppoſite face.

The ſides of all the ſix pyramids thus formed amount to twelve trapeziums and twelve triangles. Every triangle is evidently contiguous and in the ſame plane with a trapezium of the neareſt pyramid; conſequently the ſecondary cryſtal thus formed conſiſts of twelve ſides, each of which is a pentagon.

Several other examples have been given by Mr Hauy; but theſe are ſufficient to ſhew in what manner the various ſecondary forms of cryſtals are conſtructed, according to the theory of that ingenious philoſopher.

In his reſearches on this ſubject, Mr Hauy perceived, that ſome cryſtals aſſumed ſecondary forms which could not be accounted for by any decrement whatever along the edges. Thus, for inſtance, ſome bodies, the primary form of which is cubic, are ſometimes found cryſtallized in regular octagons. Mr Hauy explains the formation of theſe ſecondary cryſtals, by ſuppoſing that the decrement took place parallel, not to the edges, but to the diagonals of the faces of the primary cubes.

In order to comprehend this, let us ſuppoſe ABCD (fig. 20.) to be the ſurface of a lamina compoſed of ſmall cubes, the baſes of which are repreſented by the little ſquares in the figure. It is evident, that the cubes *a*, *b*, *c*, *d*, *e*, *f*, *g*, *h*, *i*, are in the direction of the diagonal of the ſquare ABCD; that the row of cubes *q*, *v*, *k*, *u*, *x*, *y*, *z*, is parallel to the diagonal; as alſo the row *n*, *t*, *l*, *m*, *p*, *o*, *r*, *s*; and that the whole figure might be divided into rows of ſquares, each of which would be parallel either to the diagonal AC or DB.

Now we may conceive that the laminæ of ſuperpoſition, inſtead of decreaſing by rows of cubes parallel to the edges AB, AD, decreaſe by rows parallel to the diagonals.

Let it be propoſed to conſtruct around the cube AB GF (fig. 21.), conſidered as a nucleus, a ſecondary ſolid, in which the laminæ of ſuperpoſition ſhall decreaſe on all ſides by ſingle rows of cubes, but in a direction parallel to the diagonals. Let ABCD (fig. 22.), the ſuperior baſe of the nucleus, be divided into 81 ſquares, repreſenting the faces of the ſmall cubes of which it is compoſed. Figure 23. repreſents the ſuperior ſurface of the firſt lamina of ſuperpoſition; which muſt be placed above ABCD (fig. 22.) in ſuch a manner that the points a', b', c', d', (fig. 23.) anſwer to the points *a*, *b*, *c*, *d*, (fig. 22.). By this diſpoſition the ſquares A *a*, B *b*, C *c*, D *d* (fig. 22.), which compoſe the four outermoſt rows of ſquares parallel to the diagonals AC, BD, remain uncovered. It is evident alſo, that the borders QV, ON, IL, GF (fig. 23.), project by one range beyond the borders AB, AD, CD, BC (fig. 22.), which is neceſſary, that the nucleus may be enveloped towards theſe edges: For if this were not the caſe,

caſe, re-entering angles would be formed towards the parts AB, BC, CD, DA, of the cryſtal; which angles appear to be excluded by the laws which determine the formation of ſimple cryſtals, or, which comes to the ſame thing, no ſuch angles are ever obſerved in any cryſtal. The ſolid muſt increaſe, then, in thoſe parts to which the decrement does not extend. But as this decrement is alone ſufficient to determine the form of the ſecondary cryſtal, we may ſet aſide all the other variations which intervene only in a ſubſidiary manner, except when it is wiſhed, as in the preſent caſe, to conſtruct artificially a ſolid repreſentation of a cryſtal, and to exhibit all the details which relate to its ſtructure.

The ſuperior face of the ſecond lamina will be A′ G′L′K′ (fig. 24.). It muſt be placed ſo that the points *a″*, *b″*, *c″*, *d″*, correſpond to the points *a′ b′ c′ d′* (fig. 23.), which will leave uncovered a ſecond row of cubes at each angle parallel to the diagonals AC and BD. The ſolid ſtill increaſes towards the ſides. The large faces of the laminæ of ſuperpoſition, which in fig. 23. were octagons, in fig. 24. arrive at that of a ſquare; and when they paſs that term they decreaſe on all ſides; ſo that the next lamina has for its ſuperior face the ſquare B′M′L′S′ (fig. 25.), leſs by one range in every direction than the preceding lamina (fig. 24.). This ſquare muſt be placed ſo that the points *e′*, *f′*, *g′*, *h′*, (fig. 25.) correſpond to the points *e*, *f*, *g*, *h* (fig. 24.). Figures 26, 27, 28, and 29, repreſent the four laminæ which ought to riſe ſucceſſively above the preceding; the manner of placing them being pointed out by correſponding letters, as was done with reſpect to the three firſt laminæ. The laſt lamina *z′* (fig. 30.) is a ſingle cube, which ought to be placed upon the ſquare *z* (fig. 29.).

The laminæ of ſuperpoſition, thus applied upon the ſide ABCD (fig. 22.), evidently produce four faces, which correſpond to the points A, B, C, D, and form a pyramid. Theſe faces, having been formed by laminæ, which began by increaſing, and afterwards decreaſed, muſt be quadrilaterals of the figure repreſented in fig. 31.; in which the inferior angle C is the ſame point with the angle C of the nucleus (fig. 21. and 22.); and the diagonal LQ repreſents L′G′ of the lamina A′G′L′K′ (fig. 24.). And as the number of laminæ compoſing the triangle L Q C (fig. 31.) is much ſmaller than that of the laminæ forming the triangle ZLQ, it is evident that the latter triangle will have a much greater height than the former.

The ſurface, then, of the ſecondary cryſtal thus produced, muſt evidently conſiſt of 24 quadrilaterals (for pyramids are raiſed on the other 5 ſides of the primary cube exactly in the ſame manner), diſpoſed 3 and 3 around each ſolid angle of the nucleus. But in conſequence of the decrement by one range, the three quadrilaterals which belong to each ſolid angle, as C (fig. 21.) will be in the ſame plane, and will form an equilateral triangle ZIN (fig. 32.). The 24 quadrilaterals, then, will produce 8 equilateral triangles; and conſequently the ſecondary cryſtal will be a regular octagon. This is the ſtructure of the octahedral ſulphuret of lead and of muriat of ſoda.

Decrements which take place in this manner have been called by Mr Hauy *decrements on the angles*.

There are certain cryſtals in which the decrements on the angles do not take place in lines parallel to the diagonals, but parallel to lines ſituated between the diagonals and the edges. This is the caſe when the ſubtractions are made by ranges of double, triple, &c. moleculæ. Fig. 33. exhibits an inſtance of the ſubtractions in queſtion; and it is ſeen that the moleculæ which compoſe the range repreſented by that figure are aſſorted in ſuch a manner as if of two there were formed only one; ſo that we need only to conceive the cryſtal compoſed of parallelopipedons having their baſes equal to the ſmall rectangles *a b c d*, *e d f g*, *h g i l*, &c. to reduce this caſe under that of the common decrements on the angles. To this particular kind of decrement Mr Hauy has given the name of *intermediate*.

In other cryſtals the decrements, either on the edges or on the angles, vary according to laws, the proportion of which cannot be expreſſed but by the fraction $\frac{2}{3}$ or $\frac{3}{4}$. It may happen, for example, that each lamina exceeds the following by two ranges parallel to the edges, and that it may at the ſame time have an altitude triple that of a ſimple molecule. Figure 34. repreſents a vertical geometrical ſection of one of the kinds of pyramids which would reſult from this decrement; the effect of which may be readily conceived, by conſidering that AB is a horizontal line taken on the upper baſe of the nucleus, *b a z r* the ſection of the firſt lamina of ſuperpoſition, *g f e n* that of the ſecond, &c. Theſe decrements Mr Hauy has called *mixed*.

Theſe two laſt ſpecies of decrements occur but rarely; Mr Hauy found them only in certain metallic ſubſtances.

All the metamorphoſes to which cryſtals are ſubjected depend, according to Mr Hauy, on the laws of ſtructure juſt explained, and others of the like kind. Sometimes the decrements take place at the ſame time on all the edges; as in the dodecahedron having rhombuſes for its planes, as before mentioned; or on all the angles, as in the octahedron originating from a cube. Sometimes they take place only on certain edges or certain angles. Sometimes there is an uniformity between them; ſo that it is one ſingle law by one, two, three ranges, &c. which acts on the different edges, or the different angles. Sometimes the law varies from one edge to the other, or from one angle to the other; and this happens above all when the nucleus has not a ſymmetrical form; for example, when it is a parallelopipedon, the faces of which differ by their reſpective inclinations, or by the meaſure of their angles In certain caſes the decrements on the edges concur with the decrements on the angles to produce the ſame cryſtalline form. It happens alſo ſometimes that the ſame edge, or the ſame angle, is ſubjected to ſeveral laws of decrement that ſucceed each other. In ſhort, there are caſes where the ſecondary cryſtal has faces parallel to thoſe of the primitive form, and which combine with the faces produced by the decrements to modify the figure of the cryſtal.

The cryſtals ariſing from a ſingle law of decrement have been called by Mr Hauy *ſimple ſecondary forms*; thoſe which ariſe from ſeveral ſimultaneous laws of decrement he has called *compound ſecondary forms*.

" If amidſt this diverſity of laws (he obſerves), ſometimes inſulated, ſometimes united by combinations more or leſs complex, the number of the ranges ſubtracted were itſelf extremely variable; for example, were theſe decrements by twelve, twenty, thirty, or forty ranges, or more, as might abſolutely be poſſible, the multitude of the forms which might exiſt in each kind of mineral would be immenſe, and exceed what could be imagined. But the power which effects the ſubtractions ſeems to have a very limited action. Theſe ſubtractions, for the moſt part, take place by one or two ranges of molecules. I have found none which exceeded four ranges, except in a variety of calcareous ſpar, forming part of the collection of C. Gillet Laumont, the ſtructure of which depends on a decrement by ſix ranges; ſo that if there exiſt laws which exceed the decrements by four ranges, there is reaſon to believe that they rarely take place in nature. Yet, notwithſtanding theſe narrow limits by which the laws of cryſtallization are circumſcribed, I have found, by confining myſelf to two of the ſimpleſt laws, that is to ſay, thoſe which produce ſubtractions by one or two ranges, that calcareous ſpar is ſuſceptible of two thouſand and forty-four different forms: a number which exceeds more than fifty times that of the forms already known; and if we admit into the combination decrements by three and four ranges, calculation will give 8,388,604 poſſible forms in regard to the ſame ſubſtance. This number may be ſtill very much augmented in conſequence of decrements either mixed or intermediary.

"The ſtriæ remarked on the ſurface of a multitude of cryſtals afford a new proof in favour of theory, as they always have directions parallel to the projecting edges of the laminæ of ſuperpoſition, which mutually go beyond each other, unleſs they ariſe from ſome particular want of regularity. Not that the inequalities reſulting from the decrements muſt be always ſenſible, ſuppoſing the form of the cryſtals had always that degree of finiſhing of which it is ſuſceptible; for, on account of the extreme minuteneſs of the molecules, the ſurface would appear of a beautiful poliſh, and the ſtriæ would elude our ſenſes. There are therefore ſecondary cryſtals where they are not at all obſerved, while they are very viſible in other cryſtals of the ſame nature and form. In the latter caſe, the action of the cauſes which produce cryſtallization not having fully enjoyed all the conditions neceſſary for perfecting that ſo delicate operation of nature, there have been ſtarts and interruptions in their progreſs, ſo that, the law of continuity not having been exactly obſerved, there have remained on the ſurface of the cryſtal vacancies apparent to our eyes. Theſe ſmall deviations are attended with this advantage, that they point out the direction according to which the ſtriæ are arranged in lines on the perfect forms where they eſcape our organs, and thus contribute to unfold to us the real mechaniſm of the ſtructure.

"The ſmall vacuities which the edges of the laminæ of ſuperpoſition leave on the ſurface of even the moſt perfect ſecondary cryſtals, by their re-entering and ſalient angles, thus afford a ſatisfactory ſolution of the difficulty a little before mentioned; which is, that the fragments obtained by diviſion, the external ſides of which form part of the faces of the ſecondary cryſtal, are not like thoſe drawn from the interior part. For this diverſity, which is only apparent, ariſes from the ſides in queſtion being compoſed of a multitude of ſmall planes, really inclined to one another, but which, on account of their ſmallneſs, preſent the appearance of one plane; ſo that if the diviſion could reach its utmoſt bounds, all theſe fragments would be reſolved into molecules ſimilar to each other, and to thoſe ſituated towards the centre.

"The fecundity of the laws on which the variations of cryſtalline forms depend, is not confined to the producing of a multitude of very different forms with the ſame molecules. It often happens alſo, that molecules of different figures arrange themſelves in ſuch a manner as gives riſe to like polyhedra in different kinds of minerals. Thus the dodecahedron with rhombuſes for its planes, which we obtained by combining cubic molecules, exiſts in the granite with a ſtructure compoſed of ſmall tetrahedra, having iſoſceles triangular faces; and I have found it in ſparry fluor *(fluat of lime)*, where there is alſo an aſſemblage of tetrahedra, but regular; that is to ſay, the faces of which are equilateral triangles. Nay more, it is poſſible that ſimilar molecules may produce the ſame cryſtalline form by different laws of decrement. In ſhort, calculation has conducted me to another reſult, which appeared to me ſtill more remarkable, which is, that, in conſequence of a ſimple law of decrement, there may exiſt a cryſtal which externally has a perfect reſemblance to the nucleus, that is to ſay, to a ſolid that does not ariſe from any law of decrement *."

SUCH is a ſhort view of the theory by which Mr Hauy explains the various cryſtalline forms of the ſame ſubſtance. We would with pleaſure have entered more into detail, had not moſt of his examples been deduced from ſubſtances which belong rather to mineralogy than to the elements of chemiſtry. This theory, to ſay no more of it, is, in point of ingenuity, inferior to few; and the mathematical ſkill and induſtry of its author are intitled to the greateſt applauſe.

But what we conſider as the moſt important part of that philoſopher's labours, is the method which they point out of diſcovering the figure of the integrant particles of cryſtals; becauſe it may pave the way for calculating the affinities of bodies, which is certainly by far the moſt important part of chemiſtry. This part of the ſubject, therefore, deſerves to be inveſtigated with the greateſt care.

Mr Hauy has found, that the primitive form of all the cryſtals which he has examined may be reduced to ſix; 1. The parallelopipedon in general, comprehending the cube, the rhomboid, and all ſolids terminated by ſix ſides parallel two and two; 2. The regular tetrahedron; 3. The octahedron with triangular ſides; 4. The hexagonal priſm; 5. The dodecahedron bounded by rhombs; 6. The dodecahedron bounded by iſoſceles triangles. Were we to ſuppoſe that theſe primitive forms are exactly ſimilar to the form of the integrant particles which compoſe them, it would follow, that the integrant particles of all the cryſtals hitherto formed have only ſix different forms. This ſuppoſition, however, is not probable; becauſe the ſame nucleus has been diſcovered in different ſpecies of minerals, and becauſe we can eaſily conceive integrant particles of different forms, combining in ſuch a manner as to compoſe nuclei of the ſame figure, juſt as we have ſeen that different primitive forms are capable of producing the ſame ſecondary form. Still, therefore, in endeavouring to diſcover the integrant particles of bodies, there are difficulties to remove, which hitherto, at leaſt, have been unſurmountable. But the theory of Mr Hauy may be conſidered as a firſt ſtep towards the diſcovery; and a *ſtep* in reſearches of ſo difficult a nature is of very great conſequence.

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* *Ann. de Chim.* xvii. 225.

Concluſion.

We have now finiſhed the three firſt parts of this article, which comprehend all the elementary part of chemiſtry. We ought now to proceed to the fourth part, which was to conſiſt of a chemical examination of ſubſtances as they exiſt in nature in the mineral, vegetable, and animal kingdoms; but this, for various reaſons, we ſhall defer till we come to the words MINERALOGY, and *Animal and Vegetable* SUBSTANCES.

We ſhall finiſh this article with a few remarks upon the chemical nomenclature, which for ſome time paſt has been an object of ſerious attention.

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Remarks on the chemical nomenclature.

Chemiſtry was unfortunately firſt cultivated by a ſet of ignorant men, filled with the higheſt notions of their own importance, and buoyed up with the mighty feats which they were to perform by their art. The little which they did know they were anxious to conceal; and their anxiety was no leſs to inſpire the world with high ideas of their knowledge and power. The conſequence of this was, that they loaded chemiſtry with the moſt ridiculous and whimſical names that can well be conceived. *Liver of ſulphur*, *mercury of life*, *horned moon*, *butter of antimony*, *the double ſecret*, *the corraline ſecret*, *the ſecret of vitriol*, *the wonderful ſalt*, *the ſecret ſalt*, *the ſalt with many virtues*, *the ſalt of two ingredients*, *the foliated earth of tartar*, were the names by which they diſtinguiſhed ſome of the moſt familiar preparations; and, were it worth while, a great many more names of the ſame ſtamp might eaſily be added.

As ſoon as chemiſtry had attracted the attention of men of ſcience, the abſurdity of its nomenclature was felt, and ſeveral partial improvements were at different times made in it. Macquer, in particular, diſcarded many of the ancient names, and ſubſtituted others leſs exceptionable in their place.

But ſoon after the publication of the firſt edition of his Dictionary, an evil began to be felt ſeverely, which never could have occurred to the earlier chemiſts. Hitherto the number of objects which had engaged the attention of thoſe who cultivated the ſcience had been very limited; the acids amounted only to five, the earths to four, the metals to 12 or 14, and the neutral ſalts ſcarcely exceeded 20 or 30. To remember names for ſo ſmall a number of bodies, however ridiculous they happened to be, was no very difficult matter. But about that time, in conſequence chiefly of the diſcovery of fixed air by Dr Black, which laid the foundation of pneumatic chemiſtry, the ſcience began to extend itſelf, and to enlarge its boundaries with inconceivable rapidity. The number of bodies connected with it, and which it had to deſcribe, ſoon became immenſe; and if every one of them received names not dependant upon one another, the moſt retentive memory could not have remembered the thouſandth part of them.

The difficulty of ſtudying chemiſtry from that time till the year 1782 muſt have been very great: it was even perceived and complained of by the maſters of the ſcience. In 1782 Mr de Morveau, who had undertaken the chemical part of the *Encyclopedie Methodique*, publiſhed in the *Journal de Phyſique* a new chemical nomenclature, and at the ſame time invited all thoſe perſons who were fond of chemiſtry, and intereſted in its progreſs, to propoſe objections and improvements.

This new nomenclature was formed agreeable to the five following rules:.

1. Every ſubſtance ought to have a name, and not to be denoted by a phraſe.

2. Names ought to be as much as poſſible conformable to the nature of the things ſignified by them.

3. When the character of a ſubſtance is not well enough known to determine the denomination, a name which has no meaning is preferable to one which conveys a falſe idea.

4. In the choice of new words thoſe ought to be preferred which have their roots in the dead languages moſt generally known, that the word may be eaſily ſuggeſted by the ſenſe, and the ſenſe by the word.

5. The new words ought to be as ſuitable as poſſible to the genius of the languages for which they are formed.

This nomenclature was approved of by Macquer, and by Bergman, who had himſelf propoſed one upon a plan not very different (D). He wrote to Morveau, and exhorted him to proſecute his undertaking with courage. "Do not ſpare (ſays he) a ſingle improper denomination; thoſe that are already learned will be always ſo, and thoſe that are not will learn the ſooner*."

This nomenclature was adopted by ſeveral chemiſts, and it was uſed in the greateſt part of the firſt volume of the chemical part of the *Encyclopedie Methodique*; but the new diſcoveries in chemiſtry had produced a more accurate method of reaſoning, and had enabled Lavoiſier to explain the phenomena of the ſcience without the aſſiſtance of the hypothetical principle of phlogiſton, which had hitherto been neceſſary. As the language, even in its improved ſtate, was accommodated to this principle, and preſuppoſed its exiſtence, new changes became evidently neceſſary, in order that, according to Morveau's rule, the words might denote the moſt eſſential properties of the things intended to be ſignified. Accordingly, when Morveau was in Paris in 1787, Lavoiſier, Berthollet, and Fourcroy, agreed to labour in concert with him to bring the chemical nomenclature ſtill nearer to perfection. Theſe philoſophers, aſſiſted by the mathematicians of the Royal Academy and by ſeveral chemiſts, formed a new nomenclature, which they made public in 1787.

* *Encycl. Method. Chim.* Preface.

For ſome time little attention was paid to this nomenclature by foreign chemiſts, and it ſeemed generally to be diſapproved. The adherents of the phlogiſtic ſyſtem in France, who were exceedingly numerous, viewed it as an engine artfully formed to undermine and deſtroy their favourite theory. They reſolved, therefore, unanimouſly, to cruſh, if poſſible, this new inſtrument, which they conſidered as

> ——— *in noſtros fabricata machina muros,*
> *Inſpectura domos, venturaque deſuper urbi.*

And for this purpoſe they exerted themſelves with a vigour, which was only equalled by the zeal and indefatigable exertions of their antagoniſts. A kind of civil war was thus kindled in the republic of letters, which was carried on with great animoſity: And poſterity will ſee, with regret, men of undoubted genius at times diveſting themſelves of the armour of truth and of candour, and endeavouring to ſerve their party, and ſtab their adverſaries with darts ſteeped in the poiſon of calumny and falſehood *. This conteſt, however, which was not confined to France, was productive of good effects, which infinitely ſurpaſſed all the bad ones. It occa-

† See the *Journ. de Phyſ.* for 1788, 89, 90, 91, *paſſim.*

(D) See his thoughts on a natural hiſtory of foſſils in the 4th vol. of his *Opuſc.*

occaſioned an accumulation of facts, produced a rigid examination of theories and opinions, introduced an accuracy into chemical experiments which has been of the moſt eſſential ſervice, and gave that tone and vigour to the cultivators of chemiſtry which have brought to light the moſt ſublime and unlooked-for truths. It deſerves attention, and the fact is no inconſiderable evidence in favour of the antiphlogiſtic theory, that almoſt all the illuſtrious chemiſts who at preſent adhere to it declared originally againſt it. Berthollet, Morveau, Black, Kirwan, and many other chemiſts who are now its ableſt defenders, were at firſt its moſt powerful opponents. "This ſyſtem had hardly been publiſhed in France (ſays Dr Prieſtley, who ſtill continues to adhere to the doctrine of phlogiſton) before the principal philoſophers and chemiſts of England, notwithſtanding the rivalſhip which has long ſubſiſted between the two countries, eagerly adopted it. Dr Black in Edinburgh, and as far as I hear all the Scots, have declared themſelves converts, and, what is more, the ſame has been done by Mr Kirwan, who wrote a pretty large treatiſe in oppoſition to it. The Engliſh reviewers of books, I perceive, univerſally favour the new doctrine. In America, alſo, I hear of nothing elſe. It is taught, I believe, in all the ſchools on this continent, and the old ſyſtem is entirely exploded. And now that Dr Crawford is dead, I hardly know of any perſon except my friends of the Lunar Society at Birmingham, who adhere to the doctrine of phlogiſton; and what may now be the caſe with *them* in this age of revolutions, philoſophical as well as civil, I will not at this diſtance anſwer for.

"It is no doubt *time*, and of courſe opportunity of examination and diſcuſſion, that gives ſtability to any principles. But this new theory has not only kept its ground, but has been conſtantly and uniformly advancing in reputation more then *ten years*, which, as the attention of ſo many perſons, the beſt judges of every thing relating to the ſubject, has been unremittingly given to it, is no inconſiderable period. Every year of the laſt twenty or thirty has been of more importance to ſcience, and eſpecially to chemiſtry, than any ten in the preceding century *."

We have endeavoured in the preceding article to ſtate the different theories which have ſucceſſively made their appearance in *chemiſtry* with as much fairneſs as poſſible. If we have ſucceeded, the reader will be enabled to judge for himſelf which of theſe theories is the moſt conſiſtent with truth; or rather, if we have ſucceeded, he will join with us in thinking that the theory of Lavoiſier is in moſt points an accurate account of what takes place in nature.

This we conſider as a ſufficient reaſon for having adopted the new nomenclature; for, as Morveau long ago obſerved, moſt of the objections that were made to it were rather levelled at the doctrine of thoſe who formed it, than at the nomenclature itſelf. Its ſuperiority to every other nomenclature cannot be diſputed for an inſtant; and the vaſt facility which it has added to the acquiſition of chemiſtry, muſt be acknowledged by every one who knows any thing about the ſcience. The Table of the new nomenclature will not be expected here, as it has been already given in the Appendix to the article CHEMISTRY in the *Encyclopedia*. At any rate, it would have been unneceſſary, as we have uſed the new names all along; and therefore our readers muſt by this time be well acquainted with them.

Upon the almoſt infinite number of criticiſms which have been made on the new nomenclature, and the many new terms which ſince its publication have been ſucceſſively propoſed, we do not mean to enter. Few of theſe terms can bear a compariſon with the French nomenclature, and ſtill fewer have any claim to be preferred to it; and the philoſophers who perſiſt in theſe uſeleſs innovations, are more probably actuated by the deſire of appearing to have a ſhare in the great revolution which chemiſtry has undergone, than by any hopes of being able to improve the accuracy or the elegance of its language. How few have diſplayed the magnanimity of an illuſtrious philoſopher of our own country, who, though he had invented a new nomenclature himſelf, exhorted his pupils not to uſe it, but to adopt that of the French chemiſts, which was likely ſoon to come into univerſal uſe.

Even the etymological remarks which have been made on the new nomenclature, we conſider as either of little conſequence or as ill-founded. The philoſophers who formed it have diſplayed a ſagacity and a moderation which could not be excelled, and have, upon the whole, formed a language much more ſyſtematic, and much more perfect, than could have been expected; and whoever compares it with the nomenclature propoſed in 1782 by Morveau, will ſee how great a ſhare of it is due to that illuſtrious philoſopher.

Notwithſtanding what we have here ſaid, we would not be underſtood to conſider the new nomenclature as already arrived at a ſtate of ſuch abſolute perfection, that no alteration whatever can be made in it except for the worſe. Such perfection belongs not to the works of man; nor if it did, could it be expected in this caſe, if we conſider for a moment the preſent ſtate of chemiſtry. New diſcoveries muſt occaſion additions and alterations in the nomenclature; but the authors of the new nomenclature have given us the rules by which changes and additions are to be made; and if they are adhered to, we may expect with confidence that the language of chemiſtry will in its advancement to perfection keep pace with the ſcience. We have in the preceding article ventured in an inſtance or two to adopt little improvements that have been ſuggeſted by later writers. We have taken the liberty, too, of chooſing, from the variety which the Britiſh chemiſts have propoſed, that mode of ſpelling each of the terms which appeared to us moſt agreeable to the Engliſh idiom, and moſt conformable to analogy: Whether or not we have made a proper choice muſt be left for others to determine.

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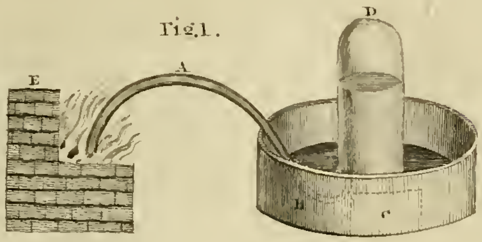
* *Conſiderations on the doctrine of phlogiſton*, Introduction.

Fig.1.



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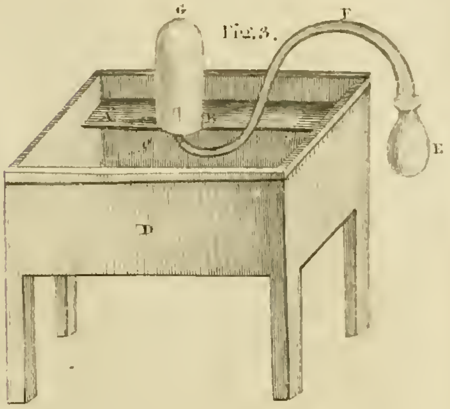

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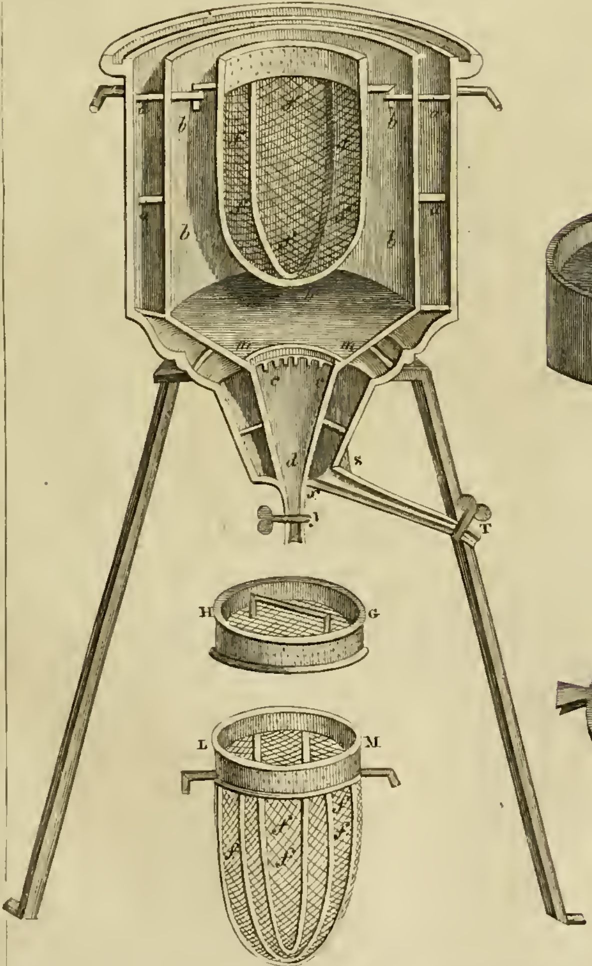

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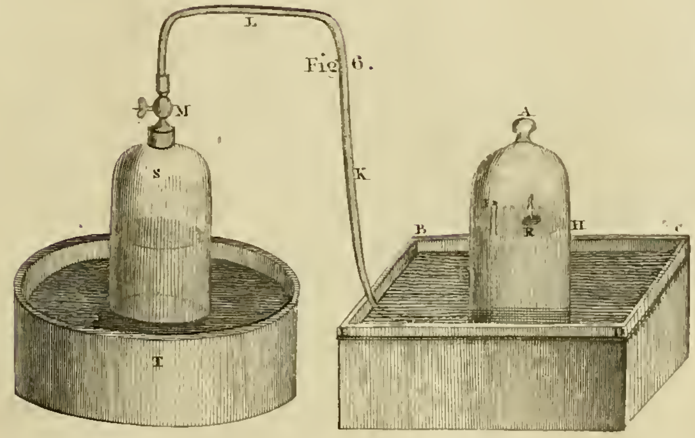

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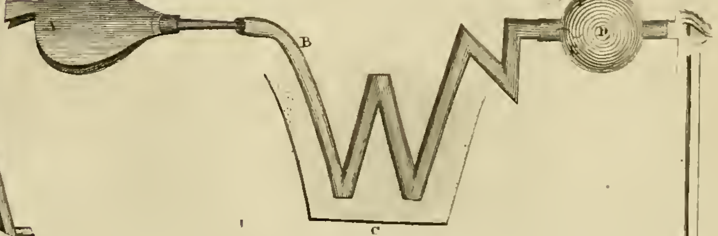

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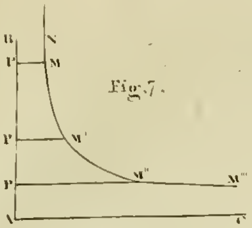

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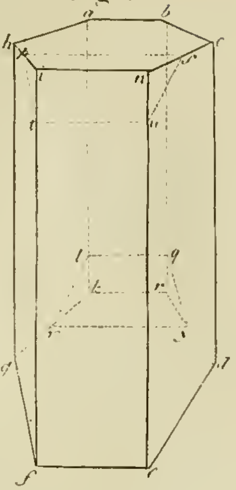

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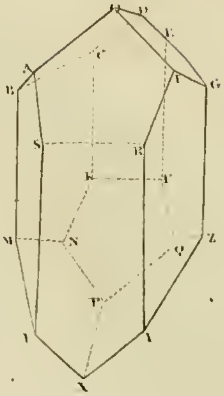

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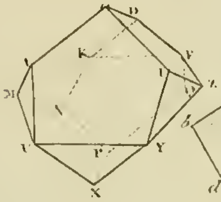

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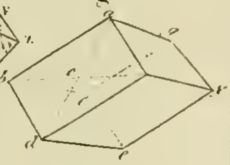

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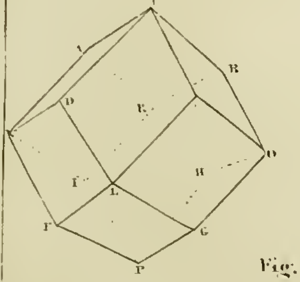

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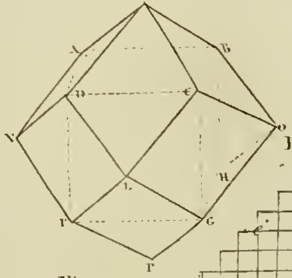

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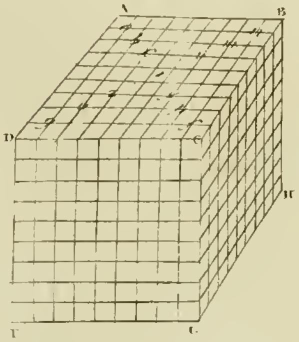

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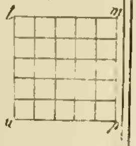

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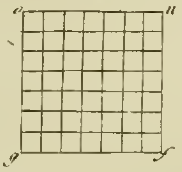

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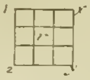

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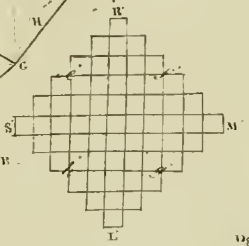

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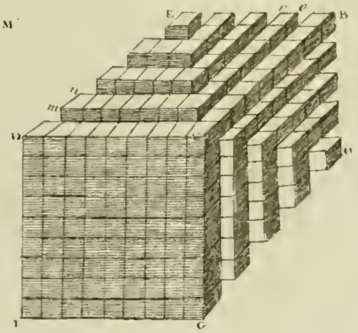

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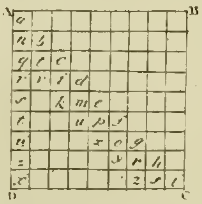

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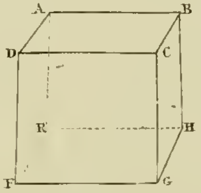

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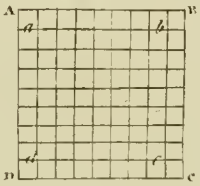

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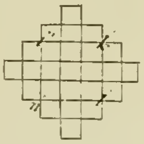

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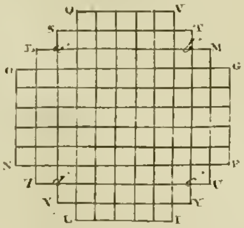

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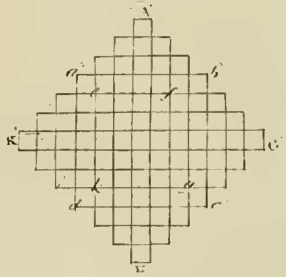

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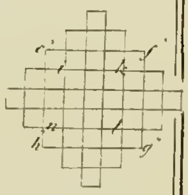

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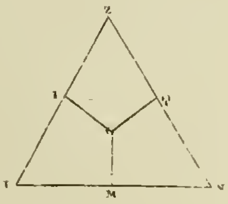


Fig. 29.

Fig. 28.

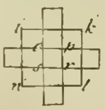


Fig. 31.

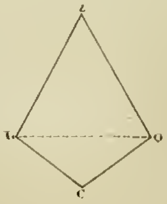


Fig. 30.

Fig. 33.

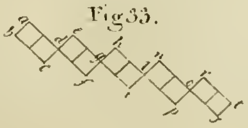
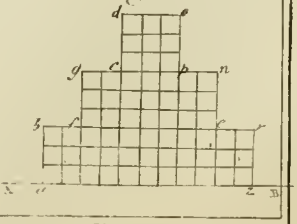


Fig. 34.



INDEX.

Cherubim.

CHERUBIM were emblematical figures; of which an account, a very vague one indeed, has been given in the *Encyclopædia Britannica*. We are far from thinking ourſelves qualified to improve that account, or to explain emblems in the Jewiſh worſhip, which even Joſephus did not underſtand; and we certainly ſhould not have reſumed the ſubject but to gratify a numerous claſs of our readers, and to comply with the requeſt of ſome highly reſpected friends.

The followers of Mr Hutchinſon, who are firmly perſuaded that their maſter brought to light from the writings of the Old Teſtament many important doctrines which had lain concealed from all the piety, all the induſtry, and all the learning of 1700 years, believe that, among other things, he and they have been able to aſcertain the form and the import of the Hebrew Cherubim. Their diſcoveries on this ſubject, as we have been told by better judges than we pretend to be, are more clearly ſtated by Mr Parkhurſt in his Hebrew Lexicon, than by any other writer of that ſchool. We ſhall therefore lay before our readers his doctrine reſpecting the form of the artificial cherubs, as well as of their emblematical meaning; and ſubjoin a few remarks, which the nature of his reaſoning has forced from us.

" *Firſt*, then, as to the *form* of the artificial cherubs in the tabernacle and temple, Moſes (ſays our author) was commanded (Exod. xxv. 18, 19.) ' Thou ſhalt make two cherubs: of beaten gold ſhalt thou make them at the two ends of the mercy-ſeat. And thou ſhalt make one cherub at the one end, and the other cherub at the other end: מן הבפרת, out of the mercy-ſeat (Margin Eng. Traſlat. of the matter of the mercy-ſeat) ſhall ye make the cherubs at the two ends thereof.' All which was accordingly performed (Exod. xxxvii, 7, 8.), and theſe cherubs were with the ark placed in the holy of holies of the tabernacle (Exod. xxvi. 33, 34. xl. 20.); as thoſe made by Solomon were afterwards in the holy of holies of the temple (1 Kings vii. 23, 27.)

We may obſerve that in Exodus Jehovah ſpeaks to Moſes of the cherubs as of figures well known; and no wonder ſince they had always been among believers in the holy tabernacle from the beginning. (See Gen. iii. 24. Wiſd. ix. 8. And though mention is made of their faces (Exod. xxv. 20. 2 Chron. iii. 13.), and of their wings, (Exod. xxv. 20. 1 Kings viii. 7. 2 Chron. iii. 11, 12.); yet neither in Exodus, Kings, nor Chronicles, have we any particular deſcription of their form. This is however very exactly, and, as it were, anxiouſly ſupplied by the prophet Ezekiel, ch. i. 5. ' Out of the midſt thereof (*i. e.* of the fire infolding itſelf, ver. 4.) דמות the likeneſs of four livings creatures or animals; דמות ארם להנה the likeneſs of a man (being) with them.' This laſt Hebrew expreſſion cannot mean that they, *i. e.* the four animals, had the likeneſs of a man, which interpretation would indeed make the prophet contradict himſelf (comp. ver. 10.); but it imports that the likeneſs of a man in glory, called (verſe 26.) דמות במראה ארם the likeneſs as the appearance of a man, and

and particularly deſcribed in that and the following verſes, was with them. Ver. 6. ‘ And there were four faces to one (דמות or ſimilitude), and four wings to one, לחם to them. So there were at leaſt two compound figures. Ver. 10. ‘ And the likeneſs of their faces; the face of a man, and the face of a lion, on the right ſide, to them four; and the face of an ox to them four; and the face of an eagle to them four.’ Ezekiel knew (ch. x. 1.—20.) that theſe were cherubs. Ver. 21. ‘ Four faces לאחר to one (cherub) and four wings to one.’ This text alſo proves that the prophet ſaw more cherubs than one, and that each had four faces and four wings. And we may be certain that the cherubs placed in the holy of holies were of the form here deſcribed by the prieſt and prophet of Ezekiel, becauſe we have already ſeen from Exodus, 1 Kings, and 2 Chronicles, that they likewiſe had faces and wings, and becauſe Ezekiel knew what he ſaw to be cherubs, and becauſe there were no four-faced cherubs any where elſe but in the holy of holies; for it is plain from a compariſon of Exod. xxvi. 1, 31. 1 Kings vi. 29, 32. and 2 Chron. iii. 14. with Ezekiel xli. 18, 19, 20. that the artificial cherubs on the curtains and vail of the tabernacle, and on the walls, doors, and vail of the temple, had only two faces; namely, thoſe of a lion and of a man.

“ For it muſt be obſerved further, that, as the word כרוב is uſed for one compound figure with four faces, and כרובים in the plural for ſeveral ſuch compounds (ſee Exod. xxv. 18, 19. xxxvii. 8. 1 Kings vi. 23—26), ſo is כרוב applied to one of the cherubic animals, as to the ox, Ezek. x. 14.; (compare ch. i. 10.) to the coupled cherub, or lion-man, Ezek. xli. 18.; and כרובים to ſeveral of the cherubic animals, as to ſeveral oxen, 1 Kings vii. 36. (compare ver. 29.) to ſeveral coupled cherubs, Exod. xxvi. 1. 1 Kings vi. 32, 35. & al. I proceed to ſhew.

“ *Secondly*, of what the cherubs were emblems, and with what propriety.

“ That the cherubic figures were emblems or repreſentatives of ſomething beyond themſelves is, I think, agreed by all, both Jews and Chriſtians. But the queſtion is, Of what they were emblematical? To which I anſwer in a word, Thoſe in the holy of holies were emblematical of the ever-bleſſed Trinity in covenant to redeem man, by uniting the human nature to the Second Perſon; which union was ſignified by the union of the faces of the lion and of the man in the cherubic exhibition, Ezek. i. 10. compare Ezek. xli. 18, 19. The cherubs in the holy of holies were certainly intended to repreſent ſome beings in heaven, becauſe St Paul has expreſsly and infallibly determined that the holy of holies was a figure or type of heaven, even of that heaven where is the peculiar reſidence of God (Heb. ix. 24.). And therefore theſe cherubs repreſented either the ever bleſſed Trinity with the man taken into the eſſence, or created ſpiritual angels. The following reaſons will, I hope, clearly prove them to be emblematical of the former, not of the latter:

“ 1*ſt*, Not of angels; becauſe (not now to inſiſt on other circumſtances in the cherubic form) no tolerable reaſon can be aſſigned why angels ſhould be exhibited with four faces apiece.

“ 2*dly*, Becauſe the cherubs in the holy of holies of the tabernacle were, by Jehovah’s order, ‘ made out of the matter of the mercy-ſeat, or beaten out of the ſame piece of gold as that was’ (Exod. xxv. 18, 19. xxxvii. 9.). Now the mercy-ſeat, made of gold and crowned, was an emblem of the Divinity of Chriſt (See Rom. iii. 25. The cherubs therefore repreſented not the angelic, but the Divine nature.

“ 3*dly*, The typical blood of Chriſt was ſprinkled before them on the great day of atonement (compare Exod. xxxvii. 9. Lev. xvi. 14. Heb. ix. 7, 12.): And this cannot in any ſenſe be referred to created angels, but muſt be referred to Jehovah only; becauſe,

“ 4*thly*, The high prieſt’s entering into the holy of holies on that day, repreſented Chriſt’s entering with his own blood into heaven ‘ to appear in the preſence of God for us’ (Heb. ix. 7, 24.) And,

5*thly*, When God ‘ raiſed Chriſt (the humanity) from the dead, he ſet him at his own right hand in the heavenly places, far above, ʽΥΠΕΡΑΝΩ, all principality and power, and might and dominion, and every name that is named, not only in this world, but alſo in that which is to come (Eph. i. 21.). Angels and authorities and powers being made ſubject unto him’ (1 Peter iii. 22.)

“ 6*thly*, The prophet Ezekiel ſaith (ch. x. 20.), ‘ This is the living creature, החיה (which muſt mean one compound figure, comp. ver. 14.) that I ſaw’ תחת inſtead of, a ſubſtitute of ‘ the Aleim of Iſrael. תחת, it is granted, may refer either to ſituation or ſubſtitution, (ſee Gen. xxx. 2. l. 19.) as the ſenſe requires. Here, notwithſtanding what is ſaid ver. 19. the latter ſenſe is preferable; becauſe it was the glory of the God of Iſrael, *i. e.* the God-man in glory, (compare ch. i. 26.) not the Aleim (the Trinity) of Iſrael that were over the cherubim; and the text ſays not, *theſe* were the living *creatures*, but, *this* was the living *creature*, which I ſaw תחת אלהי ישראל.’ Now the glory was over both the cherubims, ver. 19. but one compound cherub only was a ſubſtitute of the Aleim.

“ If it ſhould be here aſked, Why then were there two compound cherubs in the holy of holies? I anſwer, Had there not in this place been two compound cherubs, it would have been naturally impoſſible for them to repreſent what was there deſigned; for otherwiſe, all the faces could not have looked inwards toward each other, and down upon the mercy-ſeat, and on the interceding high prieſt ſprinkling the typical blood of Chriſt, (ſee Exod. xxxvii. 9.) and at the ſame time have looked outward toward the temple, לבית (Vulg. ad domum exteriorum, to the outer-houſe,) 2 Chron. iii. 13. Or, in other words, the Divine Perſons could not have been repreſented as witneſſing to each other’s voluntary engagements for man’s redemption, as beholding the ſacrifice of Chriſt’s death, typified in the Jewiſh church, and at the ſame time as extending their gracious regards to the whole world. (See Iſa. liv. 5. and Spearman’s Inquiry, p. 382. edit. Edinburgh.

“ The coupled cherub, or lion-man, on the vail and curtains of the outer tabernacle, and on the vail, doors, and walls of the temple, accompanied with the emblematic palm-tree, is ſuch a ſtriking emblem of the lion of the tribe of Judah (Rev. v. 5.) united to the man Chriſt Jeſus, as is eaſy to be perceived, but hard to be evaded. Theſe coupled cherubs appropriate the tabernacle or temple, and their vails, as emblems of Chriſt, and expreſs in viſible ſymbols what he and his apoſtles do in words. See John ii. 19, 21. Heb. viii. 2. ix. 11. x. 20.

x. 20. comp. Matt. xxvii. 51. And as the texts juſt cited from the New Teſtament afford us divine authority for aſſerting that the outer tabernacle or temple was a type of the body of Chriſt, ſo they furniſh us with an irrefragable argument to prove that the cherubs on their curtains or walls could not repreſent angels. For did angels dwell in Chriſt's body? No, ſurely: But 'in him dwelt all the fulneſs of the Godhead bodily.' (Col. ii. 9.)

" I go on to conſider the propriety of the animals in the cherubic exhibition repreſenting the Three Perſons in the ever-bleſſed Trinity. And here to obviate any undue prejudice which may have been conceived againſt the Divine Perſons being ſymbolically repreſented under any animal forms whatever, let it be remarked that Jehovah appeared as three men to Abraham (Gen. xviii.); that the ſerpent of braſs ſet up by God's command in the wilderneſs was a type or emblem of Chriſt, God-man, lifted up on the croſs (comp. Num. xxxi. 1—9. with John iii. 14, 15.); that at Jeſus's baptiſm the Holy Spirit deſcended in a bodily ſhape, like a dove, upon him (Luke iii. 21, 22.); that Chriſt, as above intimated, is expreſsly called the lion of the tribe of Judah (Rev. v. 5.); and continually in that ſymbolical book ſet before us under the ſimilitude of a lamb. All theſe are plain ſcriptural repreſentations, each of them admirably ſuited, as the attentive reader will eaſily obſerve, to the particular circumſtances or ſpecific deſign of the exhibition. Why then ſhould it appear a thing incredible, yea why not highly probable, that Jehovah Aleim ſhould, under the typical ſtate, order his own Perſons and the union of the manhood with the eſſence to be repreſented by animal forms in the cherubim of glory? Eſpecially if it be conſidered that the three animal forms, excluſive of the man (who ſtood for the very human nature itſelf) are the chief of their reſpective genera: the ox or bull of the tame or graminivorous; the lion, of the wild or carnivorous; and the eagle, of the winged kind.—But this is by no means all: For as the great agents in nature, which carry on all its operations, certainly are the fluid of the heavens, or, in other words, the fire at the orb of the ſun, the light iſſuing from it, and the ſpirit or groſs air conſtantly ſupporting, and concurring to the actions and effects of the other two; ſo we are told (Pſal. xix. 1.) that השמים מספרים כבוד אל the heavens (are) the means of declaring, recounting, or particularly exhibiting the glory of God, even his eternal power and godhead, as St Paul ſpeaks, Rom. i. 20. And accordingly Jehovah himſelf is ſometimes, though rarely (I preſume for fear of miſtakes) called by the very name שמים or שמיא heavens in the Old Teſtament, ſee 2 Chron. xxxii. 20. (comp. 2 Kings xix. 14. Iſa. xxxvii. 15.) Dan. iv. 23. or 26.; as he is more frequently expreſſed by ουρανος heaven in the New. (See Mat. xxi. 25. Mark xi. 30. 31. Luke xv. 18, 21. xx. 4, 5. John iii. 27.) Yea not only ſo, but we find in the Scriptures both of the Old and New Teſtament, that the Perſons of the eternal Three and their economical operations in the ſpiritual, are repreſented by the three conditions of the celeſtial fluid and their operations in the material world. Thus the peculiar emblem of the Word or Second Perſon is the שמש or light, and he is and does that to the ſouls or ſpirits of men which the material or natural light is and does to their bodies. (See inter al. 2 Sam. xxiii. 4. Iſa. xlix. 6. lx. 1. Mal. iv. 2. or iii. 20. Luk i. 78. ii. 32. John i. 4—9. viii. 12. xii. 35, 36, 46.) The Third Perſon has no other diſtinctive name in ſcripture but רוח in Hebrew, and Πνευμα in Greek (both which words in their primary ſenſe denote the material ſpirit or air in motion), to which appellation the epithet קדש, αγιος holy, or one of the names of God, is uſually added: and the actions of the Holy Spirit in the ſpiritual ſyſtem are deſcribed by thoſe of the air in the natural (See John iii. 8. xx. 22. Acts ii. 2.) Thus, then, the ſecond and Third Perſons of the ever-bleſſed Trinity are plainly repreſented in ſcripture by the material light and air. But it is further written, Jehovah thy Aleim is a conſuming fire. Deut. iv. 24. (Comp. Deut. ix. 23. Heb. xii. 29. Pſal. xxi. 10. lxxviii. 21. Nah. i. 2.) And by fire, derived either immediately or mediately from heaven, were the typical ſacrifices conſumed under the old diſpenſation. Since, then, Jehovah is in ſcripture repreſented by the material heavens, and even called by their name, and eſpecially by that of fire, and ſince the Second and Third Perſons are exhibited reſpectively by the two conditions of light and ſpirit, and ſince fire is really a condition of the heavenly fluid as much diſtinct from the other two as they are from each other, it remains that the peculiar emblem of the Firſt Perſon (as we uſually ſpeak) of the eternal Trinity, conſidered with reſpect to the other two, be the fire.

" Bearing then in mind that the perſonality in Jehovah is in ſcripture repreſented by the material Trinity of nature; which alſo, like their divine antitype, are of one ſubſtance, that the primary ſcriptural type of the Father is fire; of the Word, light; and of the Holy Ghoſt, ſpirit, or air in motion; we ſhall eaſily perceive the propriety of the cherubic emblems. For the ox or bull, on account of his horns, the curling hair on his forehead, and his unrelenting fury when provoked (ſee Pſal. xxii. 13) is a very proper animal emblem of fire; as the lion from his uſual tawny gold-like colour, his flowing mane, his ſhining eyes, his great vigilancy and prodigious ſtrength, is of light; and thus likewiſe the eagle is of the ſpirit or air in action, from his being chief among fowls, from his impetuous motion (ſee 2 Sam. i. 23. Job ix. 26. Jer. iv. 13. Lam. iv. 19.), and from his towering and ſurpriſing flights in the air (ſee Job xxxix. 27. Prov. xxiii. 5. xxx. 19. Iſa. xl. 31. and Bochart, vol. iii. p. 173.) And the heathen uſed theſe emblematic animals, or the like, ſometimes ſeparate, ſometimes joined, in various manners, as repreſentatives of the material Trinity of nature, which they adored. Theſe particulars Mr Hutchinſon has proved with a variety of uſeful learning, vol. vii. p. 381, et ſeq. and any perſon who is tolerably acquainted with the heathen mythology will be able to increaſe his valuable collection with many inſtances of the ſame kind from modern as well as ancient accounts of the pagan religions.

" Thus, then, the faces of the ox, the lion, and the eagle, repreſenting at ſecond hand the Three Perſons of Jehovah, the Father, the Word, and the Holy Spirit; and the union of the divine light with man being plainly pointed out by the union of the faces of the lion and the man (ſee Ezek. i. 10. xli. 18.), we may ſafely aſſert, that the cherubim of glory (Heb. ix. 5.) in the holy of holies were divinely inſtituted and proper emblems of the Three Eternal Perſons in covenant to redeem man, and of the union of the divine and human natures in the perſon of Chriſt. And we find (Gen. iii. 24) that immediately on Adam's expulſion from paradiſe, and the ceſſation of the firſt or paradiſiacal diſpenſation of religion, Jehovah Aleim himſelf ſet up theſe emblems, together with the burning flame המתהפכת rolling upon itſelf, to keep the way to the tree of life; undoubtedly, conſidering the ſervices performed before them, not to hinder, but to enable, man to paſs through it."

Thus far Mr Parkhurſt; and to his diſſertation where is the man who will deny the merit of erudition, combined with ingenuity? To the latter part of his reaſoning, however, objections obtrude themſelves upon us of ſuch force, that we know not how to anſwer them. The reader obſerves, that, according to this account, the cherubim are only at *ſecond hand* emblematical of the Holy Trinity, and that the *primary* emblem is that fluid which the author conceives to fill the ſolar ſyſtem, and to be one ſubſtance under the different appearances or modifications of *fire*, *light*, and *groſs air*. But unfortunately for this reaſoning, we are as certain as we can be of any matter of fact, that *fire* and *air* are *not* one ſubſtance; that the *groſs air* itſelf is compounded of very *different* ſubſtances; and that even *light* is a different ſubſtance from that which cauſes in us the ſenſation of heat, and to which modern chemiſts have given the name of *caloric* (See CHEMISTRY-*Index* in this Supplement). We admit, that the *primary atoms* of all matter *may be* ſubſtances of the very ſame kind, though we do not *certainly know* that they are: but this makes nothing for our author's hypotheſis; becauſe the ſun and all the planets muſt, in that caſe, be added to his one ſubſtance, which would no longer appear under a triple form. Could it indeed be proved, that all men from Adam downwards, who made uſe of cherubic figures for the very ſame purpoſe with the ancient Jews, *believed* that fire, air, and light, are different modifications of the ſame ſubſtance, their belief, though erroneous, would be a ſufficient foundation for our author's reaſoning; but of this no proof is attempted, and certainly none that is ſatisfactory could be brought.

Our learned author, indeed, takes much for granted without proof. He has not proved that anywhere the bull was the emblem or hieroglyphic of *fire*, the lion of *light*, or the eagle of *air*. We do not, it muſt be owned, know that ſuch hieroglyphics were *not* uſed in Egypt and other countries before the introduction of alphabetical characters; but unleſs they were ſo uſed by Adam, all that is here ſaid of the *propriety* of theſe emblems muſt go for nothing: Indeed we ſee not their peculiar propriety. The tawny colour, flowing mane, and fierceneſs of the lion, might, for any thing that we can perceive to the contrary, repreſent *fire* as fitly as the horns, curling hair, and fury of the bull; and if it be true, as is generally ſaid, that the eagle can look ſteadily on the ſun, he ſeems, of all the three, to be the fitteſt emblem of light.

But there are other objections to this interpretation of the word cherubim. The four animals in the Revelation, which were undoubtedly cherubim, as well as the four and twenty elders, fell down before the Lamb, and worſhipped God*. Now, ſays Dr Gregory Sharp, "it is ſcarce to be conceived, if theſe four beaſts were repreſentatives of the divine perſons, that they could with any propriety, or without the greateſt ſoleciſm, be ſaid and deſcribed to fall down before and worſhip other emblematical repreſentations of the ſame divine nature and perfections: And therefore, whatever theſe beaſts were emblems of, they could not be cherubim in Mr Hutchinſon's ſenſe of that word; it being as contrary to the rational explanation of a viſion to ſay that one emblem of the divinity ſhould worſhip another emblem of it, as it is contrary to the reaſon of mankind, and to all our notions either of the Godhead or of worſhip, to ſay that the Trinity worſhipped the Trinity, or any one Perſon in the Trinity."

This objection is admitted by our learned author to be a very plauſible one. To us it appears unanſwerable. He anſwers it, however, in the following words:

"Let it be carefully obſerved, that theſe repreſentations in Rev ch. v. and xix. are not only viſional but hieroglyphical, and therefore muſt be explained according to the analogy of ſuch emblematical exhibitions; and as at ver. 6. 'the lamb, as it had been ſlain, having ſeven horns and ſeven eyes, ſtanding in the midſt of the throne, and of the four animals, and of the four-and-twenty elders,' is evidently ſymbolical of the Lamb of God now raiſed from the dead, and inveſted with all knowledge and power both in heaven and in earth; ſo 'the four animals falling down before him' (ver. 8.), and, as it is expreſſed (ch. xix. 4.), 'worſhipping God who ſat upon the throne,' muſt, in all reaſon, be explained ſymbolically likewiſe, not from any abſtract or metaphyſical notions we may have framed to ourſelves of worſhip in general, but from the ſpecific and peculiar circumſtances of the caſe before us. Thus, likewiſe, when in 1 Chron. xxix. 20. 'All the congregation worſhipped Jehovah and the king, namely David, the worſhip to both is expreſſed by the ſame ſtrong phraſe—ישתחוו ל proſtrated themſelves to, LXX. προσεκυνησαν; yet ſurely no one will ſay that the people meant to worſhip David as God, but only to acknowledge him as king. So Adonijah, who had conteſted the crown with Solomon, came, וישתחו and worſhipped King Solomon (1 Kings i. 53.), not as God doubtleſs, but as king, thereby ſurrendering his own claim to the throne. However 'contrary therefore it may be to the reaſon of mankind, and to all our notions either of the Godhead or of worſhip, to ſay that the Trinity worſhipped the Trinity, or any one Perſon of the Trinity,' *i. e.* with divine worſhip as a creature worſhips his Creator; yet it is by no means contrary to the rational and ſcriptural explanation of an emblematic viſion, to ſay that the hieroglyphical emblems of the whole ever-bleſſed Trinity fell down and worſhipped the hieroglyphical emblem of the God-man, or God who ſat upon the throne. Since ſuch falling down, proſtration, or worſhipping, was the uſual ſymbolical act, as it ſtill is in the eaſt, not only of divine worſhip, but of acknowledging the regal power to be in the perſon ſo worſhipped; and theſe acts of the cherubic animals in Rev. v. 6. xix. 4. meant nothing more than either a ceſſion of the adminiſtration of all divine power to Chriſt God-man, or a declaration of the divine Perſons, by their hieroglyphical repreſentatives, that He muſt reign till all his enemies were made his footſtool. Comp. Mat. xxviii. 18. 1 Cor. xv. 25."

With every inclination to honour the memory of Mr Parkhurſt, who was certainly a ſcholar, and, which is of

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* Ch. v. 8. xix. 4.

of more value, a pious and a good man, we cannot help conſidering this anſwer as mere trifling. In the 18th Pſalm, the Lord is ſaid to "ride upon a cherub;" and in Ezekiel, chap. i. there is ſaid to have "been over the heads of the cherubim *a throne*, and upon that throne the likeneſs or appearance of *a man*," whom we take to be the Son of God incarnate. But is there any country in which the regal power of the ſovereign is acknowledged by his riding, not upon his ſubjects, but upon other co-equal ſovereigns? or, in which it is the cuſtom for the ſovereign to place his viceroy (for ſuch our Saviour in his *human* nature certainly is) in his throne above himſelf?

We muſt therefore confeſs, that we know not of what the cherubic figures were emblematical, and that he who labours to eſtabliſh the doctrine of the ever bleſſed Trinity by ſuch criticiſms and reaſonings as thoſe which we have examined, is either a ſecret enemy to that doctrine, or a very injudicious friend.

CHESS, the celebrated game, of which a copious account has been given in the Encyclopædia, is affirmed by Sir William Jones to have been invented by the Hindoos. "If evidence were required to prove this fact (ſays he *), we may be ſatisfied with the teſtimony of the Perſians, who, though as much inclined as other nations to appropriate the ingenious inventions of a foreign people, unanimouſly agree that the game was imported from the weſt of *India* in the ſixth century of our era. It ſeems to have been immemorially known in *Hindoſtan* by the name of *Cheturanga*, i. e. the four *angá's*, or members of an army; which are theſe, *elephants*, *horſes*, *chariots*, and *foot ſoldiers*; and in this ſenſe the word is frequently uſed by epic poets in their deſcriptions of real armies. By a natural corruption of the pure Sanſcrit word, it was changed by the old Perſians into *Chetrang*; but the Arabs, who ſoon after took poſſeſſion of their country, had neither the initial nor final letter of that word in their alphabet, and conſequently altered it further into *Shetranj*, which found its way preſently into the modern *Perſian*, and at length into the dialects of India, where the true derivation of the name is known only to the learned. Thus has a very ſignificant word in the ſacred language of the Brahmins been transformed by ſucceſſive changes into *axedrez*, *ſcacchi*, *échecs*, *cheſs*, and, by a whimſical concurrence of circumſtances, has given birth to the Engliſh word *check*, and even a name to the *exchequer* of Great Britain."

It is confidently aſſerted that Sanſcrit books on *cheſs* exiſt in Bengal; but Sir William had ſeen none of them when he wrote the memoir which we have quoted. He exhibits, however, a deſcription of a very ancient *Indian* game of the ſame kind, but more complex, and in his opinion more modern, than the ſimple cheſs of the *Perſians*. This game is alſo called *Chaturanga*, but more frequently *Chaturaji*, or the *four kings*, ſince it is played by four perſons repreſenting as many princes, two allied armies combating on each ſide. The deſcription is taken from a book called *Bhawiſhya Purán*; in which the form and principal rules of this factitious warefare are thus laid down: "Eight ſquares being marked on all ſides, the *red* army is to be placed to the eaſt, the *green* to the ſouth, the *yellow* to the weſt, and the *black* to the north. Let the *elephant* (ſays the author of the *Purán*) ſtand on the left of the *king*; next to him the *horſe*; then the *boat*; and before them all, four *foot-ſoldiers*; but the *boat* muſt be placed in the angle of the board."

"From this paſſage (ſays the preſident) it clearly appears, that an army with its four *angás* muſt be placed on each ſide of the board, ſince an *elephant* could not ſtand, in any other poſition, on the left hand of each *king*; and RADHACANT (a Pandit) informed me, that the board conſiſted, like our's, of 64 ſquares, half of them occupied by the forces, and half vacant. He added, that this game is mentioned in the oldeſt law-books, and that it was invented by the wife of a king, to amuſe him with an image of war, while his metropolis was beſieged, in the ſecond age of the world. A *ſhip* or *boat* is abſurdly ſubſtituted, we ſee, in this complex game for the *rat'h*, or armed *chariot*, which the *Bengaleſe* pronounce *rot'h*, and which the Perſians changed into *rokh*; whence came the *rook* of ſome European nations; as the *vierge* and *fal* of the French are ſuppoſed to be corruptions of *ferz* and *fil*, the *prime miniſter* and *elephant* of the Perſians and Arabs."

As fortune is ſuppoſed to have a great ſhare in deciding the fate of a battle, the uſe of dice is introduced into this game to regulate its moves; for (ſays the Purán) "if *cinque* be thrown, the *king* or a *pawn* muſt be moved; if *quatre*, the *elephant*; if *trois*, the *horſe*; and if *deux*, the *boat*. The *king* paſſes freely on all ſides, but over *one* ſquare only; and with the ſame limitation the *pawn* moves, but he advances ſtraight forward, and kills his enemy through an angle. The *elephant* marches in all directions as far as his driver pleaſes; the *horſe* runs obliquely, traverſing the ſquares; and the *ſhip* goes over two ſquares diagonally." The *elephant*, we find, has the powers of our *queen*, as we are pleaſed to call the *general* or *miniſter* of the Perſians; and the *ſhip* has the motion of the piece to which we give the unaccountable appellation of *biſhop*, but with a reſtriction which muſt greatly leſſen its value.

In the *Purán* are next exhibited a few general rules and ſuperficial directions for the conduct of the game. Thus, "the *pawns* and the *ſhip* both kill and may be voluntarily killed; while the *king*, the *elephant*, and the *horſe*, may ſlay the foe, but muſt not expoſe themſelves to be ſlain. Let each player preſerve his own forces with extreme care, ſecuring his *king* above all, and not ſacrificing a ſuperior to keep an inferior piece." Here (ſays the preſident) the commentator on the *Purán* obſerves, that the *horſe*, who has the choice of *eight* moves from any central poſition, muſt be preferred to the *ſhip*, which has only the choice of *four*. But the argument would not hold in the common game, where the *biſhop* and *tower* command a whole line, and where a knight is always of leſs value than a tower in action, or the biſhop of that ſide on which the attack is begun. "It is by the overbearing power of the *elephant* (continues the *Purán*) that the king fights boldly; let the whole army, therefore, be abandoned in order to ſecure the *elephant*. The king muſt never place one *elephant* before another, unleſs he be compelled by want of room, for he would thus commit a dangerous fault; and if he can ſlay one of two hoſtile elephants, he muſt deſtroy that on his left hand."

All that remains of the paſſage which was copied for Sir William Jones relates to the ſeveral modes in which a partial ſucceſs or complete victory may be obtained: by

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* *Aſiatic Reſearches*, vol. ii. Mem. 9.

by any one of the four players ; for, as in a diſpute between two allies, one of the kings may ſometimes aſſume the command of all the forces, and aim at a ſeparate conqueſt. Firſt, " When any one king has placed himſelf on the ſquare of another king (which advantage is called *ſinhaſana* or the *throne*) he wins a ſtake, which is doubled if he kill the adverſe monarch when he ſeizes his place ; and if he can ſeat himſelf on the throne of his ally, he takes the command of the whole army." Secondly, " If he can occupy ſucceſſively the thrones of all the three princes, he obtains the victory, which is named *cheturaji* ; and the ſtake is doubled if he kill the laſt of the three, juſt before he takes poſſeſſion of his throne ; but if he kill him on his throne, the ſtake is quadrupled. Both in giving the *ſinhaſana* and the *cheturaji* the king muſt be ſupported by the *elephants*, or by all the forces united." Thirdly, " When one player has his own king on the board, but the king of his partner has been taken, he may replace his captive ally, if he can ſeize both the adverſe kings ; or if he cannot effect their capture, he may exchange his king for one of them, againſt the general rule, and thus redeem the allied prince, who will ſupply his place." This advantage has the name of *nripacriſhta* or *recovered by the king*. Fourthly, " If a *pawn* can march to any ſquare on the oppoſite extremity of the board, except that of the king, or that of the ſhip, he aſſumes whatever power belonged to that ſquare." Here we find the rule, with a ſlight exception, concerning the advancement of *pawns*, which often occaſions a moſt intereſting ſtruggle at our common cheſs ; but it appears that, in the opinion of one ancient writer on the Indian game, this privilege is not allowable when a player has three pawns on the board ; but when only one pawn and one ſhip remains, the pawn may advance even to the ſquare of a king or a ſhip, and aſſume the power of either. Fifthly, According to the people of *Lancè*, where the game was invented, "there could be neither victory nor defeat if a king were left on the plain without force ; a ſituation which they named *cacacaſht'ha*." Sixthly, " If three ſhips happen to meet, and the fourth ſhip can be brought up to them in the remaining angle, this has the name of *vrihannauca* ; and the player of the fourth ſeizes all the others."

The account of this game in the original Sanſcrit is in verſe, and there are two or three couplets ſtill remaining, ſo very dark, either from an error in the manuſcript, or from the antiquity of the language, that Sir William Jones could not underſtand the *Pandit's* explanation of them, and ſuſpects that even to him they gave very indiſtinct ideas. It would be eaſy, however, he thinks, if it be judged worth while, to play at the game by the preceding rules ; and a little practice would perhaps make the whole intelligible.

CHEVRETTE, in artillery, is an engine employed to raiſe guns or mortars into their carriage. It is formed of two pieces of wood about four feet long, ſtanding upon a third, which is ſquare. The uprights are about a foot aſunder, and pierced with holes exactly oppoſite to one another, to receive a bolt of iron, which is put in, either higher or lower at pleaſure, to ſerve as a ſupport to a handſpike, by which the gun is raiſed up. By the author of the Military Guide, this is ſaid to be the moſt uſeful of all the inventions for raiſing guns into their carriages ; and it ſeems theſe inventions have been many.

CHICHA, the name given by the natives to the iſland of Jeſſo, which lies to the ſouth of Oku-Jeſſo, or Segalian iſland. See SEGALIAN in this Supplement.

CHIMERE, the upper robe worn by biſhops in church and in the Houſe of Peers, to which the lawn ſleeves are generally ſewed. Before the Reformation, and even after it till the reign of Queen Elizabeth, the chimere was always of *ſcarlet ſilk* ; but biſhop Hooper, ſcrupling firſt at the robe itſelf, and then at the colour of it, as too light and gay for the epiſcopal gravity, the chimere was afterwards made of *black ſatin*. The archiepiſcopal chimere has a long train.

CHIMNEY, a particular part of a houſe well known, which Profeſſor Beckmann has, in our opinion, proved to be an invention comparatively modern. It would be very unfair dealing in us to give even a large abſtract of one of the moſt curious diſſertations of a curious book, which has been but lately publiſhed, and thereby injure the intereſt of him to whom the native of Britain is indebted for the pleaſure of peruſing it in his own tongue. No man, however, can blame us for here ſtating, in ſupport of our own opinion, the profeſſor's anſwer to the paſſage of Ferrari, which we have quoted under the word CHIMNEY in the Encyclopædia.

" When the triumviri, ſays Appian *, cauſed thoſe who had been proſcribed by them to be ſought for by the military, ſome of them, to avoid the bloody hands of their perſecutors, hid themſelves in wells, and others, as Ferrarius tranſlates the words, *in fumaria ſub tecto, qua ſcilicet fumus e tecto evolvitur* (A). The true tranſlation, however (ſays Mr Beckmann), is *fumoſa cœnacula*. The principal perſons of Rome endeavoured to conceal themſelves in the ſmoky apartments of the upper ſtory under the roof, which, in general, were inhabited only by poor people ; and this ſeems to be confirmed by what Juvenal † expreſsly ſays, *Rarus venit in cœnacula miles*.

* *De bellis civil.* lib. iv. p. 962. edit. Tollii.

† *Sat.* x. ver. 17.

" Thoſe paſſages of the ancients which ſpeak of ſmoke riſing up from houſes, have with equal impropriety been ſuppoſed to allude to chimneys, as if the ſmoke could not make its way through doors and windows. Seneca ‡ writes, 'Laſt evening I had ſome friends with me, and on that account a ſtronger ſmoke was raiſed ; not ſuch a ſmoke, however, as burſts forth from the kitchens of the great, and which alarms the watchmen, but ſuch a one as ſignifies that gueſts are arrived.' Thoſe whoſe judgments are not already warped by prejudice, will undoubtedly find the true ſenſe of theſe words to be, that the ſmoke forced its way through the kitchen windows. Had the houſes been built with chimney-funnels, one cannot conceive why the watchmen ſhould have been alarmed when they obſerved a ſtronger ſmoke than uſual ariſing from them ; but as the kitchens had no conveniences of that nature, an apprehenſion of fire, when extraordinary entertainments were to be provided in the houſes of the rich for large companies, ſeems to have been well founded ; and on ſuch occaſions people appointed for that purpoſe were ſtationed

‡ *Epiſt.* 64.

(A) Ες καπνωδεις υπωροφια, η των τεγων ταις κεραμισι βυομεναις.

ſtationed in the neighbourhood to be conſtantly on the watch, and to be ready to extinguiſh the flames in caſe a fire ſhould happen. There are many other paſſages to be found in Roman authors of the like kind, which it is hardly neceſſary to mention; ſuch as that of Virgil *,

'Et jam ſumma procul villarum culmina fumant,'

and the following words of Plautus†, deſcriptive of a miſer:

'Quin divum atque hominum clamat continuo fidem,
'Suam rem periiſſe, ſeque eradicarier,
'De ſuo tigillo fumus ſi qua exit foras.'

In the *Veſpæ* of Ariſtophanes, referred to in the Encyclopædia, old Philocleon wiſhes to eſcape through the kitchen. Some one aſks, "What is that which makes a noiſe in the chimney?" "I am the ſmoke (replies the old man), and am endeavouring to get out at the chimney." "This paſſage, however (ſays the Profeſſor), which, according to the uſual tranſlation, ſeems to allude to a common chimney, can, in my opinion, eſpecially when we conſider the illuſtration of the ſcholiaſts, be explained alſo by a ſimple hole in the roof, as Reiſke has determined; and indeed this appears to be more probable, as we find mention made of a top or covering‡ with which the hole was cloſed."

In the Encyclopædia we have ſaid, that the inſtances of chimneys remaining among the ruins of ancient buildings are few, and that the rules given by Vitruvius for building them are obſcure; but we are now ſatiſfied that there are *no* remains of ancient chimneys, and that Vitruvius gives *no* rules, either obſcure or perſpicuous, for building what, in the modern acceptation of the word, deſerves the name of a chimney.

"The ancient maſon-work ſtill to be found in Italy does not determine the queſtion. Of the walls of towns, temples, amphitheatres, baths, aqueducts, and bridges, there are ſome though very imperfect remains, in which chimneys cannot be expected; but of common dwelling-houſes none are to be ſeen except at Herculaneum, and there no traces of chimneys have been diſcovered. The paintings and pieces of ſculpture which are preſerved afford us as little information; for nothing can be perceived in them that bears the ſmalleſt reſemblance to a modern chimney.

"If there were no funnels in the houſes of the ancients to carry off the ſmoke, the directions given by Columella, to make kitchens ſo high that the roof ſhould not catch fire, was of the utmoſt importance. An accident of the kind, which that author ſeems to have apprehended, had almoſt happened at Beneventum, when the landlord who entertained Mæcenas and his company was making a ſtrong fire in order to get ſome birds ſooner roaſted.

'————— ubi ſedulus hoſpes
'Pæne arſit, macros dum turdos verſat in igne;
'Nam vaga per veterem dilapſo flamma culinam
'Vulcano ſummum properabat lambere tectum§.'

Had there been chimneys in the Roman houſes, Vitruvius certainly would not have failed to deſcribe their conſtruction, which is ſometimes attended with conſiderable difficulties, and which is intimately connected with the regulation of the plan of the whole edifice. He does not, however, ſay a word on this ſubject; neither does Julius Pollux, who has collected with great care the Greek names of every part of a dwelling-houſe; and Grapaldus, who in later times made a collection of the Latin terms, has not given a Latin word expreſſive of a modern chimney *."

Our author admits the derivation of the word *chimney* to be as we have given it in the Encyclopædia; but (ſay he) "*Caminus* ſignified, as far as I have been able to learn, firſt a chemical or metallurgic furnace, in which a crucible was placed for melting and refining metals; ſecondly, a ſmith's forge; and, thirdly, a hearth on which portable ſtoves or fire-pans were placed for warming the apartment. In all theſe, however, there appears no trace of a chimney." Herodotus relates (lib. viii. c. 137.), that a king of Libya, when one of his ſervants aſked for his wages, offered him in jeſt the ſun, which at that time ſhone into the houſe through an opening in the roof, under which the fire was perhaps made in the middle of the edifice. If ſuch a hole muſt be called a chimney, our author admits that chimneys were in uſe among the ancients, eſpecially in their kitchens; but it is obvious that ſuch chimneys bore no reſemblance to our's, through which the ſun could not dart his rays upon the floor of any apartment.

"However imperfect may be the information which can be collected from the Greek and Roman authors reſpecting the manner in which the ancients warmed their apartments, it nevertheleſs ſhews that they commonly uſed for that purpoſe a large fire-pan or portable ſtove, in which they kindled wood, and, when the wood was well lighted, carried it into the room, or which they filled with burning coals. When Alexander the Great was entertained by a friend in winter, as the weather was cold and raw, a ſmall fire baſon was brought into the apartment to warm it. The prince, obſerving the ſize of the veſſel, and that it contained only a few coals, deſired his hoſt, in a jeering manner, to bring more wood or frankincenſe; giving him thus to underſtand that the fire was fitter for burning perfumes than to produce heat. Anacharſis, the Scythian philoſopher, though diſpleaſed with many of the Grecian cuſtoms, praiſed the Greeks, however, becauſe they ſhut out the ſmoke and brought only fire into their houſes †. We are informed by Lampridius, that the extravagant Heliogabulus cauſed to be burned in theſe ſtoves, inſtead of wood, Indian ſpiceries and coſtly perfumes ‡. It is alſo worthy of notice, that coals were found in ſome of the apartments of Herculaneum, as we are told by Winklemann, but neither ſtoves nor chimneys."

It is well known to every ſcholar, that the uſeful arts of life were invented in the eaſt, and that the cuſtoms, manners, and furniture of eaſtern nations, have remained from time immemorial almoſt unchanged. In Perſia, which the late Sir William Jones ſeems to have conſidered as the original country of mankind, the methods employed by the inhabitants for warming themſelves have a great reſemblance to thoſe employed by the ancient Greeks and Romans for the ſame purpoſe. According to De la Valle, the Perſians make fires in their apartments, not in chimneys as we do, but in ſtoves in the earth, which they call *tennor*. "Theſe ſtoves conſiſt of a ſquare or round hole, two ſpans or a little more in depth, and in ſhape not unlike an Italian caſk. That this hole may throw out heat ſooner, and with more ſtrength, there is placed in it an iron veſſel of the

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* *Eclog.* i. ver. 83.

† *Aulular*, act ii. ſc. 4

‡ Τηλια.

§ *Horat.* lib. i. ſat. 5.

* *Franciſci Marii Grapaldi de partibus ædium libri.*

† *Plutarch. Sympoſ.* lib. vi. 7. p. 692.

‡ *Æl. Lamprid. Vita Heliogab.* cap. 31.

ſame ſize, which is either filled with burning coals, or a fire of wood and other inflammable ſubſtances is made in it. When this is done, they place over the hole or ſtove a wooden top, like a ſmall low table, and ſpread above it a large coverlet quilted with cotton, which hangs down on all ſides to the floor. This covering condenſes the heat, and cauſes it to warm the whole apartment. The people who eat or converſe there, and ſome who ſleep in it, lie down on the floor above the carpet, and lean, with their ſhoulders againſt the wall, on ſquare cuſhions, upon which they ſometimes alſo ſit; for the *tennor* is conſtructed in a place equally diſtant from the walls on both ſides. Thoſe who are not very cold only put their feet under the table or covering; but thoſe who require more heat can put their hands under it, or creep under it altogether. By theſe means the ſtove diffuſes over the whole body, without cauſing uneaſineſs to the head, ſo penetrating and agreeable a warmth, that I never in winter experienced any thing more pleaſant. Thoſe, however, who require leſs heat let the coverlet hang down on their ſide to the floor, and enjoy without any inconvenience from the ſtove the moderately heated air of the apartment. They have a method alſo of ſtirring up or blowing the fire when neceſſary, by means of a ſmall pipe united with the tennor or ſtove under the earth, and made to project above the floor as high as one chooſes; ſo that the wind, when a perſon blows into it, becauſe it has no other vent, acts immediately upon the fire like a pair of bellows. When there is no longer occaſion to uſe this ſtove, both holes are cloſed up, that is to ſay, the mouth of the ſtove and that of the pipe which conveys the air to it, by a flat ſtone made for that purpoſe. Scarcely any appearance of them is then to be perceived, nor do they occaſion inconvenience, eſpecially in a country where it is always cuſtomary to cover the floor with a carpet, and where the walls are plaſtered. In many parts theſe ovens are uſed to cook victuals, by placing kettles over them. They are employed alſo to bake bread; and for this purpoſe they are covered with a large broad metal plate, on which the cake is laid; but if the bread is thick and requires more heat, it is put into the ſtove itſelf."

Our learned author having proved, to our entire ſatisfaction, that chimneys, ſuch as we have now in every comfortable room, were unknown to the moſt poliſhed nations of antiquity, ſets himſelf to inquire into the era of their invention; and the oldeſt account of them which he finds is an inſcription at Venice, which relates, that in the year 1347 a great many chimneys were thrown down by an earthquake. It would appear, however, that in ſome places they had been in uſe for a conſiderable time before that period; for *De Gataris*, in his Hiſtory of Padua, relates, that *Franceſco de Carraro*, lord of Padua, came to Rome in 1368, and finding no chimneys in the inn where he lodged, becauſe at that time fire was kindled in a hall in the middle of the floor, he cauſed two chimneys like thoſe which had *long* been uſed at Padua to be conſtructed by maſons and carpenters, whom he had brought along with him. Over theſe chimneys, the firſt ever ſeen at Rome, he affixed his arms, which were ſtill remaining in the time of De Gataris, who died of the plague in 1405.

Though chimneys have been thus long in uſe, they are yet far enough from being brought to perfection. There is hardly a modern houſe, eſpecially if highly finiſhed, in which there is not one room at leaſt liable to be filled with ſmoke when it is attempted to be heated by an open fire; and there are many houſes ſo infeſted with this plague as to be almoſt uninhabitable during the winter months; not to mention other great defects in common chimneys, which not being ſo obvious have attracted leſs attention. Many ingenious methods have been propoſed to cure ſmokey chimneys in every ſituation (ſee Smoke, *Encycl.*); but Count Rumford's Eſſay on this ſubject contains the moſt valuable directions that we have ſeen, not only for removing the inconveniency of ſmoke, but likewiſe for increaſing the heat of the room by a diminiſhed conſumption of fuel.

To thoſe who are at all acquainted with the nature and properties of elaſtic fluids, it muſt be obvious, that the whole myſtery of curing ſmokey chimneys conſiſts in finding out and removing the accidental cauſes which prevent the heated ſmoke from being forced up the chimney by the preſſure of the cool and therefore heavier air of the room. Though theſe cauſes are various, yet, ſays our author, that which will moſt commonly be found to operate, is the bad conſtruction of the chimney *in the neighbourhood of the fire-place.* "The great fault of all the open fire-places or chimneys for burning wood or coals in an open fire now in common uſe is, that they are much too large; or rather it is *the throat of the chimney*, or the lower part of its open canal, in the neighbourhood of the mantle, and immediately over the fire, which is too large."

To this fault, therefore, the attention ſhould be firſt turned in every attempt which is made to improve the conſtruction of chimneys; for however perfect a fire-place may be in other reſpects, if the opening left for the paſſage of the ſmoke is larger than is neceſſary for that purpoſe, nothing can prevent the warm air of the room from eſcaping through it; and whenever this happens, there is not only an unneceſſary loſs of heat, but the warm air which leaves the room to go up the chimney being replaced by cold air from without, draughts of cold air cannot fail to be produced in the room, to the great annoyance of thoſe who inhabit it. But although both theſe evils may be effectually remedied by reducing the throat of the chimney to a proper ſize, yet in doing this ſeveral precautions will be neceſſary. And firſt of all, the throat of the chimney ſhould be in its proper place; that is to ſay, in that place in which it ought to be, in order that the aſcent of the ſmoke may be moſt facilitated: now as the ſmoke and hot vapour which riſe from a fire naturally tend *upwards*, the proper place for the throat of the chimney is evidently perpendicularly *over the fire.*

But there is another circumſtance to be attended to in determining the proper place for the throat of a chimney, and that is, to aſcertain its diſtance from the fire, or *how far* above the burning fuel it ought to be placed. In determining this point there are many things to be conſidered, and ſeveral advantages and diſadvantages to be weighed and balanced.

As the ſmoke and vapour which aſcend from burning fuel riſe in conſequence of their being rarefied by heat, and made lighter than the air of the ſurrounding atmoſphere; and as the degree of their rarefaction, and conſequently their tendency to riſe, is in proportion to the intenſity of their heat; and further, as they are hotter near the fire than at a greater diſtance from it—it is clear that the nearer the throat of a chimney is to the fire, the ſtronger will be what is commonly called its *draught*, and the leſs danger there will be of its ſmoking. But, on the other hand, when the draught of a chimney is very ſtrong, and particularly when this ſtrong draught is occaſioned by the throat of the chimney being very near the fire, it may ſo happen that the draught of air into the fire may become ſo ſtrong as to cauſe the fuel to be conſumed too rapidly. There are likewiſe ſeveral other inconveniences which would attend the placing of the throat of a chimney *very near* the burning fuel.

The poſition of the throat of a chimney being once determined, the next points to be aſcertained are its ſize and form, and the manner in which it ought to be connected with the fire-place below, and with the open canal of the chimney above. But as theſe inveſtigations are intimately connected with thoſe which relate to the form proper to be given to the fire-place itſelf, we muſt conſider them all together.

Now the deſign of a chimney fire being ſimply to warm a room, it is neceſſary, firſt of all, to contrive matters ſo that the room ſhally be actually warmed; ſecondly, that it be warmed with the ſmalleſt expence of fuel poſſible; and, thirdly, that in warming it, the air of the room be preſerved perfectly pure, and fit for reſpiration, and free from ſmoke and all diſagreeable ſmells.

To determine in what manner a room is heated by an open chimney fire, it will be neceſſary firſt of all to find out *under what form* the heat generated in the combuſtion of the fuel exiſts, and then to ſee how it is communicated to thoſe bodies which are heated by it.

In regard to the firſt of theſe ſubjects of inquiry, it is quite certain that the heat which is generated in the combuſtion of the fuel exiſts under *two* perfectly diſtinct and very different forms. One part of it is *combined* with the ſmoke, vapour, and heated air which riſe from the burning fuel, and goes off with them into the upper regions of the atmoſphere; while the other part, which appears to be *uncombined*, or, as ſome ingenious philoſophers have ſuppoſed, combined only with light, and therefore called *radiant heat*, is ſent off from the fire in rays in all poſſible directions.

With reſpect to the ſecond ſubject of inquiry, namely, how this heat, exiſting under theſe two different forms, is communicated to other bodies, it is highly probable that the combined heat can only be communicated to other bodies by *actual contact* with the body with which it is combined; and with regard to the rays which are ſent off by burning fuel, it is certain that *they* communicate or generate heat only *when* and *where* they are ſtopped or abſorbed. In paſſing through air, which is tranſparent, they certainly do not communicate any heat to it; and it ſeems highly probable that they do not communicate heat to ſolid bodies by which they are reflected.

As it is the radiant heat alone which can be employed in warming a room, when fuel is burnt for this purpoſe in an open fire-place, it becomes an object of much importance to determine how the greateſt quantity of it may be generated in the combuſtion of the fuel, and how the greateſt proportion poſſible of that generated may be brought into the room.

Now the quantity of radiant heat generated in the combuſtion of a given quantity of any kind of fuel depends very much upon the management of the fire, or upon the manner in which the fuel is conſumed. When the fire burns bright, much radiant heat will be ſent off from it; but when it is *ſmothered up*, very little will be generated, and indeed very little combined heat that can be employed to any uſeful purpoſe: moſt of the heat produced will be immediately *expended* in giving elaſticity to a thick denſe vapour or ſmoke, which will be ſeen riſing from the fire; and the combuſtion being very incomplete, a great part of the inflammable matter of the fuel being merely rarefied and driven up the chimney without being inflamed, the fuel will be waſted to little purpoſe. And hence it appears of how much importance it is, whether it be conſidered with a view to economy, or to cleanlineſs, comfort, and elegance, to pay due attention to the management of a chimney fire.

Nothing can be more perfectly void of common ſenſe, and waſteful and ſlovenly at the ſame time, than the manner in which chimney fires, and particularly where coals are burned, are commonly managed by ſervants. They throw on a load of coals at once, through which the flame is hours in making its way; and frequently it is not without much trouble that the fire is prevented from going quite out. During this time no heat is communicated to the room; and what is ſtill worſe, the throat of the chimney being occupied merely by a heavy denſe vapour, not poſſeſſed of any conſiderable degree of heat, and conſequently not having much elaſticity, the warm air of the room finds leſs difficulty in forcing its way up the chimney and eſcaping than when the fire burns bright. And it happens not unfrequently, eſpecially in chimneys and fire-places ill-conſtructed, that this current of warm air from the room which preſſes into the chimney, croſſing upon the current of heavy ſmoke which riſes ſlowly from the fire, obſtructs it in its aſcent, and beats it back into the room: hence it is that chimneys ſo often ſmoke when too large a quantity of freſh coals is put upon the fire. So many coals ſhould never be put on the fire at once as to prevent the free paſſage of the flame between them. In ſhort, a fire ſhould never be ſmothered; and when proper attention is paid to the quantity of coals put on, there will be very little uſe for the pocker; and this circumſtance will contribute very much to cleanlineſs, and to the preſervation of furniture.

As we have ſeen what is neceſſary to the *generation* of the greateſt quantity of radiant heat, it remains to be determined how the greateſt proportion of that which is generated and ſent off from the fire in all directions may be made to *enter the room*, and aſſiſt in warming it.

This muſt be done, firſt, by cauſing as many as poſſible of the rays, as they are ſent off from the fire in ſtraight lines, to come *directly* into the room; which can only be effected by bringing the fire as far forward as poſſible, and leaving the opening of the fire-place as wide and as high as can be done without inconvenience: and, ſecondly, by making the ſides and back of the fire-place of ſuch a form, and conſtructing them of ſuch materials, as to cauſe the direct rays from the fire, which ſtrike againſt them, to be ſent into the room by reflection in the greateſt abundance.

Now it will be found upon examination, that the beſt form for the vertical ſides of a fire-place, or the *covings* (as they are called), is that of an upright plane, making an angle with the plane of the back of the fire-place of about 135 degrees.—According to the preſent conſtruction of chimneys, this angle is ſometimes only 90, and very ſeldom above 100 or 110 degrees; but it is obvious, that in all theſe caſes the two ſides or coverings of the fire-place are very ill-contrived for throwing into the room by reflection the rays from the fire which fall upon them.

With regard to the materials which ſhould be employed in the conſtruction of fire-places, particularly the backs and covings, it is obvious that thoſe are to be preferred which *abſorb* the *leaſt*, and of courſe *reflect* the greateſt quantity of radiant heat. Iron, therefore, and, in general, metals of all kinds, are the very worſt materials which can poſſibly be employed for the backs and covings of chimneys; whilſt fire-ſtone white-waſhed, or common bricks and mortar, covered with a thin coating of plaſter, and white-waſhed, anſwer the purpoſe extremely well. A white colour ſhould, indeed, be always given to the inſide of a chimney of whatever materials it be conſtructed; and black, which is at preſent ſo common, ſhould be carefully avoided, becauſe white reflects the moſt, and black the leaſt, radiant heat. The grate, however, cannot well be made of any thing elſe than iron; but there is no neceſſity whatever for that immenſe quantity of iron which ſurrounds grates as they are commonly fitted up, and which not only renders them very expenſive, but eſſentially injures the fire-place.

To have only pointed out the faults of the chimneys in uſe, without ſhewing how theſe faults may be corrected, would have been a work of very little value; but the Count's Treatiſe is complete, and contains the plaineſt directions for the conſtruction of fire-places. Theſe directions are introduced by an explanation of ſome technical words and expreſſions. Thus, by the *throat* of a chimney, already mentioned, he means the lower extremity of its canal, where it unites with the upper part of its open fire-place. This throat is commonly found about a foot above the level of the lower part of the mantle, and it is ſometimes contracted to a ſmaller ſize than the reſt of the canal of the chimney, and ſometimes not.

Plate XX. Fig. 1. ſhews the ſection of a chimney on the common conſtruction, in which *de* is the throat.

Fig. 2. ſhews the ſection of the ſame chimney altered and improved, in which *di* is the reduced throat.

The *breaſt* of a chimney is that part of it which is immediately behind the mantle. It is the wall which forms the entrance from below into the throat of the chimney in front, or towards the room. It is oppoſite to the upper extremity of the back of the open fire-place, and parallel to it: in ſhort, it may be ſaid to be the back part of the mantle itſelf.—In the figures 1. and 2. it is marked by the letter *d*. The width of the throat of the chimney (*de* fig. 1. and *di* fig. 2.) is taken from the breaſt of the chimney to the back, and its length is taken at right angles to its width, or in a line parallel to the mantle (*a* fig. 1. and 2.).

The bringing-forward of the fire into the room, or rather bringing it nearer to the front of the opening of the fire-place, and the diminiſhing of the throat of the chimney, being two objects principally had in view in the alterations in fire-places propoſed by the Count, it is evident that both theſe may be attained merely by bringing forward the back of the chimney. The only queſtion therefore is, How far it ſhould be brought forward? The anſwer is ſhort, and eaſy to be underſtood; bring it forward as far as poſſible, without diminiſhing too much the paſſage which muſt be left for the ſmoke. Now as this paſſage, which in its narroweſt part he calls *the throat of the chimney*, ought, for reaſons which have been already explained, to be immediately, or perpendicularly over the fire, it is evident that the back of the chimney muſt always be built perfectly upright. To determine, therefore, the place for the new back, or how far preciſely it ought to be brought forward, nothing more is neceſſary than to aſcertain how wide the throat of the chimney ought to be left, or what ſpace muſt be left between the top of the breaſt of the chimney where the upright canal of the chimney begins, and the new back of the fire-place carried up perpendicularly to that height.

Numerous experiments have convinced the Count, that, all circumſtances being well conſidered, and the advantages and diſadvantages compared and balanced, *four inches* is the beſt width that can be given to the throat of a chimney, whether the fire-place be deſtined to burn wood, coals, turf, or any other fuel. In very large halls where great fires are kept up, it may ſometimes, though very rarely, be proper to increaſe this width to four inches and a half, or even to five inches.

The next thing to be conſidered is the width which it will be proper to give to the back of the chimney; and, in moſt caſes, this ſhould be *one-third* of the width of the opening of the fire place in front. It is not indeed abſolutely neceſſary to conform with rigour to this deciſion, nor is it always poſſible; but it ſhould invariably be conformed to as far as circumſtances will permit. Where a chimney, ſays the Count, is deſigned for warming a room of a middling ſize, and where the thickneſs of the wall of the chimney in front, meaſured from the front of the mantle to the breaſt of the chimney, is nine inches, I ſhould ſet off four inches more for the width of the throat of the chimney, which, ſuppoſing the back of the chimney to be built upright, as it always ought to be, will give thirteen inches for the depth of the fire-place, meaſured upon the hearth, from the opening of the fire-place in front to the back. In this caſe, thirteen inches would be a good ſize for the width of the back; and three times thirteen inches, or 39 inches, for the width of the opening of the fire-place in front; and the angle made by the back of the fire-place and the ſides of it, or covings, would be juſt 135 degrees, which is the beſt poſition they can have for throwing heat into the room. This poſition, indeed, it may ſometimes be impoſſible to attain in altering chimneys already built; but a deviation from it of two or three degrees will be of no great conſequence; for the points of by much the greateſt importance in altering fire-places upon the principles here recommended, are the bringing forward the back to its proper place, and making it of the proper width.

Proviſion, however, muſt be made for the paſſage of the chimney-ſweeper up the chimney; and this may eaſily be done in the following manner: In building up the new back of the fire-place; when this wall (which need never be more than the width of a ſingle brick in thickneſs) is brought up ſo high that there remains no more than about ten or eleven inches between what is then the top of it and the inſide of the mantle, or lower extremity of the breaſt of the chimney, an opening or door way, eleven or twelve inches wide, muſt be begun in the middle of the back, and continued quite to the top of it, which, according to the height to which it will commonly be neceſſary to carry up the back, will make the opening abundantly ſufficient to let the chimney-ſweeper paſs. When the fire-place is finiſhed, this door-way is to be cloſed by a tile or fit piece of ſtone placed in it without mortar, and by means of a rabbit made in the brick-work, confined in its place in ſuch a manner as that it may be eaſily removed when the chimney is to be ſwept, and reſtored to its place when that work is over. Of this contrivance the reader will be able to form a clear conception from fig. 2. which repreſents the ſection of a chimney after it has been properly altered from what is exhibited in fig. 1. In this improved chimney *k l* is the new back of the fire-place; *l i* the tile or ſtone which cloſes the door-way for the chimney-ſweeper; *d i* the throat of the chimney narrowed to four inches; *a* the mantle, and *b* the ſtone placed under the mantle, ſuppoſed to have been too high, in order to diminiſh the height of the opening of the fire-place in front.

It has been obſerved above, that the new back, which it will always be found neceſſary to build in order to bring the fire ſufficiently forward, in altering a chimney conſtructed on the common principles, need never be thicker than the width of a common brick. The ſame may be ſaid of the thickneſs neceſſary to be given to the new ſides or covings of the chimney; or if the new back and covings are conſtructed of ſtone, one inch and three quarters, or two inches in thickneſs, will be ſufficient. Care ſhould be taken in building up theſe new walls to unite the back to the covings in a ſolid manner.

Whether the new back and covings are conſtructed of ſtone or built of bricks, the ſpace between them and the old back and covings of the chimney ought to be filled up, to give greater ſolidity to the ſtructure. This may be done with looſe rubbiſh, or pieces of broken bricks or ſtones, provided the work be ſtrengthened by a few layers or courſes of bricks laid in mortar; but it will be indiſpenſably neceſſary to finiſh the work where theſe new walls end, that is to ſay, at the top of the throat of the chimney, where it ends abruptly in the open canal of the chimney, by a horizontal courſe of bricks well ſecured with mortar. This courſe of bricks will be upon a level with the top of the door-way left for the chimney-ſweeper; and the void behind the door-way muſt be covered with a horizontal ſtone or tile, to be removed at the ſame time the door is removed, and for the ſame purpoſe.

From theſe deſcriptions it is clear, that where the throat of the chimney has an end, that is to ſay, where it enters into the lower part of the open canal of the chimney, *there* the three walls which form the two covings and the back of the fire-place all end abruptly. It is of much importance that they ſhould end in this manner; for were they to be ſloped outward, and raiſed in ſuch a manner as to ſwell out the upper extremity of the throat of the chimney in the form of a trumpet, and increaſe it by degrees to the ſize of the canal of the chimney, this manner of uniting the lower extremity of the canal of the chimney with the throat would tend to aſſiſt the winds, which may attempt to blow down the chimney, in forcing their way through the throat, and throwing the ſmoke backward into the room; but when the throat of the chimney ends abruptly, and the ends of the new walls form a flat horizontal ſurface, it will be much more difficult for any wind from above to find and force its way through the narrow paſſage of the throat of the chimney.

As the two walls which form the new covings of the chimney are not parallel to each other, but inclined, preſenting an oblique ſurface towards the front of the chimney, and as they are built perfectly upright, and quite flat, from the hearth to the top of the throat, where they end, it is evident that an horizontal ſection of the throat will not be an oblong ſquare; but its deviation from that form is a matter of no conſequence; and no attempts ſhould ever be made, by twiſting the covings above where they approach the breaſt of the chimney, to bring it to that form. All twiſts, bends, prominences, excavations, and other irregularities of form in the covings of a chimney, never fail to produce eddies in the current of air which is continually paſſing into, and through, an open fire-place in which a fire is burning; and all ſuch eddies diſturb either the fire or the aſcending current of ſmoke, or both; and not unfrequently cauſe the ſmoke to be thrown back into the room. Hence it appears, that the covings of chimneys ſhould never be made circular, or in the form of any other curve, but always quite flat.

For the ſame reaſon, that is to ſay, to prevent eddies, the breaſt of the chimney, which forms that ſide of the throat that is in front or neareſt to the room, ſhould be neatly cleaned off, and its ſurface made quite regular and ſmooth. This may be eaſily done by covering it with a coat of plaſter, which may be made thicker or thinner in different parts, as may be neceſſary in order to bring the breaſt of the chimney to be of the proper form.

With regard to the form of the breaſt of a chimney, this is a matter of very great importance, and which ought always to be particularly attended to. The worſt form it can have is that of a vertical plane or upright flat; and next to this the worſt form is an inclined plane. Both theſe forms cauſe the current of warm air from the room, which will, in ſpite of every precaution, ſometimes find its way into the chimney, to croſs upon the current of ſmoke which riſes from the fire in a manner moſt likely to embarraſs it in its aſcent, and drive it back.

The current of air which, paſſing under the mantle, gets into the chimney, ſhould be made *gradually to bend its courſe upwards*; by which means it will unite *quietly* with the aſcending current of ſmoke, and will be leſs likely to check it, or force it back into the room. Now this may be effected with the greateſt eaſe and certainty, merely by *rounding off* the breaſt of the chimney or back part of the mantle, inſtead of leaving it flat or full of holes and corners; and this of courſe ought always to be done.

Having thus aſcertained the form and poſition of the new covings, the ingenious author next turns his attention to the height to which they ſhould be carried. This will depend not only on the height of the mantle, but alſo, and more eſpecially, on the height of the breaſt of the chimney, or of that part of the chimney where the breaſt ends and the upright canal begins.—The back and covings muſt riſe a few inches, five or ſix for inſtance, higher than this part, otherwiſe the throat of the chimney will not be properly formed; but no advantage would be gained by carrying them higher.

One important circumſtance reſpecting chimney fire-places ſtill remains to be conſidered; and that is the grate. In placing the grate, the thing principally to be attended to is, to make the back of it coincide with the back of the fire-place. But as many of the grates now in common uſe will be found to be too large, when the fire places are altered and improved, it will be neceſſary to diminiſh their capacities by filling them up at the back and ſides with pieces of fire ſtone. When this is done, it is the front of the flat piece of fire-ſtone which is made to form a new back to the grate, which muſt be made to coincide with, and make part of the back of the fire place.—But in diminiſhing the capacities of grates with pieces of fire-ſtone, care muſt be taken not to make them *too narrow*.

The proper width for grates deſtined for rooms of a middling ſize will be from ſix to eight inches, and their length may be diminiſhed more or leſs according as the room is heated with more or leſs difficulty, or as the weather is more or leſs ſevere.—But where the width of a grate is not more than five inches it will be very difficult to prevent the fire from going out.

It frequently happens that the iron backs of grates are not vertical, or upright, but inclined backwards.—When theſe grates are ſo much too wide as to render it neceſſary to fill them up behind with fire-ſtone, the inclination of the back will be of little conſequence; for by making the piece of ſtone with which the width of the grate is to be diminiſhed in the form of a wedge, or thicker above than below, the front of this ſtone, which in effect will become the back of the grate, may be made perfectly vertical; and the iron back of the grate being hid in the ſolid work of the back of the fire-place, will produce no effect whatever; but if the grate be already ſo narrow as not to admit of any diminution of its width, in that caſe it will be beſt to take away the iron back of the grate entirely, and fixing the grate firmly in the brick-work, cauſe the back of the fire-place to ſerve as a back to the grate.

Where grates, which are deſigned for rooms of a middling ſize, are longer than 14 or 15 inches, it will always be beſt, not merely to diminiſh their lengths, by filling them up at their two ends with fire-ſtone, but, forming the back of the chimney of a proper width, without paying any regard to the length of the grate, to carry the covings through the two ends of the grate in ſuch a manner as to conceal them, or at leaſt to conceal the back corners of them in the walls of the covings.

Had theſe directions been duly attended to by the maſons who in Scotland pretend to alter chimneys on the principles of Count Rumford, we ſhould not have obſerved ſo many of the grates placed by them jutting out beyond the mantle of the chimney; nor of courſe heard ſo many complaints of rooms being rendered more ſmokey, and the conſumption of fuel increaſed by theſe pretended improvements. But when the grate is not ſet in its proper place, when its ſloping iron back is retained, when no pains have been taken to make its ends coincide with the covings of the fire-place, when the mantle, inſtead of having its back rounded off, is a vertical plane of iron cutting the column of ſmoke which riſes beneath it, and, above all, when the throat of the chimney, inſtead of four, is made, as we often ſee, fourteen inches wide; let it be remembered, that not one of Count Rumford's directions has been followed, and that his principles have as little to do with the conſtruction of ſuch a chimney as with the building of the wall of China or the pyramids of Egypt.

To contribute our aid to prevent theſe blunders for the future, we ſhall here ſubjoin the Count's directions for laying out the work; not to inſtruct maſons and bricklayers, to whom we earneſtly recommend the ſtudy of the eſſay itſelf (B), which contains much valuable information that we have omitted; but merely to give the country gentleman an opportunity of diſcovering whether the workmen whom he employs deviates far and needleſsly from the principles which he pretends to follow.

When a chimney is to be altered, after taking away the grate and removing the rubbiſh, firſt draw a ſtraight line with chalk, or with a lead pencil, upon the hearth, from one jamb to the other,—even with the front of the jambs. The dotted line A B, fig. 3. may repreſent this line.

From the middle *c* of this line, (A B) another line *c d* is to be drawn perpendicular to it, acroſs the hearth, to the middle *d*, of the back of the chimney.

A perſon muſt now ſtand upright in the chimney, with his back to the back of the chimney, and hold a plumb-line to the middle of the upper part of the breaſt of the chimney (*d*, fig. 1.), or where the canal of the chimney begins to riſe perpendicularly;—taking care to place the line above in ſuch a manner that the plumb may fall on the line *c d* (fig. 3.) drawn on the hearth from the middle of the opening of the chimney in front to the middle of the back, and an aſſiſtant muſt mark the preciſe place *e*, on that line where the plumb falls.

This being done, and the perſon in the chimney having quitted his ſtation, four inches are to be ſet off on the line *c d*, from *e*, towards *d*; and the point *f*, where theſe four inches end, (which muſt be marked with chalk, or with a pencil), will ſhow how far the new back is to be brought forward.

Through *f*, draw the line *g h* parallel to the line A B, and this line *g h* will ſhow the direction of the new back, or the ground line upon which it is to be built. The line *c f* will ſhow the depth of the new fire-place; and if it ſhould happen that *c f* is equal to about *one-third* of the line A B, and if the grate can be accommodated to the fire-place, inſtead of its being neceſſary to accommodate the fire place to the grate; in that caſe, half the length of the line *c f* is to be ſet off from *f* on the line *g f h*, on one ſide to *k*, and on the other to *i*, and the line *i k* will ſhow the ground line of the fore part of the back of the chimney.

In all caſes where the width of the opening of the fire-place in front (A B) happens to be not greater, or not

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(B) It coſts but two ſhillings; and he muſt be a poor bricklayer indeed who cannot afford to pay that ſum for inſtruction in the moſt important, as well as moſt difficult, part of his buſineſs.

not more than two or three inches greater than *three times* the width of the new back of the chimney (*i k*), this opening may be left; and lines drawn from *i* to A, and from *k* to B, will ſhow the width and poſition of the front of the new covings;—but when the opening of the fire-place in front is ſtill wider, it muſt be reduced; which is to be done in the following manner:

From *c*, the middle of the line A B, *c a* and *c b* muſt be ſet off equal to the width of the back (*i k*), added to half its width (*f i*); and lines drawn from *i* to *a*, and from *k* to *b*, will ſhow the ground plan of the fronts of the new covings.

When this is done, nothing more will be neceſſary than to build up the back and covings; and if the fire-place is deſigned for burning coals, to fix the grate in its proper place, according to the directions already given.—When the width of the fire-place is reduced, the edges of the covings *a* A and *b* B are to make a finiſh with the front of the jambs.—And in general it will be beſt, not only for the ſake of the appearance of the chimney, but for other reaſons alſo, to lower the height of the opening of the fire-place whenever its width in front is diminiſhed.

A front view of the chimney, after it has been thus altered, is exhibited in fig. 4. where the under part of the door-way is repreſented, as cloſed by the white dotted lines.

When the wall of the chimney in front, meaſured from the upper part of the breaſt of the chimney to the front of the mantle, is very thin, it may happen, and eſpecially in chimneys deſigned for burning wood upon the hearth, or upon dogs, that the depth of the chimney, determining according to the directions here given, may be too ſmall.

Thus, for example, ſuppoſing the wall of the chimney, in front, from the upper part of the breaſt of the chimney to the front of the mantle, to be only four inches, (which is ſometimes the caſe, particularly in rooms ſituated near the top of a houſe), in this caſe, if we take four inches for the width of the throat, this will give eight inches only for the depth of the fire-place, which would be too little, even were coals to be burnt inſtead of wood.—In this caſe (ſays the Count) I ſhould increaſe the depth of the fire-place at the hearth to 12 or 13 inches, and ſhould build the back perpendicular to the height of the top of the burning fuel (whether it be wood burnt upon the hearth or coals in a grate); and then, ſloping the back by a gentle inclination forward, bring it to its proper place, that is to ſay, *perpendicularly under the back part of the throat of the chimney*. This ſlope, (which will bring the back forward four or five inches, or juſt as much as the depth of the fire-place is increaſed), though it ought not to be too abrupt, yet it ought to be quite finiſhed at the height of eight or ten inches above the fire, otherwiſe it may perhaps cauſe the chimney to ſmoke; but when it is very near the fire, the heat of the fire will enable the current of riſing ſmoke to overcome the obſtacle which this ſlope will oppoſe to its aſcent, which it could not do ſo eaſily were the ſlope ſituated at a greater diſtance from the burning fuel.

Fig. 5, 6, and 7, ſhow a plan, elevation, and ſection of a fire-place conſtructed or altered upon this principle.—The wall of the chimney in front at *a*, fig. 7. being only four inches thick, four inches more added to it for the width of the throat would have left the depth of the fire-place meaſured upon the hearth *b c* only eight inches, which would have been too little;—a niche *c* and *e* was therefore made in the new back of the fire-place for receiving the grate, which niche was ſix inches deep in the centre of it, below 13 inches wide, (or equal in width to the grate,) and 23 inches high; finiſhing above with a ſemicircular arch, which, in its higheſt part, roſe ſeven inches above the upper part of the grate.—The door-way for the chimney-ſweeper, which begins juſt above the top of the niche, may be ſeen diſtinctly in both the figures 6 and 7.—The ſpace marked *g*, fig. 7. behind this door-way, may either be filled with looſe bricks, or may be left void.—The manner in which the piece of ſtone *f*, fig. 7. which is put under the mantle of the chimney to reduce the height of the opening of the fire-place, is rounded off on the inſide in order to give a fair run to the column of ſmoke in its aſcent through the throat of the chimney, is clearly expreſſed in this figure. The plan fig. 5. and elevation fig. 6. ſhow how much the width of the opening of the fire-place in front is diminiſhed, and how the covings in the new fire-place are formed.

A perfect idea of the form and dimenſion of the fire-place in its original ſtate, as alſo after its alteration, may be had by a careful inſpection of theſe figures.

In chimneys, like that repreſented in figure 8, where the jambs A and B project far into the room, and where the front edge of the marble ſlab *o*, which forms the coving, does not come ſo far forward as the front of the jambs, the workmen in conſtructing the new covings are very apt to place them,—not in the line *c A*, which they ought to do,—but in the line *c o*, which is a great fault.—The covings of a chimney ſhould never range *behind* the front of the jambs, however thoſe jambs may project into the room;—but it is not abſolutely neceſſary that the covings ſhould *make a finiſh* with the internal front corners of the jambs, or that they ſhould be continued from the back *c*, quite to the front of the jambs at *A*.—They may finiſh in front at *a* and *b*; and ſmall corners *A*, *o*, *a*, may be left for placing the ſhovels, tongs, &c.

Were the new coving to range with the front edge of the old coving *o*, the obliquity of the new coving would commonly be too great;—or the angle *d c o* would exceed 135 degrees, *which it never ſhould do*,—or at leaſt never be more than a very few degrees. No inconvenience of any importance will ariſe from making the obliquity of the covings *leſs* than what is here recommended; but many cannot fail to be produced by making it much greater.

Theſe extracts, which we have made ſo liberally from Count Rumford's eſſay on chimney fire-places, will be ſufficient, we hope, to bring fully within the comprehenſion of thoſe who are acquainted with pneumatics and pneumatic chemiſtry the principles on which chimneys and fire-places ſhould be conſtructed; but ſuch as are in a great meaſure ſtrangers to theſe ſciences will do well to conſult the eſſay itſelf. With a benevolence which does him honour, the ingenious author has expreſſed a wiſh that his doctrines on this important ſubject may be widely propagated; and to encourage artiſts to ſtudy them, he has declared to the public in general, "that as he does not intend to take out himſelf, or to ſuffer others to take out, any patent for any invention of his which may be of public utility, all perſons are at full liberty to imitate them, and vend them, for their own emolument, when and where, and in any way they may think proper."

Chimney-Sweepers are a claſs of men who earn their ſubſiſtence by clearing chimneys of ſoot, which occaſions them to ſmoke. While chimneys continued to be built in ſo ſimple a manner, and of ſuch a width as they are ſtill obſerved to be in old houſes, they were ſo eaſily cleaned that this ſervice could be performed by a ſervant with a wiſp of ſtraw, or a little bruſhwood faſtened to a rope; but after the flues, in order to ſave room, were made narrower, or when ſeveral flues were united together, the cleaning of them became ſo difficult, that they required boys, or people of ſmall ſize, accuſtomed to that employment. The firſt chimney-ſweepers in Germany came from Savoy, Piedmont, and the neighbouring territories. Theſe for a long time were the only countries where the cleaning of chimneys was followed as a trade; and hence Profeſſor Beckmann concludes with great probability, that chimneys were invented in Italy. The Lotharingians, however, undertook the buſineſs of chimney-ſweeping alſo; on which account the duke of Lotharingia was ſtyled the *imperial fire-maſter*. The firſt Germans who condeſcended to clean chimneys were miners; and the chimney-ſweepers in that empire ſtill procure their boys from the foreſt of Hartz, where the greateſt mines are wrought. Very lately, and perhaps at preſent, the greater part of the chimney-ſweepers in Paris were Savoyards, many of them not above eight years of age, who, for the paltry ſum of five ſous, which they were obliged to ſhare with their avaricious maſter, would ſcramble, at the hazard of their lives, through a narrow funnel fifty feet in length, and with their beſoms clean it from ſoot and dirt. At what preciſe period chimney-ſweeping became a trade in England and Scotland, we have not been able to learn; but among us, as well as elſewhere, young boys are employed in this buſineſs, who are ſaid to be very harſhly treated by fellows who ſtole them from the doors of cottages in the country. That children have been ſometimes kidnapped by chimney-ſweepers, we can have no doubt; but that the practice is frequent, we do not believe. We think however that the buſineſs might be wholly aboliſhed; for a narrow funnel might certainly, if not very crooked, be ſwept by a bundle of ſtraw or bruſhwood faſtened to a rope, as well as one that is wider: and the bricks which ſeparate the contiguous flues we know to be leſs injured by this method of ſweeping, when cautiouſly gone about, than by ſending boys up the chimneys.

On the 4th July 1796, letters patent were granted to Daniel Davis, of the pariſh of St Giles, Middleſex, for his invention of a machine, by which he propoſes to ſweep and cleanſe chimneys, and extinguiſh chimneys on fire, without any perſon going up the ſame, as is now the practice. The machine conſiſts of an apparatus of rack-work, of various lengths, which, by means of a hand-turn, is made to aſcend the chimney. The lengths of the rack-work are joined together by means of mortices and tenons, with a ſpring which holds them faſt. In each length is a joint, by which the rack-work will accommodate itſelf to angles or turns in the flues. To the firſt or uppermoſt length is fixed a bruſh of hair, or wire, or ſpunge, or other elaſtic ſubſtance as the occaſion may require.

This invention is doubtleſs well calculated to anſwer the purpoſe intended, and may perhaps be the means of diminiſhing the number of thoſe objects of miſery, the unfortunate chimney-ſweepers.

CHINA is an empire of ſuch antiquity and extent, the laws and cuſtoms of the people are ſo ſingular, and the populouſneſs of the country ſo very great—that it has attracted much of the attention of Europeans ever ſince it was viſited in the 13th century by Marco Paulo the Venetian traveller. Of ſuch a country it would be unpardonable not to give ſome account in a work of this nature; but we have not, in truth, much to add to what has been ſaid of China and the Chineſe in the Encyclopædia Britannica. Since the article China in that work was publiſhed, the court of Pekin has indeed been viſited by an embaſſy from Great Britain, and the origin of the people, as well as the antiquity of their empire, has been inveſtigated by Sir William Jones with his uſual diligence; but from his memoir, publiſhed in the ſecond volume of the Aſiatic Reſearches, and from Sir George Staunton's account of the embaſſy, there is not much to be extracted which would be either amuſing or inſtructive to our readers.

We have already obſerved from Groſier and others, that the Chineſe not only lay claim to the higheſt antiquity, but even contend that their firſt emperor was the firſt man. Both theſe poſitions are controverted by Sir William Jones, who, though he allows the Chineſe empire to be very ancient when compared with the oldeſt European ſtate, is yet decidedly of opinion that it was not founded at an earlier period than the 12th century before the Chriſtian era; and that the people, ſo far from being aborigines, are a mixed race of Tartars and Hindoos. He begins his inveſtigation with aſking, "Whence came the ſingular people who long had governed China, before they were conquered by the Tartars? On this problem (ſays he[*]) four opinions have been advanced, and all rather peremptorily aſſerted, than ſupported by argument and evidence. By a few writers it has been urged, that the *Chineſe* are an original race, who have dwelled for ages, if not from eternity, in the land which they now poſſeſs. By others, and chiefly by the miſſionaries, it is inſiſted that they ſprung from the ſame ſtock with the *Hebrews* and the *Arabs*. A third aſſertion is that of the Arabs themſelves, and of M. Pauw, who hold it indubitable, that they were originally *Tartars*, deſcending in wild clans from the ſteeps of Imaus: And a fourth, at leaſt as dogmatically pronounced as any of the preceding, is that of the *Brahmans*, who decide, without allowing any appeal from their deciſion, that the *Chinas* (for ſo they are named in *Sanſcrit*) were Hindoos of the military caſt, who, abandoning the privileges of their tribe, rambled in different bodies to the north-eaſt of *Bengal*; and forgetting by degrees the rites and the religion of their anceſtors, eſtabliſhed ſeparate principalities, which were afterwards united in the plains and valleys which are now poſſeſſed by them.

Of theſe opinions, Sir William having very completely demoliſhed the firſt three, proceeds to eſtabliſh the fourth, which he conſiders as intereſting as well as new in Europe. In the Sanſcrit inſtitutes of civil and religious duties, revealed, as the Hindoos believe, by Menu the

[*] *Aſiatic Reſearches*, vol. ii. mem. 25.

the ſon of Brahma, we find (ſays he) the following curious paſſage: 'Many families of the military claſs, having gradually abandoned the ordinances of the *Veda*, and the company of *Brahmans*, lived in a ſtate of degradation; as the people of *Pundraca* and *Odra*, thoſe of *Dravira* and *Camboja*, the *Yavanas* and *Sacas*, the *Paradas* and *Pahlavas*, the Chinas, and ſome other nations.' A full comment on this text (continues the preſident) would be ſuperfluous; but ſince the teſtimony of the Indian author, who, though not a divine perſonage, was certainly a very ancient lawyer, moraliſt, and hiſtorian, is direct and poſitive, diſintereſted and unſuſpected, it would decide the queſtion before us if we could be ſure that the word *China* ſignifies a *Chineſe*." Of this fact Sir William Jones took the very beſt methods to be ſatisfied. He conſulted a number of Pandits ſeparately, who all aſſured him that the word *China* has no other ſignification in *Sanſcrit*; that the *Chinas* of Menu ſettled in a fine country to the north-eaſt of *Gaur*, and to the eaſt of *Camarup* and *Napal*; that they had long been, and ſtill are, famed as ingenious artificers; and that they (the Pandits) had themſelves ſeen old Chineſe idols, which bore a manifeſt relation to the primitive religion of India. He then laid before one of the beſt informed *Pandits* a map of Aſia; and when his own country was pointed out to him, the *Pandit* immediately placed his finger on the north-weſtern provinces of China, as the place where he ſaid the *Chinas* of Menu firſt eſtabliſhed themſelves.

In the opinion of Sir William Jones, this is complete evidence that the Chineſe are deſcended from an Indian race; but he does not believe that the Chineſe empire, as we now call it, was formed when the laws of Menu were collected; and for his calling this fact in queſtion, he offers reaſons, which to us are perfectly ſatisfactory. By a diligent and accurate compariſon of ancient Sanſcrit writings, he has been able to fix the period of the compilation of thoſe laws at between 1000 and 1500 years before Chriſt; but by the evidence of Confucius himſelf, he proves, that if the Chineſe empire was formed, it could be only in its cradle in the 12th century before our era. In the ſecond part of the work, intitled *Lún Yú*, Confucius declares, that "although he, like other men, could relate, as mere leſſons of morality, the hiſtories of the firſt and ſecond imperial houſes, yet, *for want of evidence*, he could give no certain account of them." Now, ſays Sir William, if the Chineſe themſelves do not pretend that any hiſtorical monument exiſted in the age of Confucius preceding the riſe of their third dynaſty, about 1100 years before the Chriſtian epoch, we may juſtly conclude that their empire was then in its infancy, and did not grow to maturity till ſome ages afterwards. Nay, he is inclined to bring its origin ſtill lower down. "It was not, ſays he, till the eighth century before the birth of our Saviour, that a ſmall kingdom was erected in the province of *Shen ſi*, the capital of which ſtood nearly in the 35th degree of northern latitude, and about five degrees to the weſt of *Si-gan*. That country and its metropolis were both called *Chin*; and the dominion of its princes was gradually extended to the eaſt and weſt. The territory of *Chin*, ſo called by the old Hindoos, by the Perſians, and by the Chineſe, gave its name to a race of emperors, whoſe tyranny made their memory ſo unpopular, that the modern inhabitants of China hold the word in abhorrence, and ſpeak of themſelves as the people of a milder and more virtuous dynaſty: but it is highly probable that the whole nation deſcended from the *Chinas* of Menu, and mixing with the *Tartars*, by whom the plains of *Honan* and the more ſouthern provinces were thinly inhabited, formed by degrees the race of men whom we now ſee in poſſeſſion of the nobleſt empire in Aſia."

In ſupport of this opinion, which the accompliſhed author offers as the reſult of long and anxious inquiries, he obſerves, that the Chineſe have no ancient monuments from which their origin can be traced, even by plauſible conjecture; that their ſciences are wholly *exotic*; that their mechanic arts have nothing in them which any ſet of men, in a country ſo highly favoured by nature, might not have diſcovered and improved; that their philoſophy ſeems yet in ſo rude a ſtate as hardly to deſerve the appellation; and that their popular religion was imported from *India* in an age comparatively modern. He then inſtitutes a compariſon between the mythology of the Chineſe and that of the Hindoos; of which the reſult is, that the former people had an *ancient* ſyſtem of ceremonies and ſuperſtitions which has an apparent affinity with ſome parts of the oldeſt Indian worſhip. "They believed in the agency of genii or tutelary ſpirits, preſiding over the ſtars and the clouds; over lakes and rivers, mountains, valleys, and woods; over certain regions and towns; over all the elements, of which, like the Hindoos, they reckoned five; and particularly over *fire*, the moſt brilliant of them. To thoſe deities they offered victims on high places. And the following paſſage from one of their ſacred books, ſays Sir William, is very much in the ſtyle of the Brahmans: 'Even they who perform a ſacrifice with due reverence, cannot perfectly aſſure themſelves that the divine ſpirits accept their oblations; and far leſs can they, who adore the gods with languor and oſcitancy, clearly perceive their ſacred illapſes.' Theſe (continues the Preſident) are imperfect traces indeed, but they *are* traces of an affinity between the religion of Menu and that of the *Chinas*, whom he names among the apoſtates from it; and beſides them, we diſcover many other very ſingular marks of relation between the Chineſe and the old Hindoos.

"This relation (he thinks) appears in the remarkable period of 432,000, and the cycle of 60 years; in the predilection for the myſtical number *nine*; in many ſimilar faſts and great feſtivals, eſpecially at the ſolſtices and equinoxes; in the obſequies, conſiſting of rice and fruits offered to the manes of their anceſtors; in the dread of dying childleſs, leſt ſuch offerings ſhould be intermitted; and perhaps in their common abhorrence of *red* objects, which the Indians carried ſo far, that Menu himſelf, where he allows a *Brahman* to trade, if he cannot otherwiſe ſupport life, abſolutely forbids his trading in any ſort of *red* cloths, whether linen, or woollen, or made of woven bark. In a word, ſays Sir William Jones, all the circumſtances which have been mentioned ſeem to prove (as far as ſuch a queſtion admits proof), that the Chineſe and Hindoos were originally the ſame people; but having been ſeparated near 4000 years, they have retained few ſtrong features of their ancient conſanguinity, eſpecially as the Hindoos have preſerved their old language and ritual, while the Chineſe very ſoon loſt both; and the Hindoos have conſtantly intermarried among themſelves, while the Chineſe, by a mixture of Tartarian blood from the time of their firſt eſtabliſhment, have at length formed a race diſtinct in appearance both from Indians and Tartars."

Sir George Staunton, who accompanied the Earl of Macartney on his embaſſy to the Emperor of China, does not indeed directly controvert this reaſoning; but overlooking it altogether, gives to the Chineſe a much higher antiquity than Sir William Jones is inclined to allow them. Taking it for granted that their *cycle* is their own, and that it is not the offspring of aſtronomical ſcience, but of repeated obſervations, he ſeems to give implicit credit to thoſe annals of the empire which almoſt every other writer has conſidered as fabulous.

"Next to the ſtudies which teach the economy of life, the Chineſe (ſays he) value moſt the hiſtory of the events of their own country, which is, to them, the globe; and of the celeſtial movements which they had an opportunity of obſerving at the ſame time." In regard to the former, he tells us, that "from about *three* centuries before the Chriſtian era the tranſactions of the Chineſe empire have been regularly, and without any intervening chaſm, recorded both in official documents and by private contemporary writers. Nowhere had hiſtory become ſo much an object of public attention, and nowhere more the occupation of learned individuals. Every conſiderable town throughout the empire was a kind of univerſity, in which degrees were conferred on the proficient in the hiſtory and government of the ſtate. Hiſtorical works were multiplied throughout. The accounts of *recent* events were expoſed to the correction of the witneſſes of the facts, and compilations of former tranſactions to the criticiſms of rival writers." In regard to the latter, the movements of the heavenly bodies, he thinks that in no country are there ſtronger inducements or better opportunities to watch them than in China; and hence he infers, that the cycle of ſixty years is of Chineſe formation. "In a climate (ſays he) favourable to aſtronomy, the balance of hours beyond the number of days during which the ſun appeared to return oppoſite to, and to obſcure, or to mix among the ſame fixed ſtars, might be aſcertained in a ſhort time; and occaſioned the addition of a day to every fourth year, in order to maintain regularity in the computation of time, in regard to the return of the ſeaſons; but many ages muſt have paſt before a period could have been diſcovered, in which the unequal returns of the ſun and moon were ſo accurately adjuſted, that at its termination the new and full moons ſhould return, not only to the ſame day, but within an hour and a half of the time they had happened, when the period commenced. The knowledge of ſuch a period or cycle could be obtained only by a multiplicity of careful and accurate obſervations. Many revolutions of thoſe great luminaries muſt have been completed, and numberleſs conjunctions have paſt over, before their returns could be aſcertained to happen in the ſame day, at the end of nineteen years. The ſmall difference of time between the returning periods of this cycle, was partly leſſened by the intervention of another of 60 years, or of 720 revolutions of the moon, which, with the ſettled intercalation of 22 lunations, were at firſt ſuppoſed to bring a perfect coincidence of the relative poſitions of the ſun and moon: but even according to this period, every new year was made conſtantly to recede, in a very ſmall degree, which the Chineſe corrected afterwards from time to time. This cycle anſwered a double purpoſe, one as an era for chronological reckoning, and the other as a regulating period for a luni-ſolar year. Each year of the cycle is diſtinguiſhed by the union of two characters, taken from ſuch an arrangement of an unequal number of words placed in oppoſite columns, that the ſame two characters cannot be found again together for ſixty years. The firſt column contains a ſeries of ten words, the other twelve; which laſt are, in fact, the ſame that denote the twelve hours or diviſions of the day, each being double the European hour. The firſt word or character of the firſt ſeries or column of ten words, joined to the firſt word of the ſecond ſeries or column of twelve, marks the firſt year of the cycle; and ſo on until the firſt ſeries is exhauſted, when the eleventh word of the ſecond ſeries, combined with the firſt of the firſt ſeries, marks the eleventh year of the cycle; and the twelfth or laſt of the ſecond ſeries, joined with the ſecond of the firſt ſeries, ſerves for denoting the twelfth year. The third of the firſt ſeries becomes united in regular progreſſion with the firſt of the ſecond ſeries, to mark the thirteenth year; and proceeding by this rule, the firſt character in the firſt and in the ſecond ſeries cannot come again together for ſixty years, or until the firſt year of the ſecond cycle. The Chriſtian year 1797 anſwers to the 54th year of the 60th Chineſe cycle, which aſcertains its commencement to have been 2277 years before the birth of Chriſt; unleſs it be ſuppoſed that the official records and public annals of the empire, which bear teſtimony to it, ſhould all be falſified, and that the cycle when firſt eſtabliſhed ſhould have been antidated; which is indeed as little probable as that the period, for example, of the Olympiads ſhould be aſſerted to have commenced many ages prior to the firſt Olympic games."

This is a very poſitive deciſion againſt the opinion of a man whoſe talents and knowledge of oriental learning were ſuch as to give to his opinions on ſuch ſubjects the greateſt weight. If the ſtatements and reaſonings of Sir George Staunton be accurate, the Chineſe empire muſt have ſubſiſted at leaſt 3000 years before the Chriſtian era; for he ſays expreſsly, that *many ages* muſt have elapſed before the commencement of that cycle, which, according to him, commenced 2277 years before the birth of Chriſt. But ſurely Confucius was as well acquainted with the ancient annals of his own country, and the credibility which is due to them, as any man of the preſent age, whether Chineſe or European; and we have ſeen, that he conſidered none of them as authentic which relate events previous to the 11th century before our era. Even this is by much too early a period at which to rely upon them with implicit confidence, if it be true, as Sir George informs us, that the tranſactions of the empire have been regularly recorded only from about *three* centuries before the birth of Chriſt. With reſpect to the cycle, there is every probability that it was derived from India, where we know that aſtronomy has been cultivated as a ſcience from time immemorial, and where, we have ſhewn in another place, that the commencement of the cycle was actually antedated (ſee PHILOSOPHY, n° 9. *Encycl.*) We have therefore no heſitation in preferring Sir William Jones's opinion of the origin of the Chineſe empire to Sir George Staunton's; not merely becauſe we believe the

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the former of theſe gentlemen to have been more converſant than the latter with Chineſe literature, but becauſe we think his reaſoning more conſiſtent with itſelf, and his concluſion more conſonant to that outline of chronology, which, as he obſerves, has been ſo correctly traced for the laſt 2000 years, that we muſt be hardy ſceptics to call it in queſtion.

There is another point very nearly related indeed to this, about which theſe two learned men likewiſe differ. Sir George Staunton informs us, that "no accounts of a general deluge are mentioned in Chineſe hiſtory." Sir William Jones, on the other hand, in the diſcourſe already quoted, ſays, "I may aſſure you, after full inquiry and conſideration, that the Chineſe, like the Hindoos, believe this earth to have been wholly covered with water, which, in works of undiſputed authenticity, they deſcribe as *flowing abundantly, then ſubſiding, and ſeparating the higher from the lower age of mankind.*" To which of theſe authors ſhall we give credit? The high antiquity which Sir George Staunton aſſigns to the Chineſe empire, rendered it neceſſary for the perſons from whom he drew his information to get quit by any means of an univerſal deluge. The ſyſtem of Sir William Jones left him at liberty to admit or reject that event according to evidence; and in addition to the authentic records to which he appeals, he quotes a mythological fable of the Chineſe, and another of the Hindoos, which, though he lays not upon them any great ſtreſs, appear to us, when compared together, not only to corroborate his opinion reſpecting the deſcent of the Chineſe, but likewiſe to ſhew that both they and the Hindoos have preſerved a traditionary account of the deluge very ſimilar to that which is given by Moſes. The Chineſe fable is this: "The mother of FO-HI was the *daughter of Heaven*, ſurnamed *Flower-loving*; and as the nymph was walking alone on the brink of a river with a ſimilar name, ſhe found herſelf on a ſudden encircled with a *rainbow*; ſoon after which ſhe became pregnant, and at the end of twelve years was delivered of a ſon, radiant as herſelf, who, among other titles, had that of *Sui*, or *the Star of the Year*." In the mythological ſyſtem of the Hindoos, "the nymph ROHINI, who preſides over the fourth lunar manſion, was the favourite miſtreſs of SOMA or the Moon, among whoſe numerous epithets we find *Cumudanáyaca*, or delighting in a ſpecies of *water-flower* that bloſſoms at night. The offspring of ROHINI and SOMA was BUDHA, regent of a planet; and he married ILA, whoſe father was preſerved in a MIRACULOUS ARK from an univerſal deluge." The learned preſident ſhews, that, according to the Brahams, the Chineſe deſcended from BUDA; and he mentions a divine perſonage connected with the Chineſe account of the birth of FO-HI, whoſe name was NIU-VA. But if all theſe circumſtances be laid together, it will appear, we think, pretty evident, that the two ancient nations have preſerved the ſame tradition of an univerſal deluge, and that the Chineſe RAINBOW and NIU-VA, with the Indian ARK, point to the flood of NOAH.

To Sir William Jones's derivation of the Chineſe from the Hindoos, the ſtate of their written language may occur as an objection; for ſince it is certain that alphabetical characters were in uſe among the Hindoos before the period at which he places the emigration of the *Chinas*, how, it may be aſked, came theſe people to drop the mode of writing practiſed by their anceſtors, and to adopt another ſo very inconvenient as that which the Chineſe have uſed from the foundation of their empire? The force of this objection, however, will vaniſh, when it is remembered that the *Chinas* were of the military caſt; that they had gradually abandoned the ordinances of the Veda, and were in conſequence degraded; and that they rambled from their native country in ſmall bodies. We do not know that the military caſt among the Hindoos was ever much devoted to letters; there is the greateſt reaſon to believe that a degraded caſt would neglect them; and it is certain that ſmall bodies of men, wandering in deſerts, would have their time and their attention completely occupied in providing for the day that was paſſing over them. That the *Chinas* ſhould have forgotten the alphabetical characters of the Hindoos, is therefore ſo far from being an objection to Sir William Jones's account of their deſcent from that people, that it is the natural conſequence of the manner in which he ſays they rambled from Hindoſtan to the northern provinces of what now conſtitutes the Chineſe empire.

Of the origin of the characters which are uſed by this ſingular people, the illuſtrious preſident of the Aſiatic Society gives the following account from a Chineſe writer named LI YANG PING. "The earlieſt of them were nothing more than the outlines of viſible objects, earthly and celeſtial; but as things merely intellectual could not be expreſſed by thoſe figures, the grammarians of *China* contrived to repreſent the various operations of the mind by metaphors drawn from the productions of nature. Thus the idea of roughneſs and of rotundity, of motion and reſt, were conveyed to the eye by ſigns repreſenting a mountain, the ſky, a river, and the earth. The figures of the ſun, the moon, and the ſtars, differently combined, ſtood for ſmoothneſs and ſplendour, for any thing artfully wrought, or woven with delicate workmanſhip. Extenſion, growth, increaſe, and many other qualities, were painted in characters taken from the clouds, from the firmament, and from the vegetable part of the creation. The different ways of moving, agility and ſlowneſs, idleneſs and diligence, were expreſſed by various inſects, birds, fiſhes, and quadrupeds. In this manner paſſions and ſentiments were traced by the pencil, and ideas not ſubject to any ſenſe were exhibited to the ſight; until by degrees new combinations were invented, new expreſſions added, the characters deviated imperceptibly from their primitive ſhape, and the Chineſe language became not only clear and forcible, but rich and elegant in the higheſt degree *."

Of this language, both as it is ſpoken and written, Sir George Staunton has given an account ſo clear and ſcientific, that it will undoubtedly place him high among the moſt eminent philologiſts of the 18th century. As there is nothing relating to the Chineſe more wonderful than their language, which is very little underſtood in Europe, we ſhall lay before our readers a pretty copious abſtract of what he ſays on the ſubject, referring them for further information to his account of Lord Macartney's Embaſſy to China.

"In the Chineſe tongue (ſays Sir George) the ſounds of ſeveral letters in moſt alphabets are utterly unknown, and the organs of a native advanced in life cannot pronounce them. In endeavouring to utter the

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* *Aſiatic Reſearches*, vol ii. Memoir 13.

ſounds of B, D, R, and X, for inſtance, he ſubſtitutes ſome other ſounds to which the ſame organ has been accuſtomed; L for R, and, as we have reaſon to think from ſome expreſſions of Sir William Jones's, F for B. The nice diſtinctions between the tones and accents of words nearly reſembling each other in ſound, but varying much in ſenſe, require a nicety of ear to diſtinguiſh, and of vocal powers to render them exactly. Synonymous words are therefore frequently introduced in Chineſe dialogue to prevent any doubt about the intended ſenſe; and if in an intricate diſcuſſion any uncertainty ſhould ſtill remain as to the meaning of a particular expreſſion, recourſe is had to the ultimate criterion of tracing with the finger in the air, or otherwiſe, the form of the character, and thus aſcertaining at once which was meant to be expreſſed. In a Chineſe ſentence there is no marked diſtinction of ſubſtantives, adjectives, or verbs; nor any accordance of gender, number, and caſe. A very few particles denote the paſt, the preſent, and the future; nor are thoſe auxiliaries employed when the intended time may be otherwiſe inferred with certainty. A Chineſe who means to declare his intention of departing to-morrow, never ſays that he *will* depart to-morrow; becauſe the expreſſion of the morrow is ſufficient to aſcertain that his departure muſt be future. The plural number is marked by the addition of a word, without which the ſingular always is implied. Neither the memory nor the organs of ſpeech are burthened with the pronunciation of more ſounds to expreſs ideas than are abſolutely neceſſary to mark their difference. The language is entirely monoſyllabic. A ſingle ſyllable always expreſſes a complete idea. Each ſyllable may be ſounded by an European conſonant preceding a vowel, ſometimes followed by a liquid. Such an order of words prevents the harſhneſs of ſucceeding conſonants ſounding ill together; and renders the language as ſoft and harmonious as the Italian is felt to be, from the rarity of conſonants, and the frequency of its vowel terminations.

"The names or ſounds, by which men may be firſt ſuppoſed to have diſtinguiſhed other animals, when occaſion offered to deſignate them in their abſence, were attempts at an imitation of the ſounds peculiar to thoſe beings; and ſtill, in Chineſe, the name, for example, of a cat, is a pretty near reſemblance of its uſual cry. It occurred as naturally to endeavour, in ſpeaking, to imitate the voice, if practicable, as it was in writing to ſketch a rude figure of the object of deſcription. It is obſervable, that the radical words of moſt languages, ſeparated from the ſervile letters which mark their inflections, according to their conjugations or declenſions, are monoſyllabic. A part of each radical word is retained in compoſition to denote the meaning and etymology of the compound, which thus becomes polyſyllabic; but the Chineſe grammarians, aware of the inconvenience reſulting from the length and complication of ſounds, confined all their words, however ſignificant of combined ideas, to ſingle ſounds; and retained only in writing, ſome part at leaſt of the form of each character denoting a ſimple idea, in the compound characters conveying complex ideas."

This is a very plauſible, and perhaps the true, account of the monoſyllabic form of the Chineſe language; but it is proper to ſtate the different account which is given of this peculiarity by Sir William Jones. "It has ariſen, according to him, from the ſingular habits of the people; for though their common tongue be ſo *muſically* accented as to form a kind of recitative, yet it wants thoſe *grammatical* accents without which all human tongues would appear monoſyllabic. Thus *Amita*, with an accent on the firſt ſyllable, means, in the *Sanſcrit* language, *immeaſurable*, and the natives of Bengal pronounce it *Omito;* but when the religion of BUDDHA, the ſon of Máyá, was carried into *China*, the people of that country, unable to pronounce the name of their new god, called him FOE, the ſon of MO-YE.; and divided his epithet *Amita* into three ſyllables O-MI-TO, annexing to them certain ideas of their own, and expreſſing them in writing by three diſtinct ſymbols. Hence it is that they have clipped their language into monoſyllables, even when the ideas expreſſed by them, and the written ſymbols for thoſe ideas, are very complex."

"In the Chineſe language Sir George Staunton informs us, that there is a certain order, or ſettled ſyntax, in the ſucceſſion of words in the ſame ſentence; a ſucceſſion fixed by cuſtom, differently in different languages, but founded on no rule or natural order of ideas, as has been ſometimes ſuppoſed; for though a ſentence conſiſts of ſeveral ideas, to be rendered by ſeveral words, theſe ideas all exiſt and are connected together in the ſame inſtant; forming a picture or image, every part of which is conceived at once. The formation of Chineſe ſentences is often the ſimpleſt and moſt artleſs poſſible, and ſuch as may naturally have occurred at the origin of ſociety. To interrogate, for example, is often at leaſt to require the ſolution of a queſtion, whether the ſubject of doubt be in a particular way or the contrary; and accordingly a Chineſe inquiring about his friends health, will ſometimes ſay, *hou, poo hou?* The literal meaning of which words is, "well, not well?" A ſimple character repeated ſtands ſometimes for more than one of the objects which ſingly it denotes, and ſometimes for a collective quantity of the ſame thing. The character of *moo* ſingly is a tree, repeated is a thicket, and tripled is a foreſt.

"In Chineſe there are ſcarcely fifteen hundred diſtinct ſounds. In the written language there are at leaſt eighty thouſand characters or different forms of letters, which number divided by the firſt gives nearly fifty ſenſes or characters upon an average to every ſound expreſſed; a diſproportion, however, that gives more the appearance than the reality of equivocation and uncertainty to the oral language of the Chineſe.

"The characters of the Chineſe language were originally traced, in moſt inſtances, with a view to expreſs either real images, or the allegorical ſigns of ideas: a circle, for example, for the ſun, and a creſcent for the moon. A man was repreſented by an erect figure, with lines to mark the extremities. It was evident that the difficulty and tediouſneſs of imitation will have occaſioned ſoon a change to traits more ſimple and more quickly traced. Of the entire figure of a man, little more than the lower extremities only continue to be drawn, by two lines forming an angle with each other. A faint reſemblance, in ſome few inſtances, ſtill remains of the original forms in the preſent hieroglyphic characters; and the gradation of their changes is traced in ſeveral Chineſe books. Not above half a dozen of the preſent characters conſiſt each of a ſingle line; but moſt of of them conſiſt of many, and a few of ſo many as ſeventy different ſtrokes. The form of thoſe characters has not been ſo flux as the ſound of words, as appears in the inſtance of almoſt all the countries bordering on the Chineſe Sea or Eaſtern Aſia, where the Chineſe written, but not the oral language, is underſtood; in like manner, as one form of Arabic figures to denote numbers, and one ſet of notes for muſic, are uniform and intelligible throughout Europe, notwithſtanding the variety of its languages.

“ A certain order or connection is to be perceived in the arrangement of the written characters of the Chineſe; as if it had been formed originally upon a ſyſtem to take place at once, and not grown up, as other languages, by ſlow and diſtant intervals. Upwards of two hundred characters, generally conſiſting each of a few lines or ſtrokes, are made to mark the principal objects of nature, ſomewhat in the manner of Biſhop Wilkin's diviſions, in his ingenious book on the ſubject of univerſal language, or real character. Theſe may be conſidered as the genera or roots of language, in which every other word or ſpecies, in a ſyſtematic ſenſe, is referred to its proper genus. The heart is a genus, of which the repreſentation of a curve line approaches ſomewhat to the form of the object; and the ſpecies referable to it include all the ſentiments, paſſions, and affections, that agitate the human breaſt. Each ſpecies is accompanied by ſome mark denoting the genus or heart. Under the genus *hand* are arranged moſt trades and manual exerciſes. Under the genus *word* every ſort of ſpeech, ſtudy, writing, underſtanding, and debate. A horizontal line marks a unit; croſſed by another line it ſtands for ten, as it does in every nation which repeats the units after that number. The five elements, of which the Chineſe ſuppoſe all bodies in nature to be compounded, form ſo many genera, each of which comprehends a great number of ſpecies under it. As in every compound character or ſpecies, the abridged mark of the genus is diſcernible by a ſtudent of that language, in a little time he is enabled to conſult the Chineſe dictionary, in which the compound characters or ſpecies are arranged under their proper genera. The characters of theſe genera are placed at the beginning of the dictionary, in an order which, like that of the alphabet, is invariable, and ſoon becomes familiar to the learner. The ſpecies under each genus follow each other, according to the number of ſtrokes of which each conſiſts, independently of the one or few which ſerve to point out the genus. The ſpecies wanted is thus ſoon found out. Its meaning and pronunciation are given through other words in common uſe; the firſt of which denotes its ſignification and the other its ſound. When no one common word is found to render exactly the ſame ſound, it is communicated by two words with marks, to inform the inquirer that the conſonant of the firſt word and the vowel of the ſecond joined together form the preciſe ſound wanted.

“ The compoſition of many of the Chineſe characters often diſplays conſiderable ingenuity, and ſerves alſo to give an inſight into the opinions and manners of the people. The character expreſſive of happineſs includes abridged marks of land, the ſource of their phyſical, and of children that of their moral, enjoyments. This character, embelliſhed in a variety of ways, is hung up almoſt in every houſe. Sometimes written by the hand of the emperor, it is ſent by him as a compliment, which is very highly prized, and ſuch as he was pleaſed to ſend to the embaſſador.

“ Upon the formation, changes, and alluſions of compound characters, the Chineſe have publiſhed many thouſand volumes of philological learning. Nowhere does criticiſm more abound, or is more ſtrict. The introduction or alteration of a character is a ſerious undertaking, and ſeldom fails to meet with oppoſition. The moſt ancient writings of the Chineſe are ſtill claſſical amongſt them. The language ſeems in no inſtance to have been derived from or mixed with any other. The written ſeems to have followed the oral language ſoon after the men who ſpoke it were formed into a regular ſociety. Though it is likely that all hieroglyphical languages were originally founded on the principles of imitation, yet in the gradual progreſs towards arbitrary forms and ſounds, it is probable that every ſociety deviated from the originals in a different manner from the others; and thus for every independent ſociety there aroſe a ſeparate hieroglyphic language. As ſoon as a communication took place between any two of them, each would hear names and ſounds not common to both; each reciprocally would mark down ſuch names in the ſounds of its own characters, bearing, as hieroglyphics, a different ſenſe. In that inſtance, conſequently, thoſe characters ceaſe to be hieroglyphics, and were merely marks of ſound. If the foreign ſounds could not be expreſſed but by the uſe of a part of two hieroglyphics, in the manner mentioned to be uſed ſometimes in Chineſe dictionaries, the two marks joined together become in fact a ſyllable. If a frequent intercourſe ſhould take place between communities ſpeaking different languages, the neceſſity of uſing hieroglyphics merely as marks of ſound would frequently recur. The practice would lead imperceptibly to the diſcovery that, with a few hieroglyphics, every ſound of the foreign language might be expreſſed; and the hieroglyphics which anſwered beſt this purpoſe, either as to exactneſs of ſound or ſimplicity of form, would be ſelected for this particular uſe; and ſerving as ſo many letters, would form in fact together what is called an alphabet. Thus, the paſſage from hieroglyphic to alphabetic writing may naturally be traced, without the neceſſity of having ‘ recourſe to divine inſtruction, as ſome learned men have conjectured, on the ground that the art of writing by an alphabet is too refined and artificial for untutored reaſon.’

“ The Chineſe printed character is the ſame as is uſed in moſt manuſcripts, and is chiefly formed of ſtraight lines in angular poſitions, as moſt letters are in Eaſtern tongues, eſpecially the Sanſcrit; the characters of which, in ſome inſtances, admit of additions to their original form, producing a modification of the ſenſe. A running hand is uſed by the Chineſe only on trivial occaſions, or for private notes, or for the eaſe and expedition of the writer; and differs from the other as much as an European manuſcript does from print. There are books with alternate columns of both kinds of writing for their mutual explanation to a learner.

“ The principal difficulty in the ſtudy of Chineſe writings ariſes from the general excluſion of the auxiliary particles of colloquial language, that fix the relation between indeclinable words, ſuch as are all thoſe of the Chineſe language. The judgment muſt be conſtantly exerciſed.

exerciſed by the ſtudent, to ſupply the abſence of ſuch aſſiſtance. That judgment muſt be guided by attention to the manners, cuſtoms, laws, and opinions of the Chineſe, and to the events and local circumſtances of the country, to which the alluſions of language perpetually refer. If it in general be true, that a language is difficult to be underſtood in proportion to the diſtance of the country where it is ſpoken, and that of him who endeavours to acquire it, becauſe in that proportion the alluſions to which language has continually recourſe are leſs known to the learner, ſome idea may be conceived of the obſtacles which an European may expect to meet in reading Chineſe, not only from the remoteneſs of ſituation, but from the difference between him and the native of China in all other reſpects. The Chineſe characters are in fact ſketches or abridged figures, and a ſentence is often a ſtring of metaphors. The different relations of life are not marked by arbitrary ſounds, ſimply conveying the idea of ſuch connection; but the qualities naturally expected to ariſe out of ſuch relations become frequently the name by which they are reſpectively known. Kindred, for example, of every degree is thus diſtinguiſhed with a minuteneſs unknown in other languages. That of China has diſtinct characters for every modification known by them of objects in the phyſical and intellectual world. Abſtract terms are no otherwiſe expreſſed by the Chineſe than by applying to each the name of the moſt prominent objects to which it might be applied, which is likewiſe indeed generally the caſe of other languages. Among the Latins the abſtract idea of virtue, for example, was expreſſed under the name of valour or ſtrength (*virtus*), being the quality moſt eſteemed among them, as filial piety is conſidered to be in China. The words of an alphabetic language being formed of different combinations of letters or elemental parts, each with a diſtinct ſound and name, whoever knows and combines theſe together, may read the words without the leaſt knowledge of their meaning; not ſo hieroglyphic language, in which each character has indeed a ſound annexed to it, but which bears no certain relation to the unnamed lines or ſtrokes of which it is compoſed. Such character is ſtudied and beſt learned by becoming acquainted with the idea attached to it; and a dictionary of hieroglyphics is leſs a vocabulary of the terms of one language with the correſpondent terms in another, than an encyclopædia containing explanations of the ideas themſelves repreſented by ſuch hieroglyphics. In ſuch ſenſe only can the acquiſition of Chineſe words be juſtly ſaid to engroſs moſt of the time of men of learning among them. The knowledge of the ſciences of the Chineſe, however imperfect, and of their moſt extenſive literature, is certainly ſufficient to occupy the life of man. Enough, however, of the language is imperceptibly acquired by every native, and may, with diligence, be acquired by foreigners for the ordinary concerns of life; and further improvements muſt depend on capacity and opportunity."

Next to the ſingular ſtructure of the oral and written language of the Chineſe, there is perhaps nothing in their hiſtory more ſurpriſing to a native of Europe than the number of the people, and the means by which they contrive to procure ſubſiſtence, without foreign trade, in a country ſo crouded, and at the ſame time not everywhere of a fertile ſoil. In the Encyclopædia, the population of this vaſt empire is ſtated, from M. Groſier, at 200 millions: but great as this is, when compared with the population of every other extenſive country, it appears to be far ſhort of the truth. Sir George Staunton has publiſhed a ſtatement, taken from one of the public offices in the capital, and given by a great and reſpectable manderin to Lord Macartney, in which it is ſhewn that China Proper contains not fewer than 333 millions of inhabitants. As the extent of the country is 1,297,999 ſquare miles, there are of courſe very near 260 inhabitants to every ſquare mile; and of theſe miles a very conſiderable proportion conſiſts of nothing but barren rocks. That this account is accurate there can be little doubt; for the extent of the provinces was aſcertained by aſtronomical obſervations, as well as by admeaſurement; and the number of individuals is regularly taken in each diviſion of a diſtrict by a tythingman, or every tenth maſter of a family. Theſe returns are collected by officers reſident ſo near as to be capable of correcting any groſs miſtake, and are all lodged in the great regiſter of Pekin.

For this exceſſive population our author ſatisfactorily accounts. Celibacy, ſays he, is rare in China, even in the military profeſſion; the marriages are prolific as well as early, and the influence of the patriarchal ſyſtem, to be explained afterwards, is ſuch, that a man's children adds to his wealth. It is reckoned a diſcredit to be without offspring; and they who have none adopt others, who become theirs excluſively. In caſe of marriage, ſhould a wife prove barren, a ſecond may be eſpouſed in the lifetime of the firſt. The opulent, as in moſt parts of the Eaſt, are allowed, without reproach, to keep concubines, of whom the children are conſidered as being thoſe of the legitimate wife, and partake in all the rights of legitimacy. "Accidents ſometimes of extraordinary drought, and ſometimes of exceſſive inundations, occaſionally produce famine in particular provinces, and famine diſeaſe; but there are few drains from moral cauſes either of emigration or foreign navigation. The number of manufactures, whoſe occupations are not always favourable to health, whoſe conſtant confinement to particular ſpots, and ſometimes in a cloſe or tainted atmoſphere, muſt be injurious, and whoſe reſidence in towns expoſes them to irregularities, bears but a very ſmall proportion to that of huſbandmen in China. In general there ſeems to be no other bounds to Chineſe populouſneſs than thoſe which the neceſſity of ſubſiſtence may put to it. Theſe boundaries are certainly more enlarged than in other countries. The whole ſurface of the empire is, with trifling exceptions, dedicated to the production of food for man alone. There is no meadow, and very little paſture; nor are fields cultivated in oats, beans, or turnips, for the ſupport of cattle of any kind. Few parks or pleaſure grounds are ſeen, excepting thoſe belonging to the emperor. Little land is taken up for roads, which are few and narrow, the chief communication being by water. There are no commons, or lands ſuffered to lie waſte by the neglect, or the caprice, or for the ſport of great proprietors. No arable land lies fallow. The ſoil, under a hot and fertilizing ſun, yields annually, in moſt inſtances, double crops, in conſequence of adapting the culture to the ſoil, and of ſupplying its defects by mixture with other earths, by manure, by irrigation, by careful and judicious induſtry of every kind. The labour of man is little diverted from that induſtry to to miniſter to the luxuries of the opulent and powerful, or in employments of no real uſe. Even the ſoldiers of the Chineſe army, except during the ſhort intervals of the guards which they are called to mount, or the exerciſes, or other occaſional ſervices which they perform, are moſtly employed in agriculture. The quantity of ſubſiſtence is increaſed alſo, by converting more ſpecies of animals and vegetables to that purpoſe than is uſual in other countries. And even in the preparation of their food the Chineſe have economy and management."

The government of China is deſpotic; and it is a curious ſpectacle to behold ſo large a proportion of the whole human race, connected together in one great ſyſtem of polity, ſubmitting quietly, and through ſo conſiderable an extent of country, to one great ſovereign; and uniform in their laws, their manners, and their language, but differing eſſentially in each of theſe reſpects from every other portion of mankind: and neither deſirous of communicating with nor forming any deſigns againſt the reſt of the world. To produce ſuch a phenomenon, many cauſes muſt be combined; but perhaps the principal are to be found in the patriarchal ſyſtem already mentioned, in the laws and cuſtoms of the empire, and in the belief that the emperor is the vicegerent of heaven, and guided in all his actions by divine inſpiration.

The patriarchal ſyſtem is founded upon that filial piety which the philoſophers of China have uniformly repreſented as the greateſt of human virtues. Theſe ſages, while they ſucceſsfully inculcated this duty, have left parental affection to its own natural influence; and hence in China parents are leſs frequently neglected than infants are expoſed. The laws of the empire, to corroborate the diſpoſition to filial obedience, furniſh an opportunity for puniſhing any breach of it, by leaving a man's offspring entirely within his own power: and hence it is, that with the poor, marriage, as we have ſaid, is a meaſure of prudence; becauſe the children, particularly the ſons, are bound to maintain their parents.

A Chineſe dwelling is generally ſurrounded by a wall ſix or ſeven feet high. Within this incloſure a whole family, of three generations, with all their reſpective wives and children, will frequently be found. One ſmall room is made to ſerve for the individuals of each branch of the family, ſleeping in different beds, divided only by mats hanging from the ceiling. One common room is uſed for eating.

The prevalence of this cuſtom, of retaining the ſeveral branches of a family under the ſame roof, is attended with important effects. It renders the younger temperate and orderly in their conduct under the authority and example of the older; and it enables the whole to ſubſiſt, like ſoldiers in a meſs, with more economy and advantage. As the venerable patriarch of each habitation preſides over his deſcendants with the authority of a magiſtrate; ſo the different orders of magiſtrates are, in their different diſtricts and provinces, looked up to with the veneration due from children to their parents, while the emperor is revered as the grand patriarch of the whole empire.

Another thing which contributes much to the permanency of the government and the internal quiet of the empire is, that in China there is leſs inequality in the fortunes than in the conditions of men. The ancient annals of the empire teſtify, that for a long period of time, the earth, like the other elements of nature, was enjoyed by its inhabitants almoſt in common. Their country was divided into ſmall equal diſtricts; every diſtrict was cultivated conjointly by eight labouring families, which compoſed each hamlet; and they enjoyed all the profit of their labours, except a certain ſhare of the produce reſerved for public expences. It is true, indeed, that after a revolution, deplored in all the Chineſe hiſtories, which happened prior to the Chriſtian era, the uſurper granted all the lands away to the partners of his victories, leaving to the cultivators of the ſoil a ſmall pittance only out of the revenue which it yielded. Property in land alſo became hereditary: but in proceſs of time, the moſt conſiderable domains were ſubdivided into very moderate parcels by the ſucceſſive diſtribution of the poſſeſſions of every father equally among all his ſons; the daughters being always married without dower. It very rarely happened that there was but an only ſon to enjoy the whole property of his deceaſed parents; and it could ſcarcely be increaſed by collateral ſucceſſion.

From the operations of all thoſe cauſes, there was a conſtant tendency to level wealth; and few could ſucceed to ſuch an accumulation of it as to render them independent of any efforts of their own for its increaſe. Beſides, wealth alone confers in China but little importance, and no power; nor is property, without office, always perfectly ſecure. There is no hereditary dignity, which might accompany, and give it pre-eminence and weight. The delegated authority of government often leans more heavily on the unprotected rich than on the poor, who are leſs objects of temptation. And it is a common remark among the Chineſe, that fortunes, either by being parcelled out to many heirs, or by being loſt in commercial ſpeculations, gaming, or extravagance, or extorted by oppreſſive mandarines, ſeldom continue to be conſiderable in the individuals of the ſame family beyond the third generation. To aſcend again the ladder of ambition, it is neceſſary, by long and laborious ſtudy, to excel in the learning of the country, which alone qualifies for public employments.

There are properly but three claſſes of men in China: men of letters, from whom the mandarines are taken; cultivators of the ground; and mechanics, including merchants. In Pekin alone is conferred the higheſt degree of literature upon thoſe who, in public examinations, are found moſt able in the ſciences of morality and government as taught in the ancient Chineſe writers; with which ſtudies the hiſtory of their country is intimately blended. Among ſuch graduates all the civil offices in the ſtate are diſtributed by the emperor; and they compoſe all the great tribunals of the empire. The candidates for thoſe degrees are ſuch as have ſucceeded in ſimilar examinations in the principal city of each province. Thoſe who have been choſen in the cities of the ſecond order, or chief town of every diſtrict in the province, are the candidates in the provincial capital. They who fail in the firſt and ſecond claſſes have ſtill a claim on ſubordinate offices, proportioned to the claſs in which they had ſucceeded. Thoſe examinations are carried on with great ſolemnity, and apparent fairneſs. Military rank is likewiſe given to thoſe who are found upon competition to excel in the military art, and in warlike exerciſes. This diſtribution of offices contributes greatly to the peace of the empire; for the people cheerfully ſubmit to the authority of thoſe whom they believe to be placed over them by merit alone, and love that conſtitution which brings within the reach of the meaneſt ſubject, who has talents and induſtry, the higheſt ſtation next to the ſupreme.

“The great tribunals are ſituated, for the ſake of convenience, near the ſouthern gate of the imperial palace at Pekin. To them accounts of all the tranſactions of the empire are regularly tranſmitted. They are councils of reference from the emperor, to whom they report every buſineſs of moment, with the motives for the advice which they offer on the occaſion. There is a body of doctrine compoſed from the writings of the earlieſt ages of the empire, confirmed by ſubſequent lawgivers and ſovereigns, and tranſmitted from age to age with increaſing veneration, which ſerves as rules to guide the judgment of thoſe tribunals. This doctrine ſeems, indeed, founded on the broadeſt baſis of univerſal juſtice, and on the pureſt principles of humanity.

“His imperial majeſty generally conforms to the ſuggeſtions of thoſe tribunals. One tribunal is directed to conſider the qualifications of the different mandarines for different offices, and to propoſe their removal when found incapable or unjuſt. One has for object the preſervation of the manners or morals of the empire, called by Europeans *the tribunal of ceremonies*, which it regulates on the maxim; that exterior forms contribute not a little to prevent the breach of moral rules. The moſt arduous and critical is the tribunal of cenſors; taking into its conſideration the effect of ſubſiſting laws, the conduct of the other tribunals, of the princes and great officers of ſtate, and even of the emperor himſelf. There are ſeveral ſubordinate tribunals; ſuch as thoſe of mathematics, of medicine, of public works, of literature and hiſtory. The whole is a regular and conſiſtent ſyſtem, eſtabliſhed at a very early period, continued with little alterations through every dynaſty, and revived after any interruption from the caprice or paſſions of particular princes. Whatever deviation has been made by the preſent family on the throne, ariſes from the admiſſion of as many Tartars as Chineſe into every tribunal.” The opinions of the former are ſuppoſed always to preponderate; and many of them are indeed men of conſiderable talents and ſtrength of mind, as well as poliſhed manners. They are, however, in general, fitter for military than civil offices. The hardy education, the rough manners, the active ſpirit, the wandering diſpoſition, the looſe principles, and the irregular conduct, of the Tartar, fit him better for the profeſſion, practice, and purſuits of war, than the calm, regulated, and domeſtic habits of the Chineſe. Warriors ſeem naturally the offspring of Tartary, as literati are of China; and accordingly, the principal military commands are conferred on natives of the former country, as, with many exceptions indeed, the chief civil offices are on thoſe of the latter.

A military mandarin, who was much with Lord Macartney, and was himſelf a diſtinguiſhed officer, aſſerted that, “including Tartars, the total of the army in the pay of China amounted to 1,000,000 infantry and 800,000 cavalry. From the obſervations made by the embaſſy in the courſe of their travels through the empire, of the garriſons in the cities of the ſeveral orders, and of the military poſts at ſmall diſtances from each other, there appeared nothing unlikely in the calculation of the infantry; but they met few cavalry. If the number mentioned really do exiſt, a great proportion of them muſt have been in Tartary, or on ſome ſervice diſtant from the route of the embaſſy.

“Of the troops, eſpecially cavalry, a vaſt number are Tartars, who have a higher pay than their Chineſe fellow-ſoldiers. The principal officers of confidence in the army are Tartars alſo. None of either nation are received into the ſervice but ſuch as are healthy, ſtrong, and ſightly. The pay and allowances of a Chineſe horſeman are three Chineſe ounces, heavier than European ounces, and three-tenths of an ounce, of ſilver, and fifteen meaſures or rations (the weight not mentioned) of rice every lunar month. A Tartar horſeman, ſeven ſimilar ounces of ſilver, and 20 meaſures of rice for the ſame period. A Chineſe foot ſoldier has one ounce and ſix-tenths of an ounce of ſilver, and ten meaſures of rice; and a Tartar of the ſame deſcription has two ounces of ſilver and ten meaſures of rice every lunar month. The Emperor furniſhes the arms, accoutrements, and the upper garment, to all the ſoldiers. Beſide their ordinary pay and allowances, they alſo receive donations from the Emperor on particular occaſions; as when they marry, and when they have male children born. On the death of their parents they obtain ‘a gift of conſolation;’ as do their families when the ſoldiers themſelves die.

“The public revenues of China Proper are ſaid to be little leſs than 200,000,000 of ounces of ſilver, which may be equal to about 66,000,000 of pounds ſterling; or about three times thoſe of France before the late ſubverſion. From the produce of the taxes all the civil and military expences, and the incidental and extraordinary charges, are firſt paid upon the ſpot out of the treaſuries of the reſpective provinces where ſuch expences are incurred; and the remainder is remitted to the Imperial treaſury at Pekin. This ſurplus amounted in the year 1792 to the ſum of 36,614,328 ounces of ſilver, or 12,204,776 pounds ſterling, according to an account taken in round numbers. In caſe of inſurrections, or other occurrences requiring extraordinary expences, they are generally levied by additional taxes on the provinces adjacent to the ſcene of action, or connected with the occaſion of the expence.

“In the adminiſtration of the vaſt revenue of the ſtate, the opportunities of committing abuſes are not often neglected; as may be inferred from the frequent confiſcation to the Emperor in conſequence of ſuch tranſgreſſions. It is indeed affirmed, that much corruption and oppreſſion prevail in moſt of the public departments, by which conſiderable fortunes are acquired, notwithſtanding the modicity of the public ſalaries.”

With ſuch a ſtanding army and ſo vaſt a revenue, it will no longer appear wonderful that one man ſhould govern with deſpotic ſway even the immenſe multitude of people who inhabit the empire of China, eſpecially trained up as thoſe people are in habits of filial ſubmiſſion to their ſuperiors. But there are ſome circumſtances in the ſyſtem of Chineſe policy, not yet mentioned, which contribute perhaps more than even theſe habits and that power to preſerve the ſtability of the government. The Emperor reſerves to himſelf alone the right of relieving the wants of the poor, produced by famine or any other unforeſeen calamity. On ſuch occaſions he always comes forward. He orders the public granaries to be opened; remits the taxes to thoſe who are viſited with misfortune; affords aſſiſtance to enable them to retrieve their affairs; and appears to his ſubjects as ſtanding almoſt in the place of Providence in their favour. He is perfectly aware by how much a ſtronger chain he thus maintains his abſolute dominion, than the mere dread of puniſhment would afford. The emperor, to whom the Britiſh embaſſy was ſent, ſhewed himſelf ſo jealous of retaining the excluſive privilege of benevolence to his ſubjects, that he not only rejected, but was offended at, a propoſal once made to him by ſome conſiderable merchants, to contribute towards the relief of a ſuffering province; whilſt he ſcrupled not, at the ſame time, to accept the donation of a rich widow towards the expences of a war in which he was engaged.

This veneration, excited towards the emperor by his apparent benevolence, is increaſed by an opinion zealouſly inſtilled into the people, that he has the faculty of predicting future events of the greateſt importance. The Chineſe, given up to the dotages of judicial aſtrology, are firmly perſuaded that eclipſes of the ſun and moon have a powerful influence on the operations of nature and the tranſactions of mankind; and the periods of their occurrence become, of courſe, objects of attention and ſolicitude. The government of the country, ever anxious to eſtabliſh its authority in the general opinion of its ſuperior wiſdom and conſtant care for the welfare of the people, employs the European miſſionaries at Pekin (for it is doubtful if any one of the natives has ſo much ſcience) to calculate eclipſes, and then announces them to the people with that ſolemnity which is fitted to enſure veneration for the ſuperintending power whence ſuch knowledge is immediately derived to them. Eclipſes of the ſun, in particular, are conſidered as omenous of ſome general calamity; and as great pains are taken to inſpire them with a belief that their proſperity is owing to the wiſdom and virtues of their ſovereign, ſo they are tempted to attribute to ſome deficiency on his part whatever they think portentous. To this prejudice the emperor finds it prudent to accommodate his conduct. He never ventures on any undertaking of importance at the approach of a ſolar eclipſe, but affects to withdraw himſelf from the preſence of his courtiers, to examine ſtrictly into his late adminiſtration of the empire, in order to correct any error, for the commiſſion of which the eclipſe may have been an admonition. On theſe occaſions he invites his ſubjects to give him freely their advice: but it is plain that advice muſt be offered with great deference to a being for whoſe admonition the motions of the ſun and moon are believed to be regulated; and while ſuch notions are implicitly admitted, the perſon of the Chineſe emperor, as well as his authority, muſt be looked upon by his ſubjects as ſomething more than human. This is in fact the caſe. He is not only approached in perſon with teſtimonies of the utmoſt reſpect, but is adored when abſent with all the rites and ceremonies which are uſed by the Chineſe in the worſhip of their divinities. On his birth-day, at the new and full moon, and probably on other feſtivals, all the mandarines reſident in the neighbourhood of any of his numerous palaces aſſemble about noon, and repairing to the palace, ſolemnly proſtrate themſelves nine times before the throne, their foreheads ſtriking the floor each time; whilſt incenſe is burning on tripods on each ſide of it, and offerings are made, on an alter before it, of tea and fruits to the ſpirit of the abſent emperor. Over the throne are ſeen the Chineſe characters of glory and perfection; and the name of the Deity is given to the emperor, who is conſidered by his votaries as poſſeſſing in ſome ſenſe the attribute of ubiquity. Mr Barrow, one of the gentlemen of the embaſſy, was preſent at *Yuen-min-yuen*, one of the imperial palaces, when theſe idolatrous rites of adoration were performed; and he was aſſured that they took place on that day in all parts of the empire, the proſtraters being everywhere attentive to turn their faces towards the capital.

That he who claims adoration in his abſence does not appear on his birth-day to receive the compliments of his ſubjects, will not ſurpriſe the reader. The manner in which that feſtival is celebrated at the palace, where the emperor happens to be reſident, is thus deſcribed by Sir George Staunton, who witneſſed this more than auguſt ceremony at the palace of *Zhe-hal* in Tartary. "The princes, tributaries, ambaſſadors, great officers of ſtate, and principal mandarines, were aſſembled in a vaſt hall; and upon particular notice, were introduced into an inner building, bearing, at leaſt, the ſemblance of a temple. It was chiefly furniſhed with great inſtruments of muſic, among which were ſets of cylindrical bells, ſuſpended in a line from ornamented frames of wood, and gradually diminiſhing in ſize from one extremity to the other, and alſo triangular pieces of metal arranged in the ſame order as the bells. To the ſound of theſe inſtruments a ſlow and ſolemn hymn was ſung by eunuchs, who had ſuch a command of their voices as to reſemble the effect of the muſical glaſſes at a diſtance. The performers were directed, in gliding from one tone to another, by the ſtriking of a ſhrill and ſonorous cymbal; and the judges of muſic among the gentlemen of the embaſſy were much pleaſed with their execution. The whole had indeed a grand effect. During the performance, and at particular ſignals, nine times repeated, all the perſons proſtrated themſelves nine times, except the ambaſſador and his ſuit, who made a profound obeiſance (A). But he whom it was meant to honour, continued, as if it were in imitation of the Deity, inviſible the whole time."

That the awful impreſſion meant to be made upon

(A) The Chineſe court, which conſiders all other ſovereigns as ſubordinate to their own, exacts from foreign miniſters, as well as from natives of the empire, nine proſtrations upon their firſt introduction to the emperor. This demand was made, in the laſt century, of the Dutch, who inſtantly complied with it in hopes of obtaining in return ſome lucrative advantages; and the conſequence was, that their ambaſſador was treated with neglect, and diſmiſſed without promiſe of the ſmalleſt favour. It was likewiſe made of a Ruſſian ambaſſador in the preſent century; but he would not comply with it, until a regular agreement was made for its return, on a like occaſion, to his own ſovereign. Lord Macartney, who was repeatedly urged to go through the ſame abject ceremony, diſplayed ſuch firmneſs and addreſs, that after much evaſion it was at laſt announced to him, that his imperial majeſty would be ſatisfied with the ſame form of reſpectful obedience that the Engliſh are in the habit of paying to their own ſovereign; and upon theſe terms his lordſhip was introduced and graciouſly received.

the minds of men by this apparent worſhip of a fellow-mortal might not be too quickly effaced, all ſcenes of ſport and gaiety were poſtponed to the next day, when a variety of entertainments was exhibited in the preſence of the emperor, ſurrounded by his court and tributary princes.

Notwithſtanding the general veneration of the Chineſe for the perſon and government of their emperor, the mandarines aſſerted that a ſect had for ages ſubſiſted in the country, whoſe chief principles were founded on an antipathy to monarchy, and who nouriſhed hopes of at laſt ſubverting it. Their meetings were held in the utmoſt ſecrecy, and no man avowed any knowledge of them; but a ſort of inquiſition was ſaid to be eſtabliſhed in order to find them out, and they who were ſuſpected of ſuch ſentiments were cut off, or hunted out of ſociety. Should the French declaration of the rights of man, which, through the zeal of its authors, has been tranſlated into one of the languages of India, find its way into China (of which the court is ſaid to be much afraid), it would indeed be a powerful engine in the hands of this ſecret ſect to ſap the foundations of the ancient government. The minds of many of the Chineſe are far from ſatisfied with their condition, which lays both their perſons and their fortunes at the mercy of the mandarines. No private man in China is exempted from corporal puniſhment, which may be inſtantly inflicted on him at the nod of a magiſtrate; and when he has occaſion to ſpeak to a great mandarine, he is obliged, by the police of the country, to throw himſelf on his knees, and in that poſture to communicate his buſineſs. The mandarine himſelf, on the other hand, lies under the hardſhip of being frequently reſponſible for events which he could not controul. Upon the general principle that it is his duty to watch over the morals of the people, he is in many caſes conſidered as a criminal for not preventing crimes which he had not been able to prevent. The mandarines are thus aware of not being guaranteed by good conduct againſt diſgrace; and feeling the chagrin of inſecurity, many of them muſt doubtleſs be ripe for a revolt. Fear may keep them quiet during the reign of a ſovereign poſſeſſed of abilities and vigilance; but the maxims which regulate the imperial ſucceſſion are ſuch, that a firm confederacy could hardly fail at the death of an emperor to introduce great changes into the conſtitution. The throne of China is neither hereditary nor elective. The choice of a ſucceſſor is left entirely to the reigning prince, who may exclude, as has been inſtanced, even his own offspring and family. To prevent commotions and fraud, it is no uncommon practice for the emperor, during his lifetime, to declare his ſucceſſor; for when his ſucceſſion is ſettled by a written teſtament, the throne is not always filled by him for whom it was deſtined. The father of the emperor to whom the Britiſh embaſſy was ſent, is ſaid to have obtained poſſeſſion of the throne by ſuddenly entering the palace in the laſt moments of his predeceſſor, and ſubſtituting his own name in a teſtament intended for the exaltation of another.

To what has been ſaid in the Encyclopædia of the religion of the Chineſe, we have here very little to add. Various deities are worſhipped in the empire by very different rites and ceremonies; but there is in China no ſtate religion. None is paid, preferred, or encouraged by it. The emperor is of one faith; many of the mandarines of another; and the majority of the common people of a third, which is that of Fo. The men of letters venerate rather than adore Confucius; and meet to honour and celebrate his memory in halls of a ſimple but neat conſtruction. The numerous and lower claſſes of the people are leſs able than inclined to contribute much towards the erection of large and coſtly edifices for public worſhip: their attention is almoſt wholly engaged by their houſhold gods; for every houſe has its altar and its deities.

“ No people are, in fact, more ſuperſtitious than the common Chineſe. Beſide the habitual offices of devotion on the part of the prieſts and females, the temples are particularly frequented by the diſciples of Fo previouſly to any undertaken of importance; whether to marry, or go a journey, or conclude a bargain, or change ſituation, or for any other material event in life, it is neceſſary firſt to conſult the ſuperintendant deity. This is performed by various methods. Some place a parcel of conſecrated ſticks, differently marked and numbered, which the conſultant, kneeling before the altar, ſhakes in a hollow bamboo, until one of them falls on the ground; its mark is examined, and referred to a correſpondent mark in a book which the prieſt holds open, and ſometimes even it is written upon a ſheet of paper paſted upon the inſide of the temple. Polygonal pieces of wood are by others thrown into the air. Each ſide has its particular mark; the ſide that is uppermoſt when fallen on the floor is in like manner referred to its correſpondent mark in the book or ſheet of fate. If the firſt throw be favourable, the perſon who made it proſtrates himſelf in gratitude, and undertakes afterwards with confidence the buſineſs in agitation. But if the throw ſhould be adverſe, he tries a ſecond time, and the third throw determines, at any rate, the queſtion. In other reſpects, the people of the preſent day ſeem to pay little attention to their prieſts. The temples are, however, always open for ſuch as chooſe to conſult the decrees of heaven. They return thanks when the oracle proves propitious to their wiſhes. Yet they oftener caſt lots to know the iſſue of a projected enterpriſe than ſupplicate for its being favourable; and their worſhip conſiſts more in thankſgiving than in prayer.

“ The Chineſe are ſeldom ſaid to carry the objects to be obtained by their devotion beyond the benefits of this life. Yet the religion of Fo profeſſes the doctrine of the tranſmigration of ſouls, and promiſes happineſs to the people on conditions, which were no doubt originally intended to conſiſt in the performance of moral duties; but in lieu of which are too frequently ſubſtituted thoſe of contributions towards the erection or repair of temples, the maintenance of prieſts, and a ſtrict attention to particular obſervances. The neglect of theſe is announced as puniſhable by the ſouls of the defaulters paſſing into the bodies of the meaneſt animals, in whom the ſufferings are to be proportioned to the tranſgreſſions committed in the human form.”

Though the Chineſe artiſts are very ingenious as mere workmen, there is hardly any thing which deſerves the name of ſcience in the whole empire. So little is the ſtudy of mathematics cultivated, that there are few ſhopkeepers in China who can perform the ordinary operations of arithmetic; but caſt up their accounts by means of an inſtrument called *ſwanpan* (See

Swanpan, *Encycl.*). Though the compoſition of gunpowder was certainly known in China much earlier than in Europe, and though the Chineſe had employed it from the beginning in blaſting rocks, and in making a vaſt variety of fire-works; yet Sir George Staunton ſeems convinced, that they never thought of the invention of guns till they were taught by the Europeans to introduce them into their armies.

The ſtate of phyſic in this vaſt country is extremely low, being nowhere taught in public ſchools or colleges. "A young man who wiſhes to become a phyſician, has no other way of acquiring medical knowledge than by engaging himſelf to ſome practitioner as an apprentice. He has thus the opportunity of ſeeing his maſter's practice, of viſiting his patients with him, and of learning ſuch parts of his knowledge and ſecrets as the other chooſes to communicate to him. The emoluments of the profeſſion ſeldom exceed the ſkill of the practitioner. As many copper coin as ſcarcely are equal to ſixpence ſterling is ſaid to be the uſual fee among the people; and perhaps quadruple among the mandarines. Medicine is not divided in China into diſtinct branches as in moſt parts of Europe. The ſame perſon acts as phyſician, ſurgeon, and apothecary. The ſurgical part of the profeſſion is ſtill more backward than the others. Amputation, in caſes of compound fracture and gangrene, is utterly unknown; and death is the ſpeedy conſequence of ſuch accidents. The Chineſe method of inoculation, which was introduced into the empire about the beginning of the tenth century of our era, is as follows: When the diſeaſe breaks out in any diſtrict, the phyſicians of the place carefully collect a quantity of ripe matter from puſtules of the proper ſort; which being dried and pulveriſed, is cloſely ſhut up in a porcelain jar, ſo as to exclude from it the atmoſpheric air; and in this manner it will retain its properties for many years. When the patient has been duly prepared by medicines, generally of an aperient kind, and ſtrictly dieted for a ſhort time, a lucky day is choſen to ſprinkle a little of the variolus powder upon a ſmall piece of fine cotton wool, and to inſert it into the noſtrils of the patient.

"No male phyſician is allowed to attend a pregnant woman, and ſtill leſs to practiſe midwifery; in the indelicacy of which both ſexes ſeem to agree in China. There are books written on that art for the uſe of female practitioners, with drawings of the ſtate and poſition of the infant at different periods of geſtation; together with a variety of directions and preſcriptions for every ſuppoſed caſe that may take place: the whole mixed with a number of ſuperſtitious obſervances.

Many practitioners of phyſic take the advantage, as elſewhere, of the obſcurity in which that art is involved, and of the ignorance and credulity of the people, to gain money by the ſale of noſtrums and ſecrets of their own. They diſtribute hand bills, ſetting forth the efficacy of their medicines, with atteſted cures annexed to them. And there is one ſect which boldly arrogates to itſelf the poſſeſſion of a medical ſecret *not to die!* To thoſe who had all the enjoyments of this life, there remained unaccompliſhed no other wiſh than that of remaining for ever in it. And accordingly ſeveral ſovereigns of China have been known to cheriſh the idea of the poſſibility of ſuch a medicine. They had put themſelves, in full health, under the care of thoſe religious empirics, and took large draughts of the boaſted beverage of immortality. The compoſition did not conſiſt of merely harmleſs ingredients; but probably of ſuch extracts and proportions of the poppy, and of other ſubſtances and liquors, as occaſioning a temporary exaltation of the imagination, paſſed for an indication of its vivifying effects. Thus encouraged, they had recourſe to frequent repetitions of the doſe, which brought on quickly languor and debility of ſpirits: and the deluded patients often became victims to deceit and folly in the flower of their age.

"There are in China no profeſſors of the ſciences connected with medicine. The human body is never, unleſs privately, diſſected there. Books, indeed, with drawings of its internal ſtructure are ſometimes publiſhed; but theſe are extremely imperfect, and conſulted, perpaps, oftener to find out the name of the ſpirit under whoſe protection each particular part is placed, than for obſerving its form and ſituation.

"It is a matter of doubt, whether natural hiſtory, natural philoſophy, or chemiſtry, be, as ſciences, much more improved than anatomy in China. There are ſeveral treatiſes, indeed, on particular ſubjects in each. The Chineſe likewiſe poſſeſs a very voluminous Encyclopædia, containing many facts and obſervations relative to them; but from the few reſearches which the gentlemen of the embaſſy had leiſure or opportunity to make during their ſhort viſit to the country, they perceived no traces of any general ſyſtem or doctrine by which ſeparate facts or obſervations were connected and compared, or the common properties of bodies aſcertained by experiment; or where kindred arts were conducted on ſimilar views, or rules framed, or deductions drawn from analogy, or principles laid down to conſtitute a ſcience."

Of all people the Chineſe are perhaps the moſt eager in their curioſity about foreigners coming among them, and the moſt indifferent about the countries of ſuch foreigners. They have been always in the habit of confining their ideas to their own country, emphatically ſtyled *the middle kingdom*. No Chineſe ever thinks of quitting it, except a few of deſperate fortunes reſiding near the ſea-coaſt, or ſea-faring men, who form a claſs, in a great meaſure, apart from ſociety. Even foreign commodities conſumed in China remind them only of Canton, whence they received them, as if produced in it; and theſe commodities they conſider, perhaps properly, as of no real benefit to the empire. Regions out of Aſia are ſcarcely mentioned in their books, or noticed in their diſtorted maps; and the great body of the people would be little gratified with accounts of ſuch regions, which did not contain tales of wonders not performed at home, or of powers exerted beyond the ordinary boundaries of nature.

CHINESE pump. See Pump in this Supplement.

Chinese Weights are ſo very different in many reſpects from thoſe in uſe elſewhere, that it will at leaſt gratify the curioſity of our readers to take ſome notice of them in this Work. Of theſe weights Charles Coquebert has preſented a ſpecimen to the Philomathematical Society in Paris. They are made of copper, and bear a great reſemblance in form to the body of a violin. Like that inſtrument, they are rounded off at the extremities, and indented on the ſides to admit the fingers. The faces are flat and parallel, and have Chineſe characters

racters engraven on the upper ſurface. They advance in a regular decimal progreſſion, of which Coquebert has diſcovered four diſtinct ſeries, the units of which are in the proportion of 1, 10, 100, 1000. Inſtead of employing a combination of one, two, four, and eight units, or after the new ſyſtem of one, two, and five units, the Chineſe have a diſtinct weight for every intermediate number between one and ten. Thus they have weights of 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 20, 30, 40, 50, 60, 70, 80, 90, &c. Of courſe, thoſe weights which ſtand related to each other in the proportion of 6 to 7, 7 to 8, 8 to 9, 9 to 10, differ ſo little in ſize, that it would be impoſſible to diſtinguiſh them without the help of the characters which are engraven upon the face. This is confeſſedly a defect in the ſyſtem. Of the four different ſeries exhibited to the ſociety, the higheſt bears in China the name of *kin*, and is nearly of equal value with a pound avoirdupois. The kin contains ten times the number of units of the next inferior weight, which the Chineſe denominate *leang* or *loam*, and which the Europeans call *tael*, *taille*, or Chineſe *ounce*. This ounce is divided into ten *tſien*, which anſwers nearly to our drachm. The tſien is again ſubdivided into ten *fen*. The Chineſe extend the decimal ſubdiviſion of their weights conſiderably farther. They have diſtinct names, which are all monoſyllabic, for nine ſeries below the fen. Suppoſing the kin to ſtand for unity, they have,

1,	0	0	0	0	0	0	0	0	0	0	0	0
kin,	leang	tſien	fen	li	hav	ſen	tchin	yai	miao	mo	tſun	ſun

The Chineſe weights, compared with the greateſt preciſion, and with the help of the beſt inſtruments, bear the following proportion to our weights: The kin is equal to 1 pound 12 ounces 2 drachms 24 grains; the leang 1 ounce 1 drachm 60 grains; the tſien 70 grains $\frac{8}{10}$; the fen 7 grains $\frac{8}{100}$. Conſequently the laſt of this ſeries, the ſun, amounts to no more than 0 grains 00000000708.

Chinese Wheel is an engine employed in the province of *Kiang-ſee*, and probably through the whole empire, for raiſing water from rivers to irrigate plantations of ſugar canes, on a ſandy ſoil, conſiderably elevated above the level of the river. By Sir George Staunton, who ſays that it is ingenious in its contrivance, cheap in its materials, eaſy in its operation, and effectual to its purpoſe, it is thus deſcribed:

"Two hard wood-poſts or uprights are firmly fixed in the bed of the river, in a line perpendicular to its bank. Theſe poſts ſupport the axis, about ten feet in length, of a large and durable wheel, conſiſting of two unequal rims, the diameter of one of which, cloſeſt to the bank, being about fifteen inches ſhorter than that of the outer rim; but both dipping in the ſtream, while the oppoſite ſegment of the wheel riſes above the elevated bank. This double wheel is connected with the axis, and is ſupported by 16 or 18 ſpokes obliquely inſerted near each extremity of the axis, and croſſing each other at about two-thirds of their length. They are there ſtrengthened by a concentric circle, and faſtened afterwards to the rims: the ſpokes inſerted in the interior extremity of the axis reaching the outer rim, and thoſe proceeding from the exterior extremity of the ſame axis, reaching the inner and ſmaller rim. Between the rims and the croſſing of the ſpokes is woven a kind of cloſe baſket-work, ſerving as laddle-boards or floats, which meeting ſucceſſively the current of the ſtream, obey its impulſe, and turn round the wheel. To both its rims are attached ſmall tubes or ſpouts of wood, with an inclination of about 25 degrees to the horizon, or to the axis of the wheel. The tubes are cloſed at their outer extremity, and open at the oppoſite end. By this poſition the tubes, which happen in the motion of the wheel to be in the ſtream with their mouths or open ends uppermoſt, fill with water. As that ſegment of the wheel riſes, the mouths of the tubes attach to it, alter their relative inclination, but not ſo much as to let their contents flow out till ſuch ſegment of the wheel becomes the top. The mouths of thoſe tubes are then relatively depreſſed, and pour the water into a wide trough placed on poſts, from whence it is conveyed as may be wanted among the canes.

"The only materials employed in the conſtruction of this water-wheel, except the nave or axis, and the poſts on which it reſts, are afforded by the bamboo. The rims, the ſpokes, the laddle-boards or floats, and the tubes or ſpouts, and even the cords, are made of entire lengths, or ſingle joints, or large pieces, or thin ſlices, of the bamboo. Neither nails, nor pins, nor ſcrews, nor any kind of metal, enters into its conſtruction. The parts are bound together firmly by cordage, alſo of ſlit bamboo. Thus, at a very trifling expence, is conſtructed a machine which, without labour or attendance, will furniſh, from a conſiderable depth, a reſervoir with a conſtant ſupply of water adequate to every agricultural purpoſe.

"Theſe wheels are from 20 to 40 feet in diameter, according to the height of the bank and conſequent elevation to which the water is to be raiſed. Such a wheel is capable of ſuſtaining with eaſe 20 tubes or ſpouts, of the length of four feet, and diameter two inches in the clear. The contents of ſuch a tube would be equal to ſix-tenths of a gallon, and a periphery of 20 tubes, twelve gallons. A ſtream of a moderate velocity would be ſufficient to turn the wheel at the rate of four revolutions in one minute, by which would be lifted 48 gallons of water in that ſhort period; in one hour, 2880 gallons; and 69120 gallons, or upwards of 300 tons of water, in a day."

Sir George, who ſaw this wheel in motion, thinks it preferable in many reſpects to any machine yet in uſe for ſimilar purpoſes. He obſerves, that, while it approaches near to the Perſian wheel, of which a deſcription and figure is given in the article Hydrostatics, *Encycl.* it is more ſimple than that wheel in its contrivance, and much leſs expenſive. This is indeed true; but the ſimpleſt engine of the kind, and therefore the beſt that has yet been invented, is perhaps that which is employed to throw water into the moſs of Blair Drummond in Perthſhire. See Moss, *Encycl.*

CHOPINE, Choppine, or *Chopeene*, a high ſhoe, or rather clog, worn 200 years ago by the Italians.

Tom Coryat, in his Crudities 1611. p. 262, calls them *chapineys*, and gives the following account of them: "There is one thing uſed of the Venetian women, and ſome others dwelling in the cities and towns ſubject to the ſigniory of Venice, that is not to be obſerved, I thinke, amongſt any other women in Chriſtendome, which is ſo common in Venice, that no women whatſoever goeth without it, either in her houſe or abroad, *a thing made of wood and covered with leather of ſundry colors, ſome with white, ſome redde, ſome yellow. It is called a* chapiney, *which they wear under their ſhoes.* Many of them are curiouſly painted; ſome alſo of them I have ſeen fairly gilt; ſo uncomely a thing, in my opinion, that it is pitty this fooliſh cuſtom is not cleane baniſhed and exterminated out of the citie. *There are many of theſe chapineys of a great height, even half a yard high*, which maketh many of their women that are very ſhort ſeeme much taller than the talleſt women we have in England. Alſo I have heard it obſerved among them, that by how much the nobler a woman is, by ſo much the higher are her *chapineys*. All their gentlewomen, and moſt of their wives and widowes that are of any wealth, are aſſiſted eyther by men or women when they walke abroad, to the end they may not fall. They are borne up moſt commonly by the left arme, otherwiſe they might quickly take a fall."

CHOWDRY, in Bengal, the poſſeſſor of ſeveral *Talooks*. It is alſo uſed as ſynonymous with *Talookdar*, anciently a collector. See TALOOK in this Supplement.

CHRISOM was not, as is ſaid in the Encyclopædia, a face-cloth or piece of linen laid over the child's head when it was baptized; but it was a white veſture or garment, which, immediately after it was baptiſed, the prieſt put upon it, ſaying, "Take this white veſture as a token of the innocency, which, by God's grace in this holy ſacrament of baptiſm, is given unto thee, and for a ſign whereby thou art admoniſhed, ſo long as thou liveſt, to give thyſelf to innocence of living, that after this tranſitory life thou mayeſt be partaker of life everlaſting. Amen."

As ſoon as the prieſt had pronounced theſe words, he anointed the infant upon the head, ſaying, "Almighty God, the Father of our Lord Jeſus Chriſt, who hath regenerated thee by water and the Holy Ghoſt, and hath given unto thee the remiſſion of all thy ſins; he vouchſafe to anoint thee with the unction of his Holy Spirit, and bring thee to the inheritance of everlaſting life. Amen."

It was from this anointing or *chriſm* that the white garment got the name of *chriſom*, which, after being worn a few days, was offered to the prieſt to be kept in the church or veſtry, in order to be produced as evidence againſt the perſon whoſe chriſom it was, ſhould he afterwards deny the faith in which he had been baptized. Theſe ceremonies were retained, for ſome time after the reformation, in the church of England, which ordered the mother of the child (if the child was then alive) to offer, when ſhe was churched, the *chriſom* and other accuſtomed offerings. If the child died before its mother was churched, the *chriſom* was not given to the prieſt, but employed as a ſhroud, in which the body was buried; and hence it is that chriſoms are now enumerated, moſt abſurdly indeed, in the weekly bills of mortality. We ſay abſurdly; becauſe children who die unbaptized are called *chriſoms*, though the chriſom, when it was uſed, was never put on till baptiſm. See *Whitby on the Book of Common Prayer, &c.*

CHRONOLOGICAL CHARACTERS are characters by which times are diſtinguiſhed. Of theſe ſome are natural or aſtronomical; others, artificial or hiſtorical. The natural characters are ſuch as depend on the motions of the ſtars or luminaries, as *eclipſes, ſolſtices, equinoxes*, the *different aſpects of the planets*, &c. The artificial characters are thoſe that have been invented and eſtabliſhed by men; as the *ſolar cycle*, the *lunar cycle*, &c. Hiſtorical chronological characters are thoſe ſupported by the teſtimony of hiſtorians, when they fix the *dates* of certain *events* to certain *periods*. *Hutton's Mathematical Dictionary.*

CHRONOSCOPE, a word ſometimes uſed to denote a pendulum or machine to meaſure time.

CHUCKIAH, in Bengal, the juriſdiction of a *Fogedar*. See FOGEDÂR in this Supplement.

CHURCH is a word which has many different ſignifications, all ſufficiently explained in the Encyclopædia Britannica, where there is likewiſe given a conciſe *hiſtory* of the Chriſtian church (ſee HISTORY, Sect. ii.), defective, indeed, but perhaps not more ſo than was to be expected from the limits of the work and the extent of the ſubject.

Of the conſtitution of the primitive and apoſtolical church, no man can have a correct notion who has not taken the trouble to conſult the primitive and apoſtolical writers; for, as we have elſewhere obſerved, all modern compilers of eccleſiaſtical hiſtory are more or leſs prejudiced in behalf of the particular church to which they belong, and wreſt the language of the original writers ſo as to make them bear witneſs to the antiquity of *modes of faith* and *eccleſiaſtical polity*, which are not perhaps a hundred years old.

On this account we ſhall not here attempt to correct what we really think the miſtakes of him who compiled the ſection of eccleſiaſtical hiſtory in the Encyclopædia. Moſheim and Sir Peter King, whom he ſeems to have implicitly followed, were indeed great men; and it would be folly to deny that the *Hiſtory* of the former, and the *Inquiry* of the latter *into the Conſtitution of the Primitive Church*, are works of learning and ingenuity; but it is not perhaps too much to ſay, that both authors wrote under the influence of prejudice. Our readers will diſcover how cloſely either the one or the other has adhered to truth, by ſtudying the eccleſiaſtical writers of the firſt four centuries. Such a ſtudy will make them acquainted with the doctrines, diſcipline, and worſhip of the church before it was incorporated with the ſtate; and we know not that kind of knowledge which is of more importance to the divine, however much it may be deſpiſed in this age of affected ſcience and real ignorance.

Of the principal churches at preſent exiſting, a pretty full account is given in the Encyclopædia, either under their different denominations, or under the titles of thoſe tenets by which they are chiefly diſtinguiſhed; ſo that from that Work alone a reader may form a tolerably accurate notion of the faith, worſhip, conſtitution, and diſcipline of the church of Rome, the churches of England and Scotland, the Lutheran and Calviniſtical churches on the continent of Europe, as well as of the various ſects which have ariſen in theſe kingdoms during the courſe of the laſt and preſent centuries. There is, however, one church which boaſts of a very high antiquity, and is certainly ſpread over a larger extent of country than all the other churches that we have mentioned, of which the account given in the Encyclopædia is exceedingly defective. Our readers will perceive that the church to which we allude is

1
The Greek church.

The Greek CHURCH, which comprehends in its boſom (A) a conſiderable part of Greece, the Grecian iſles, Wallachia, Moldavia, Egypt, Abyſſinia, Nubia, Lybia, Arabia, Meſopotamia, Syria, Cilicia, and Paleſtine. which are all under the juriſdiction of the patriarchs of Conſtantinople, Alexandria, Antioch, and Jeruſalem. If to theſe we add the whole of the Ruſſian empire in Europe, great part of Siberia in Aſia, Aſtracan, Caſan, and Georgia—it will be evident that the Greek church has a wider extent of territory than the Latin, with all the branches which have ſprung from it; and that it is with great impropriety that the church of Rome is called by her members the *catholic* or univerſal church. That in theſe widely diſtant countries the profeſſors of Chriſtianity are agreed in every minute article of belief, it would be raſh to aſſert; but there is certainly ſuch an agreement among them with reſpect both to faith and to diſcipline, that they mutually hold communion with each other, and are in fact but one church.

2
The faith of that church.

As the Greek church has no public or eſtabliſhed articles, like thoſe of the churches of England and Scotland, we can collect what is its doctrine only from its creeds, from the councils whoſe decrees it receives (B), from the different offices in its liturgies, and from the catechiſms which it authoriſes to be taught. "The doctrine of the Trinity, and the articles of the Nicene and Athanaſian creeds, are received by the Greeks in common with other Chriſtians. In one particular, indeed, they differ from the other churches of Europe, whether Romiſh or reformed. They believe that the Holy Spirit proceeds from the father only, and not from the Father and the Son; and in defence of this opinion they appeal to eccleſiaſtical hiſtory, the acts of councils, the writings of the fathers, ancient manuſcripts, and eſpecially to a copy of the creed of Conſtantinople, engraven on two tables of ſilver, and hung up in the church of St Peter at Rome by order of Leo III. Of the Nicene or Conſtantinopolitan creed, therefore, as it is received by them, the eighth article runs in theſe words, 'I believe in the Holy Ghoſt, the Lord and Giver of life, who proceedeth from the FATHER, and with the Father and the Son together is worſhipped and glorified:' And the correſponding article of the Athanaſian creed is of courſe, "The Holy Ghoſt is of the FATHER, neither made, nor created, nor begotten, but proceeding †."

3
It admits of pictures, but not of graven images.

Though the biſhops and clergy of the Greek church abhor the uſe of images, which they pretend to be one cauſe of their ſeparation from the ſee of Rome, they admit into their churches the pictures of ſaints to inſtruct, they ſay, the ignorant, and to animate the devotion of others. This practice they conſider as by no means contrary to the ſecond commandment of the decalogue, which, according to them, prohibits only the worſhipping of ſuch idols as the Gentiles believed to be gods; whereas their pictures, being uſed merely as remembrancers of Chriſt and the ſaints, have written on each of them the name of the perſon whom it is meant to repreſent. Dr King aſſures us that the more learned of the Ruſſian clergy would willingly allow no repreſentation whatever of God the Father; and that, during the reign of Peter the Great, the ſynod not only cenſured the uſe of ſuch pictures in churches, but petitioned the emperor that they might be everywhere taken down. Peter, however, though he fully concurred in opinion with the ſynod, thought this a meaſure for which the minds of his ſubjects were not ripe, and dreaded, that if carried into execution it would occaſion a general inſurrection. Such pictures, therefore, though not more impious than abſurd, are ſtill in uſe; and in many churches, as well ancient as modern, the figure of Daniel's *Ancient of Days*, together with that of *Chriſt* and a *dove*, are painted in one group to ſignify the Holy Trinity. Nay, when our author was in St Peterſburg, not thirty years ago, there was in the church of St Nicholas the picture of an old man holding a globe, and ſurrounded with angels, on which GOD THE FATHER was inſcribed; and we have not heard that the picture has been ſince taken down.

4
Invocation of ſaints.

In the Greek as well as in the Roman church, the invocation of ſaints is practiſed, but they are not invoked in either as deities, but merely as interceſſors with the Supreme God, "it being more modeſt (ſay the Greeks), as well as more available, to apply to them to intercede with God, than to addreſs ourſelves immediately to the Almighty." Plauſible as this reaſoning may at firſt ſight appear, it aſcribes to the ſaints the divine attribute of ubiquity, and is likewiſe in direct contradiction to the doctrine of St Paul, who hath taught us, that as "there is one God, ſo there is but one mediator between God and man, the man Chriſt Jeſus."

5
Prayers for the dead.

The Greek church, at the celebration of the Lord's Supper, commemorates the faithful departed, and even prays for the remiſſion of their ſins; but ſhe allows not of purgatory, nor pretends to determine dogmatically concerning the ſtate or condition of departed ſouls. She muſt, however, believe that no final judgment is paſſed upon the great body of mankind (C) till the conſummation of all things, otherwiſe ſuch prayers could not be offered without abſurdity; and in this part of her doctrine ſhe is certainly countenanced by all the writers of the primitive church, if not by ſome paſſages of the ſacred ſcriptures *. The practice of praying for the dead is loudly condemned in every Proteſtant country, and yet there is no Chriſtian who does not in effect pray

† Dallaway's *Conſtantinople, Ancient and Modern*, and King's *Rites and Ceremonies*, &c.

* *Math.* xxv. 19, 20, —31—34. 2 *Tim.* i. 18, iv. 8.

(A) King's *Rites and Ceremonies of the Greek Church*—Bruce's *Travels to the Source of the Nile*—and Lobo's *Voyage to Abyſſinia.*

(B) In the Greek church ſeven general councils are received, and nine provincial ones. The ſeven general councils are, 1. The council of Nice, held in the year 325, under Conſtantine. 2. The firſt council of Conſtantinople, held A. D. 381, under Theodoſius the Great. 3. The council of Epheſus, A. D. 431, in the reign of Theodoſius Minor. 4. The council of Calcedon, A. D. 451, in the reign of Marcian. 5. The ſecond council of Conſtantinople, A. D. 553, in the reign of Juſtinian. 6. The third council of Conſtantinople in Trull, A. D. 680, in the reign of Conſtantine Pagonatus. 7. The ſecond council of Nice, A. D. 787.

(C) We ſay the great body of mankind, becauſe ſhe doubtleſs believes that Enoch, Elias, and thoſe ſaints who roſe with our Saviour, have been already judged, and now enjoy their reward in heaven.

pray for his departed friends. This may appear a paradox, but it is an obvious and a certain truth; for where is the man who believes in a general judgment, and does not *wiſh* that his deceaſed wife, or parent, or child, or friend, "may find mercy of the Lord in that day?" Such a wiſh is the eſſence of a prayer; which conſiſts not of the ſounds in which our ſentiments are cloathed, but in the aſpirations of a devout heart.

6
Grants no indulgencies.

Supererogation, with its conſequent indulgencies and diſpenſations, which were once ſo profitable, and afterwards ſo fatal to the intereſts of the court of Rome, are utterly diſallowed in the Greek church, which likewiſe lays no claim to the character of infallibility. She is indeed, like ſome other churches, very inconſiſtent on this laſt topic; for whilſt ſhe pretends not to an abſolute exemption from error, her clergy ſeem to conſider their own particular mode of worſhip as that which alone is acceptable to God.

7
Predeſtination.

Predeſtination is a dogma of the Greek church, and a very prevailing opinion amongſt the people of Ruſſia; "and I muſt do the juſtice (ſays Dr King) to thoſe who have written upon it, eſpecially the lateſt authors of that country, to ſay that they have treated it, as depending on the attribute of preſcience in the divine nature, with a much better kind of logic than that with which ſuch points are generally diſcuſſed." As our author has not given us the reaſoning of the Ruſſian doctors on this difficult ſubject, we cannot hazard any opinion of our own on the ſoundneſs of their logic; but from the ſtate of ſcience in that vaſt empire, as it was repreſented to us by an abler judge than he, we doubt of its being entitled to the praiſe which he beſtows on it. (See RUSSIA, n° 104. *Encycl.*)

8
Seven ſacraments.

In the Greek church there are ſeven *ſacraments*; or, as they are there termed, *myſteries*, viz. *baptiſm*: the *chriſm*, or baptiſmal unction; the *euchariſt*; *confeſſion*; *ordination*; *marriage*; and the myſtery of *the holy oil*, or *euchelaion*. By the Greeks a myſtery is defined to be "a ceremony or act appointed by God, in which God giveth or ſignifieth his grace; and of the ſeventh which they celebrate, four are to be received by all Chriſtians, viz. *baptiſm*, the *baptiſmal unction*, the *euchariſt*, and *confeſſion*. Of theſe, *baptiſm* and the *euchariſt* are deemed the chief; and of the other three, none, not even the *euchelaion*, is conſidered as obligatory upon all.

With reſpect to baptiſm, we know not that they hold any peculiar opinions. They conſider it indeed as ſo abſolutely neceſſary to ſalvation, that in caſes of extremity, when a prieſt or deacon cannot be had, it may be adminiſtered by a midwife or any other perſon, and is not to be repeated on any occaſion whatever. In this opinion, as well as in the practice founded on it, they are in perfect harmony with the church of Rome, which, as every perſon knows, has for many ages allowed the validity of lay-baptiſm in caſes of neceſſity. The Portugueſe Jeſuits, who in the laſt century viſited Abyſſinia in the capacity of miſſionaries, have maintained that, once every year, all grown people are in that country baptiſed: but Mr Bruce has ſhewn, by the moſt incontrovertible evidence, that this was a mere fiction, invented to throw odium upon what the church of Rome calls the eaſtern chiſm, and abhors perhaps more than paganiſm itſelf.

9
Daily ſervice of the church,

The daily ſervice of the Greek church is ſo long and ſo complicated, that it is impoſſible for us to give an adequate account of it without ſwelling this article far beyond its due proportion. Of this the reader will be convinced, when he is informed that the ſeveral books containing the church ſervice for all the days in the year, amount to more than twenty volumes in folio, beſides one large volume called *the regulation*, which contains the directions how the reſt are to be uſed.

10
Intricate and tedious.

The four goſpels make one volume by themſelves; and whenever the goſpel is read in any ſervice, the deacon exclaims; "Wiſdom, ſtand up. Let us hear the holy goſpel." The prieſt then ſaith, "The leſſon from the goſpel according to St Matthew, St Mark, &c." The deacon ſays again, "Let us ſtand." The choir, at the beginning and end of the goſpel, always ſays, "Glory be to thee, O Lord, glory be to thee." From the old teſtament and the epiſtles extracts only are uſed in the ſervice; and when they are to be read, the deacon calls out, "Attend."

The ſervice of this church as it now ſtands, and was at firſt drawn up in writing, is calculated for the uſe of monaſteries; and when it was afterwards applied to parochial churches, many of the offices or forms, which were compoſed for different hours of the day and night, were uſed as one ſervice, without the ſlighteſt alteration being made to avoid repetitions. Something of this kind has taken place in the church of England, where the matins, the litany, and the communion, which were formerly three diſtinct ſervices, read at different times of the day, are now run into one ſervice; which by thoſe not accuſtomed to it is therefore deemed long, as well as deformed by needleſs repetitions.

11
Begins in the evening.

The ſervice of every day, whether it has a vigil or not, begins in the evening of what we would call the preceding day, as among the Jews; and for the ſame reaſon, becauſe it is ſaid in the Moſaic account of the creation, that "the evening and the morning were the firſt day." The ſeveral ſervices, according to the original or monkiſh inſtitution, are, 1. *The veſpers*, which uſed to be celebrated a little before ſun-ſet; 2. *The after-veſpers*, anſwering to the *completorium* of the Latin church, which uſed to be celebrated after the monks had ſupped, and before they went to bed; 3. *The meſonyecticon*, or midnight ſervice; 4. *The matins* at break of day, anſwering to the *laudes* of the Romiſh church; 5. The *firſt hour* of prayer, or *prima*, at ſun-riſe; 6. The *third hour*, or *tertia*, at the third hour of the day; 7. The *ſixth hour*, or *ſexta*, at noon; 8. The *ninth hour*, or *nona*, in the afternoon at the ninth hour of the day. Theſe are called the canonical hours; but it is to be obſerved, that the *after-veſpers* were not added till a late period, before which the reaſon aſſigned for the number of ſervices being ſeven, was, that David ſaith, "Seven times a-day will I praiſe thee." When all the pſalms and hymns were ſung, theſe daily ſervices could not poſſibly have been performed in leſs than twelve or fourteen hours. In the church of Ruſſia, and probably in other branches of the Greek church, there are at preſent but three ſervices in the day: the *ninth hour*, the *veſpers*, and the *after-veſpers* making one; the *meſonyecticon*, the *matins*, and *prima*, another; and the *third* and *ſixth hour*, with the *communion*, the laſt. In all the ſervices, except the communion, prayers and praiſes are offered to ſome ſaint; and to the Virgin Mary, almoſt as often as to God; and in ſome of the ſervices, after every ſhort prayer uttered by the deacon or the prieſt, the choir chaunts "Lord have mercy upon us," thirty, forty, or fifty times, ſucceſſively.

Though the number of ſervices is the ſame every day, the ſervices themſelves are conſtantly varying in ſome particular or other, as there is not a day which, in the Greek church, is not either a faſt or a feſtival. Beſides the ſaints, whoſe feſtivals are marked in the calendar, and who are ſo very numerous that there are more than one for every day in the year, there are other ſaints and feſtivals, to which ſome portion of the ſervice for every day of the week is appropriated. Thus, Sunday is dedicated to the reſurrection: Monday, to the angels; Tueſday, to St John Baptiſt; Wedneſday, to the Virgin and the croſs; Thurſday, to the apoſtles; Friday, to the paſſion of Chriſt; and Saturday, to the ſaints and martyrs. For theſe days there are particular hymns and ſervices, in two volumes folio, to which there is a ſupplement containing ſervices for the ſaints and feſtivals, as they occur in the calendar throughout the year. Theſe different ſervices are mixed together, and adjuſted by the directions contained in the book of *regulation*; and it is the difficulty of this adjuſtment which makes the public worſhip of the Greek church ſo very intricate, that, as was ſaid of the ſervice of the Engliſh church before the Reformation, "there is more buſineſs to find out what ſhould be read, than to read it when found out."

12
Mode of adminiſtering baptiſm.

We have obſerved, that the Greeks have no peculiar opinions reſpecting the nature of baptiſm; but the rites and ceremonies with which that ordinance is adminiſtered will appear to our unlearned readers very extraordinary. On the day that a woman is delivered, the prieſt goes to the houſe, and uſes a form of prayer for her and for the child. On the eighth day the child ſhould be regularly carried to the church, where the prieſt having ſigned it with the ſign of the croſs on the forehead, on the mouth, and on the breaſt, offers up for it a prayer, in which he firſt gives it a name, commonly the name of the ſaint for that day in the calendar; he then takes it from the midwife, and ſtanding before the picture of the bleſſed Virgin, he makes the ſign of the croſs with the infant, uttering a kind of hymn in honour of the Virgin and of Simeon, who held in his boſom the Saviour of our ſouls. He then diſmiſſes the company with an exhortation not to delay the baptiſing of the infant, ſhould it appear in danger of death before the regular time for its baptiſm.

On the fortieth day after her delivery, the mother ſhould attend the church to be purified, and carry the child again to be preſented, the perſon who is to be ſponſor being preſent. Upon their arrival at the church door, the prieſt utters ſome pious exclamations; and then, the mother holding the child in her arms and bowing down her head, he makes the ſign of the croſs upon her and the child, and laying his hand upon its head, he prays that the woman may be cleanſed from every ſin and from every defilement, and that the child may be ſanctified and endued with underſtanding, with wiſdom, and with gentleneſs of manners. He then ſigns it again, and again prays for it, for its parents, and for its ſponſor; after which, if it has been privately baptiſed, he takes it in his arms, and makes with it the ſign of the croſs before the door of the church, ſaying, "N. N. the ſervant of God, enters into the church, in the name of the Father, and of the Son, and of the Holy Ghoſt, now and for ever, even unto ages of ages. Amen." He then carries the child into the church, ſaying, "he ſhall go into thine houſe, and ſhall worſhip toward thy holy temple;" and advancing into the middle of the church, he ſays, "In the midſt of thy church ſhall he praiſe thee." Then, if the child be a boy, he carries him within the rails of the altar; but if a girl, only to the door, and ſays "*Nunc dimittis* (D);" after which he delivers it to the ſponſor, who makes three reverences, and retires.

This is called the preſentation of the child in the temple, and can only be performed after it has been baptized. In the detail we have given, we have ſuppoſed that it was baptized privately before the purification of the mother, which is now indeed commonly the caſe. Such baptiſm, however, is not regular, being allowed only in caſes of neceſſity; and when it has not taken place, the mother and child are diſmiſſed as ſoon as ſhe is purified, and return at ſome other time, not fixed, in order that the child may be publicly baptized.

Previous to baptiſm, the child, though not two months old, muſt be ſolemnly initiated into the church as a catechumen (See CATECHUMEN, *Encycl.*) By thoſe whoſe religion is a reaſonable ſervice, ſuch initiation of an infant will be conſidered as a very idle ceremony; and the rites with which it is performed are not well calculated to give it even a fictitious importance. At the door of the church the prieſt unties the girdle of the infant; takes off all his clothes but one looſe garment; turns him towards the eaſt, with his head uncovered, his feet naked, and his hands held down; blows thrice in his face; ſigns him thrice with the ſign of the croſs on the forehead and on the breaſt, and lays his hand upon his head, praying that his "*ancient* error may be put away from him; that his heart may be filled with faith, hope, and charity; and that he may walk in the ways of God's commandments." The prieſt then four times exorciſes the infant, commanding Satan, in the firſt exorciſm, to "tremble, depart, and flee from Chriſt's creature, nor dare to return again, nor dare to lurk concealed within him, or to meet him, or to meditate againſt him, either in the evening or the morning, at midnight or at noon-day." In the laſt exorciſm he blows thrice upon the child's mouth, upon his forehead, and upon his breaſt; ſaying, each time, "Drive away from him every evil and unclean ſpirit that lurks in him, and hath made itſelf a neſt in his heart." The child is now become a catechumen, and, being turned to the weſt, uncovered, without ſhoes, and his hands lifted up, the prieſt repeatedly aſks him if he *renounces* and *has* renounced the Devil and all his works? and receiving from the ſponſor the proper anſwer, he ſays, "Blow and ſpit upon him;" and having blown and ſpit upon the catechumen, he turns him to the eaſt, and holding down his hands, aſks him repeatedly if he be joined to Chriſt, and if he believes in him? The catechumen or his ſponſor replies to each queſtion, that he is, and has been, joined to Chriſt; and as a proof of his

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(D) We quote the words of Dr King. Is it poſſible that in the Greek church Latin hymns are uſed, or that Greek hymns have Latin deſignations?

his faith he repeats, from beginning to end, the Nicene creed. After a repetition of the formerly repeated queſtions and anſwers, the prieſt prays that the catechumen may be called to God's holy ſanctification, and receive the grace of God's holy baptiſm.

Baptiſm may be celebrated immediately after the candidate has been made a catechumen, or on any ſubſequent day at no great diſtance. In the firſt part of the form there is not much that is ſingular, or with which every ſcholar is not acquainted. After praying that the water may be ſanctified, in terms differing little from thoſe which are uſed in the moſt reſpectable Proteſtant churches, the prieſt dips his fingers in it, ſigns it thrice with the ſign of the croſs; and then blowing upon it, ſays three times, “Let every adverſe power be confounded under the ſign of the croſs.” He then ſolemnly exorciſes it of the dæmon of darkneſs and all evil ſpirits; and prays, that “the perſon to be baptiſed therein may put off the old man, which is corrupt after the luſt of fraud, and may put on the new man after the image of Him that made him. After this, he blows thrice into a veſſel of oil of olives held by the deacon, ſigns it thrice with the ſign of the croſs; and prays fervently, that it may “become to thoſe who are anointed with faith, and are partakers thereof, the unction of incorruption, the armour of righteouſneſs, the renewing of ſoul and body, for turning aſide all machinations of the devil, and for deliverance from all evil.” He then ſings allelujah thrice with the people, and pours the oil on the top of the water; and making three croſſes with it, ſays aloud, “Bleſſed be God, who enlighteneth and ſanctifieth every man that cometh into the world, now and forever, even unto ages of ages.” The perſon to be baptized is then preſented; and the prieſt, taking ſome of the oil with two fingers, and making the ſign of the croſs on his forehead, on his breaſt, and betwixt his ſhoulders, ſays, “N the ſervant of God is anointed with the oil of gladneſs, in the name of the Father, and of the Son, and of the Holy Ghoſt, now and forever, even unto ages of ages. Amen.” He then ſigns him on the breaſt and the middle of the back, ſaying, “For the healing of his ſoul and body;” then on the ears, ſaying, “For hearing the faith;” then on the palms of the hands, ſaying, “Thy hands have made me and faſhioned me;” then on the feet, “That he may walk in the way of thy commandments.” After the whole body is thus anointed, the prieſt baptizes him, uſing the trine immerſion; which is unqueſtionably the moſt primitive manner. He takes the child in his arms, and holding him upright with his face towards the eaſt, he ſays, “N the ſervant of God is baptized (*dipping him the firſt time*), in the name of the Father, Amen; in the name of the Son (*dipping him again*), Amen; and of the Holy Ghoſt (*dipping him the third time*), Amen, now and for ever, even unto ages of ages. Amen.” After the baptiſm, the prieſt wipes his hands, and with the people ſings thrice, from beginning to end, the 32d Pſalm; he then puts upon the baptized perſon a white garment; ſaying, “N the ſervant of God is clothed with the garment of righteouſneſs, in the name of the Father, and of the Son, and of the Holy Ghoſt, now and for ever, even unto ages of ages (E).” He then prays that he may be delivered from the evil one, and all his inſidious ſnares; that he may be confirmed in the true faith; and that he may preſerve his ſoul in purity and righteouſneſs: and proceeds immediately to anoint him with the *Holy Chriſm*.

13 The baptiſmal chriſm.

This chriſm is a very different thing from the oil with which he was anointed previous to baptiſm, and which was uſed in the conſecration of the baptiſmal water. It can be prepared only by a biſhop, and only on one day in the year, *viz.* Thurſday in Paſſion-week; and as the anointing with it is ſubſtituted in place of the apoſtolical rite of laying on hands, called *confirmation* in the weſtern churches, great quantities of it are of courſe prepared at once, and diſtributed through the different churches of each dioceſe. The chriſm conſiſts of the following ingredients, which in different proportions are all boiled together, and afterwards ſolemnly conſecrated by the biſhop: Fine oil (we ſuppoſe of olives), white wine, ſtyrax calamita (F), palm-dew, roſe-flowers, black palm-gum, Baſil-gum, marjoram, thick and thin oil of nutmegs in very different quantities, oil of cinnamon, oil of cloves, lignum Rhodii, oil of oranges, oil of marjoram, oil of lavendar, oil of roſemary, eſſence of roſemary, cedar, black balſam of Peru, ſandarac, whiteſt maſtic, and Venice turpentine. With this holy mixture the baptized perſon is anointed, the prieſt making with it the ſign of the croſs on his forehead, on his eyes, his noſtrils, his mouth, both ears, his breaſt, his hands, and his feet; ſaying at each part, “The ſeal of the gift of the Holy Ghoſt. Amen.” Then with the ſponſor and the child he goes thrice round the font, turning from the right to the left; the choir, in the mean time, ſinging, “As many of you as are baptized unto Chriſt have put on Chriſt, allelujah.”

Seven days after this ceremony is performed, the child is again brought to the church; when the prieſt, after praying for him, unties his girdle and linen clothes, waſhes him with clean water, and, ſprinkling him, ſays, “Thou haſt been juſtified, enlightened, ſanctified in the name of our Lord Jeſus Chriſt, and with the Spirit of our God.” Then taking a new ſponge moiſtened with water, he waſhes his face, breaſt, &c.; ſaying, “Thou haſt been baptized, enlightened, anointed, ſanctified, waſhed, in the name of the Father, and of the Son, and of the Holy Ghoſt, now and for ever, even unto ages of ages. Amen.”

14 The tonſure.

The laſt ceremony appended to baptiſm is that of the tonſure, or ſhaving the head of the child in the form of the croſs. At what time this rite crept into the church it would not be eaſy to diſcover. Some think it received its origin from the religious ceremonies of the Heathen, who certainly rounded the corners

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(E) The reader will perceive, that many of theſe rites and ceremonies are common to the Greek church and the church of Rome in the celebration of the ſacrament of baptiſm.

(F) We quote the words of Dr King, taking it for granted that our readers will pardon our not giving ourſelves much trouble to diſcover, on the preſent occaſion, what particular ſpecies or variety of the ſtorax he means by this deſignation. See Styrax, *Encycl.*

of their heads, and marred their beards, at a very early period, in honour of their idols (See Theology, n° 155. *Encycl*,) ; and ſome pious, but fooliſh Chriſtians, eſteemed it highly commendable to transfer to the true God that worſhip, in a different form, which had been rendered by their anceſtors to falſe deities. Others will have the tonſure to typify the dedication of the perſon to the ſervice of God ; the cutting off of the hair being always conſidered as a mark of ſervitude. Be theſe conjectures as they may, the prieſt, after the child is baptized, offers up for him ſeveral prayers, all alluding to the rite to be performed; and then cuts his hair croſswiſe, ſaying, " N the ſervant of God is ſhorn, in the name of the Father, and of the Son, and of the Holy Ghoſt, now and for ever, even unto ages of ages. Amen."

15 The Greeks have three communion-offices.

We have given a full account of the manner in which the ſacrament of baptiſm is celebrated among the Greeks, that the reader may have ſome notion of the childiſh ſuperſtition of that church, with which certain zealous Proteſtants in England were very deſirous, at the beginning of this century, to form a union. There is no occaſion for dwelling ſo long upon their other offices. For the celebration of the Lord's Supper they have three liturgies that are occaſionally uſed, *viz.* that of St Chryſoſtom, which is in ordinary daily uſe ; that of St Baſil, uſed on particular days ; and that of the *preſanctified*, as it is called, which is uſed on the Wedneſdays and Fridays during the great faſt before Eaſter. Between the liturgies of St Chryſoſtom and St Baſil there is no eſſential difference; and the office of the preſanctified is merely a form of diſpenſing the communion with elements which had been conſecrated on the preceding Sunday. We would gladly inſert the liturgy of St Chryſoſtom, or at leaſt ſuch an abſtract of it as we have given of the form of adminiſtering baptiſm ; but as our limits will not permit us to do ſo, we muſt refer ſuch of our readers as have any curioſity reſpecting ſubjects of this nature to *Dr King's Rites and Ceremonies of the Greek Church*.

16 Strange ceremony at the offertory.

17 The conſecration of the elements.

It is proper, however, to obſerve here, that many ſuperſtitious ceremonies have been added to the ſervice ſince the age of St Chryſoſtom, and that no man can compare his genuine works with the liturgy which now goes under his name, and entertain the ſmalleſt doubt but that the latter has been greatly, though gradually, corrupted. In the offertory there is a ſtrange ceremony, called *the ſlaying of the Holy Lamb*, when the prieſt, taking into his left hand one of the five loaves which are to be conſecrated, thruſts a ſpear into the right ſide of it ; ſaying, " He was led as a lamb to the ſlaughter ;" then into the left ſide, adding, " And as a blameleſs lamb before his ſhearers is dumb, ſo he openeth not his mouth :" then into the upper part of the loaf ; ſaying, " In his humiliation his judgment was taken away :" and into the lower part ; adding, " And who ſhall declare his generation ?" He then thruſts the ſpear obliquely into the loaf, lifting it up, and ſaying, " For his life was taken away from the earth." After this he lays down the loaf, and cutting it croſswiſe, ſays, " The Lamb of God, which taketh away the ſins of the world, is ſlain for the life and ſalvation of the world." All this, and more to the ſame purpoſe, is unqueſtionably modern; but we have no doubt but that the prieſt uſes the words of Chryſoſtom himſelf, when, in the conſecration of the elements, he ſays, " We offer unto thee this reaſonable, this unbloody ſacrifice ; and we implore, we pray thee, we humbly beſeech thee, to ſend down the Holy Spirit upon us, and thoſe oblations preſented unto thee ; and make this bread the precious body of thy Chriſt ; and that which is in this cup the precious blood of thy Chriſt, changing them by thy Holy Spirit."

18 Tranſubſtantiation.

Dr King obſerves, that this invocation of the Holy Spirit upon the elements, which in the eaſtern church is always uſed after the words of Chriſt, " This is my body, this is my blood, &c." is inconſiſtent with the Popiſh doctrine of tranſubſtantiation : and he is undoubtedly right ; for the church of Rome teaches, that the change is made about the middle of the maſs, when the prieſt, taking into his hand firſt the bread and then the wine, pronounces over each ſeparately the ſacred words of conſecration; *i. e.* the words of Chriſt. " It is the office of the prieſt, in this and in all other ſacraments (ſays a dignitary of that church), only to perform the outward ſenſible part ; but the inward inviſible effect is the work of the great God, who accordingly changes the ſubſtance of the bread and wine into the body and blood of Chriſt the very inſtant that the ſacred words of conſecration are pronounced by the prieſt over them." But if this be ſo, it would be impious, and we believe that by the church of Rome it is deemed impious, to pray afterwards, that God would ſend down his Holy Spirit to change into the body and blood of Chriſt elements which he had already changed into that body and blood, in conſequence of the prieſt's pronouncing over them the all-powerful words of Chriſt. Yet is it certain, that in the preſent Greek church tranſubſtantiation is as much an article of faith as in the church of Rome ; for now every biſhop at his conſecration declares, in the moſt ſolemn manner, that he believes and " underſtands that the tranſubſtantiation of the body and blood of Chriſt, in the holy ſupper, is effected by the influence and operation of the Holy Ghoſt, when the biſhop or prieſt invokes God the Father in theſe words, *and make this bread the precious body of thy Chriſt*, &c." This is indeed a different account from that of the Latin church of the time at which this portentous change is wrought; but ſuch difference is a matter of very little importance (G). If the change itſelf be admitted, the conſequence muſt be the ſame, whether it be ſuppoſed to take place when the

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(G) Mr Bruce ſeems to doubt whether tranſubſtantiation be the doctrine of the Abyſſinian church, and relates a converſation which he had on the ſubject with a prieſt ; who ſolemnly affirmed, that he never believed in the converſion of the ſubſtance of the bread and wine into the ſubſtance of our Saviour's body and blood. It muſt be remembered, however, that the prieſt had at the time a powerful reaſon for wiſhing that doctrine not to be true. The Jeſuits uniformly atteſt, that the Abyſſinians believe in the real preſence ; though it muſt not be forgotten that Ludolf was of a different opinion, and that no man had ſtudied the language of Abyſſinia more ſucceſsfully than he.

the prieſt pronounces the words of inſtitution, or after he has invoked the deſcent of the Holy Ghoſt; in either caſe it leads to idolatry. It may be proper to mention, that in the Greek church it is deemed eſſential to the validity of this holy ſacrament, that a little warm water be mixed with the wine; that the napkin, which is ſpread over the holy table, and anſwers to the *corporale* of the church of Rome, be conſecrated by a biſhop, and that it have ſome ſmall particles of the reliques of a martyr mixed in the web, otherwiſe the euchariſt cannot be adminiſtered. In this church children may receive the communion immediately after baptiſm; and the lay communicants, of whatever age, receive both the elements together, the bread being ſopped in the cup: The clergy receive them ſeparately.

19 The laity communicate in both kinds.

20 Confeſſion in the Greek church.

We have obſerved, that one of the ſeven *myſteries* or ſacraments of the Greek church is *confeſſion;* but among the Greeks it is a much more rational and edifying ſervice than in the church of Rome. In the Greek church the end of confeſſion is the amendment of the penitent; in the church of Rome it is to magnify the glory of the prieſt. In the former church, the confeſſors pretend only to abate or remit the penance, declaring the pardon from God alone; in the latter, they take upon them to forgive the ſin itſelf. The Greek church preſcribes confeſſion four times in the year to all her members; but the laity, for the moſt part, confeſs only once a year previous to receiving the holy communion; and to this they are in Ruſſia obliged by the laws of the empire.

21 Matrimony.

The ceremonies with which matrimony is performed in the Greek church conſiſt of three diſtinct offices, formerly celebrated at different times, after certain intervals, which now make but one ſervice. Firſt, there was a ſolemn ſervice, when the parties betrothed themſelves to each other, by giving and receiving rings or other preſents, as pledges of their mutual fidelity and attachment. The ancient uſage was for the man to receive a gold ring and the woman a ſilver one, which is ſtill alluded to in the rubric, though, in the preſent practice, the rings are generally both of gold. At this time the dowry was paid, and certain obligations were entered into to forfeit ſums in proportion to it, if either of the parties ſhould refuſe to ratify the engagement. At this ceremony, called the μνηστρον, or *recording of the pledges before witneſſes,* the prieſt gives lighted tapers to the parties to be contracted, making the ſign of the croſs on the forehead of each with the end of the taper before he deliver it.

The ſecond ceremony, which is properly the marriage, is called the office of *matrimonial coronation,* from a ſingular circumſtance in it, that of *crowning* the parties. This is done in token of the triumph of continence; and therefore it has, in ſome places, been omitted at ſecond marriages. Formerly theſe crowns were garlands made of flowers or ſhrubs; but now there are kept, in moſt churches, crowns of ſilver or ſome other metal for the celebration of matrimony. At the putting of them on, the prieſt ſays, "N, the ſervant of God, is crowned for the handmaid of God; and "N, handmaid of God, is crowned for the ſervant of God, in the name of the Father, and of the Son, and of the Holy Ghoſt;" adding thrice, "O Lord our God, crown them with glory and honour."

The third ceremony is that of diſſolving the crowns on the eighth day; after which the bride is conducted to the bridegroom's houſe, immediately to enter on the cares of his family.

22 Regular and ſecular clergy.

With reſpect to diſcipline and government, the Greek church bears a ſtriking reſemblance to that of Rome. In both there is the ſame diviſion of the clergy into regular and ſecular; the ſame ſpiritual juriſdiction of biſhops and their officials, and the ſame diſtinction of ranks and offices. In ſome points the diſcipline of the Greeks differs from that of the Romans. All orders of ſecular clergy in the Greek church inferior to biſhops are permitted to marry; but celibacy, and the aſſumption of the monaſtic habits, are indiſpenſably requiſite in thoſe who are candidates for the mitre. The regular clergy, ſays Mr Dallaway, are generally men of a certain education; whereas the ſeculars are of the meaner ſort, and illiterate in the extreme.

23 Five orders of clergy.

In the Greek church there are five orders of clergy promoted by the impoſition of hands; but it does not appear that the ordination of the reader, or of the ſubdeacon, is conſidered as a ſacrament. The forms uſed in the ordination of deacons, preſbyters, and biſhops, are ſerious and ſignificant (H), bearing in themſelves evidence of great antiquity. The candidate for the deaconate or prieſthood kneels before the holy table, and the biſhop, laying his right hand on his head, ſaith, "The divine grace, which healeth our infirmities, and ſupplieth our defects, promoteth N, the moſt pious *ſubdeacon,* to the order of *deacon;*" or, in the caſe of the prieſthood, "The moſt pious *deacon* to the order of a *preſbyter;* let us pray for him, that the Grace of the Holy Spirit may come upon him." It does not appear, from Dr King's account of theſe offices, that in the Greek church the attending preſbyters lay on their hands together with the biſhop at the ordination of a preſbyter,

24 Form of ordination.

(H) We muſt except thoſe uſed in the church of Abyſſinia, which, according to Mr Bruce, are ſhamefully indecent. "A number of men and children preſent themſelves at a diſtance, and there ſtand, from humility, not daring to approach the *abuna* or biſhop. He then aſks who theſe are? and they tell him that they want to be deacons. On this, with a ſmall iron croſs in his hand, after making two or three ſigns, he blows with his mouth twice or thrice upon them; ſaying, *Let them be deacons.* I ſaw once (ſays our author) all the army of Begemder made deacons, juſt returned from ſhedding the blood of 10,000 men. With thoſe were mingled about 1000 women, who conſequently having part of the ſame blaſt and brandiſhment of the croſs, were as good deacons as the reſt. In the ordination of prieſts a little more ceremony is uſed; for they muſt be able to read a chapter of St Mark, which they do in a language of which the abuna underſtands not one word. They then give him a brick of ſalt, to the value perhaps of ſixpence, for their ordination; which, on account of this preſent, the Jeſuits maintained to be Simoniacal." There is but one biſhop or abuna in Abyſſinian, and he is always a foreigner, ſubordinate in his juriſdiction to the patriarch of Alexandria.

preſbyter, as is practiſed in the church of England; but ſeveral biſhops lay on their hands together with the archbiſhop at the conſecration of a biſhop.

25 Solemn conſecration of biſhops.

This is indeed a very ſolemn ceremony. The candidate for the epiſcopate, who is always an *archimandrite* or *hieromonachus*, i. e. an abbot or chief monk in ſome monaſtery, being named to the vacant ſee, and the election being confirmed, repairs, at the time appointed, to the church where the conſecration is to be performed. Being arrived, he is introduced by the proto-pope (I) and proto-deacon to the archbiſhop and biſhops, who are arranged in proper order on a temporary theatre or platform erected in the church for the occaſion. He there gives an account of his faith; declares ſolemnly that he has neither given nor promiſed money, or any bribe-worthy ſervice, for his dignity; and promiſes to adhere ſteadily to the traditions and canons of the eaſtern church, to viſit his dioceſe regularly, and to oppoſe ſtrenuouſly all innovations and hereſies, particularly the errors of the Latin church. This being done, the archbiſhop ſays, "The grace of the Holy Spirit, through my humility, exalts thee N. archimandrite or hieromonachus, beloved of God, to be biſhop of the cities N. N. which God preſerve." With much ceremony the biſhop elect is then conducted from the theatre, within the rails of the holy altar, where he kneels down with the other biſhops, who hold open over his head the holy goſpel with the letters inverted, the archbiſhop ſaying aloud, "The divine grace, which always healeth our infirmities, and ſupplieth our defects, by my hand conducteth thee N. archimandrite or hieromonachus, beloved of God, biſhop elect of the cities of N. N. which God preſerve!—Let us pray therefore for him, that the Grace of the moſt Holy Spirit may come upon him." Then the prieſts ſay thrice, "Lord have mercy upon us;" and while the biſhops continue to hold the goſpel, the archbiſhop ſigns the newly conſecrated biſhop thrice with the ſign of the croſs, ſaying, "In the name of the Father, and of the Son, and of the Holy Ghoſt, now and for ever, even unto ages of ages. Amen." Then all the biſhops putting their right hands on his head, the archbiſhop prays that he may be confirmed in the office of which they have judged him worthy, that his prieſthood may be rendered irreproachable, and that he himſelf may be made holy and worthy to be heard of God. After this, one of the aſſiſting biſhops reads a ſhort litany in a low voice, to be heard only by thoſe within the altar, and the other biſhops make the reſponſes. At the end of the litany the archbiſhop, laying his hand again upon the head of the newly conſecrated biſhop, prays in very decent and devout terms, that Chriſt will render him an imitator of himſelf, the true Shepherd; that he will make him a leader of the blind, a light to thoſe who walk in darkneſs, and a teacher of infants; that he may ſhine in the world, and receive at laſt the great reward prepared for thoſe who contend boldly for the preaching of the goſpel. After this the paſtoral-ſtaff is delivered to the new biſhop, with a very proper and ſolemn exhortation from the archbiſhop, to feed the flock of Chriſt committed to his care.

The laſt ſacrament of the Greek church is that of the holy oil or euchelaion, which is not confined to perſons *periculoſe ægrotantibus, et mortis periculo imminente*, like the extreme unction of the Romiſh church; but is adminiſtered, if required, to devout perſons upon the ſlighteſt malady. Though this ordinance is derived from St James, chap. v. ver. 14, 15. it is by no means deemed neceſſary to ſalvation, or obligatory upon all Chriſtians; and it is well that it is not, for ſeven prieſts are required to adminiſter it regularly, and it cannot be adminiſtered at all by leſs than three. The oil is conſecrated with much ſolemnity; after which each prieſt, in his turn, takes a twig, and dipping it in the oil now made holy, anoints the ſick perſon croſs-wiſe, on the forehead, on the noſtrils, on the paps, the mouth, the breaſt, and both ſides of the hands, praying that he may be delivered from the bodily infirmity under which he labours, and raiſed up by the grace of Jeſus Chriſt.

26 The lavipedium.

In the Greek, as well as in the Latin church, there is a ſervice, called the divine *lavipedium*, obſerved on the Thurſday of paſſion-week, in imitation of our Saviour's humility. At Conſtantinople Jeſus Chriſt is, on this occaſion, perſonified by the Patriarch, and everywhere elſe by the biſhop of the dioceſe, and the twelve apoſtles by twelve regular prieſts, when a ludicrous conteſt ariſes who ſhall repreſent Judas; for the name attaches for life. This office is performed at the weſt end of the church, where an arm-chair is ſet at the bottom, facing the eaſt, for the biſhop; and on each ſide are placed twelve chairs for the twelve prieſts, who are to repreſent the twelve apoſtles. The prayers and hymns uſed on this occaſion are exceedingly beautiful and appropriate; and when the firſt goſpel, relating our Saviour's waſhing of his diſciples feet, begins to be read, the biſhop or patriarch riſes up, and takes off his pontifical veſtments by himſelf without aſſiſtance. He then girds himſelf with a towel, and taking a baſon of water in his hand, kneels down and waſhes one foot of each prieſt, beginning with the youngeſt; and after having waſhed it he kiſſes it. All this is done as the ſeveral circumſtances are read; and when he comes to the laſt prieſt, who is ſuppoſed to repreſent Peter, that prieſt riſeth up and ſaith, "Lord, doſt thou waſh my feet?" &c. The biſhop anſwers in the words of our Saviour; and having finiſhed the whole, puts on his garments again, and ſits down; and as the ſecond goſpel is read (K), repeats the words of our Saviour, "Know ye what I have done unto you?" &c. The office is certainly ancient, and, if decently performed, muſt be affecting.

27 The privileges of the patriarch of Conſtantinople.

Under the word Patriarchs, *Encycl.* we have given a ſufficient account of the riſe of the patriarchates, as well as of the various degrees of rank and authority claimed by the biſhops of ſeveral other ſees in the Greek chuch. It may be proper to add here, that after the taking of Conſtantinople by Mohammed II. he continued to the patriarch of that city the ſame preſent which the Greek emperors had been accuſtomed to make—a paſtoral ſtaff, a white horſe, and four hundred ducats in gold. To the Greek church and the maintenance of its clergy he left indeed ample revenues, which they have gradually ſacrificed to their inconſtancy,

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(I) In the Greek church all pariſh prieſts are called *papas* or popes; and the proto-pope is an archpreſbyter.

(K) The firſt goſpel is John xiii. 3—12. The ſecond goſpel is John xiii. 12—18.

cy, their ambition, and their private jealouſy. Still, however, the patriarch of Conſtantinople fills a very lucrative and high office. "Beſides the power of nominating the other three patriarchs, and all epiſcopal dignitaries (ſays Mr Dallaway), he enjoys a moſt extenſive juriſdiction, compriſing the churches of Anatolia, Greece, Wallachia, Moldavia, and the iſlands of the Archipelago. Since the cloſe of the ſixteenth century, the Ruſſian church has claimed a juriſdiction independent of the ſee of Conſtantinople; though appeals have been made to that ſee in caſes of extraordinary importance. The influence of the patriarch with the Porte is very extenſive, as far as his own nation is concerned. His memorials are never denied; and he can, in fact, command the death, the exile, impriſonment for life, depoſition from offices, or pecuniary fine, of any Greek whom he may be inclined to puniſh with rigour, or who has treated his authority with contempt. On the death of the patriarch the moſt eager competition is exerted to fill the vacant throne; which, as it is obtained by bribery and intrigue, is of courſe a very unſtable ſeat to the ſucceſsful candidate, ſhould another offer to accept the appointment at a lower ſalary." For a fuller account of the doctrines, diſcipline, and worſhip of the Greek church at preſent, we refer the reader to *King's Rites and Ceremonies of the Greek Church in Ruſſia*, and to *Dallaway's Conſtantinople ancient and modern* (publiſhed in 1797); from which two works this abſtract has been moſtly taken.

CHUSAN-Islands, a cluſter of ſmall iſlands on the eaſt coſt of China, which were viſited by Lord Macartney in his courſe to Pekin. Moſt of theſe iſlands ſeem to be hills riſing regularly out of the ſea, and rounded at top, as if any points or angles exiſting in their original formation had been gradually worn off into a globular and uniform ſhape. Many of them, though cloſe to each other, are divided by channels of great depth. They reſt upon a foundation of grey or red granite, ſome part reſembling porphyry, except in hardneſs. They were, certainly, not formed by the ſucceſſive alluvian from the earth brought into the ſea by the great river at whoſe mouth they are ſituated, like the numerous low and muddy iſlands at the mouth of the Po, and many others; but ſhould rather be conſidered as the remains of part of the continent thus ſcooped and furrowed, as it were, into iſlands, by the force of violent torrents carrying off, further into the ſea, whatever was leſs reſiſtable than the rocks juſt mentioned. Some of them wore a very inviting aſpect; one in particular, called Poo-too, is deſcribed as a perfect paradiſe. This ſpot was choſen, no doubt, for its natural beauties, and afterwards embelliſhed, by a ſet of religious men, who, to the number of three thouſand, poſſeſs the whole of it, living there in a ſtate of celibacy. It contains four hundred temples, to each of which are annexed dwelling-houſes and gardens for the accommodation of thoſe monks. This large monaſtery, as it may be called, is richly endowed, and its fame is ſpread throughout the empire.

The Engliſh Eaſt India Company had once a factory at Chuſan, the principal of theſe iſlands, from which they were many years ago interdicted. This, according to the account of a Chineſe merchant who remembered the factory, was not occaſioned by any offence given by the Engliſh, but by the avarice of the officers governing at Canton, who draw large ſums from the accumulation of foreign trade in that port. Perhaps, too, the exceſſive jealouſy of the Chineſe government might fancy danger in the unreſtrained communication between foreigners and the ſubjects of that empire in ſeveral of its ports at the ſame time.

Ting-hai, the chief town of Chuſan, reſembles Venice, but on a ſmaller ſcale. It is ſurrounded, as well as interſected, by canals, over which are thrown ſteep bridges, aſcended by ſteps like the Rialto. The ſtreets are narrow, and paved with ſquare flat ſtones; but the houſes, unlike the Venetian buildings, are low and moſtly of one ſtory. The ornaments of theſe buildings are confined chiefly to the roofs, on the ridges of which are uncouth figures of animals in clay, ſtone, or iron. The town is full of ſhops, containing chiefly articles of clothing, food, and furniture, diſplayed to full advantage. Even coffins are painted in a variety of lively and contraſting colours. The ſmaller quadrupeds, including dogs, intended for food, are expoſed alive for ſale, as well as poultry, and fiſh in tubs of water, with eels in ſand. When the gentlemen belonging to the embaſſy were at Ting-hai, they were ſtruck with the number of places where tin-leaf and ſticks of odoriferous wood were ſold for burning in the temples, which indicated no ſlight degree of ſuperſtition in the people. Superſtition, however, made them not idle; for throughout the whole place there was a quick and active induſtry. Men paſſed buſily through the ſtreets, while not an individual was ſeen aſking alms; and the women were employed in the ſhops. At Chuſan, the number of valuable harbours, or places of perfect ſecurity for ſhips of any burden, is almoſt equal to the number of iſlands. This advantage, together with that of their central ſituation, in reſpect to the eaſtern coſt of China, and the vicinity of Corea, Japan, Leoo-keoo, and Formoſa, attract conſiderable commerce, eſpecially to Ning-poo, a city of great trade in the adjoining province of Che-chiang, to which all the Chuſan iſlands are annexed. From one port in that province twelve veſſels ſail annually for copper to Japan.

According to Brookes, Chuſan is in N. Lat. 30. 0. and E. Long. 124. 0.

CINARA, or Cynara, which we tranſlate *artichoke*, is, according to Profeſſor Beckmann, the name which was given by the ancients to a plant very different from the artichoke of our kitchen gardens, though he admits that they belong to the ſame genus. The proofs which he adduces for the truth of his opinion are too tedious to be introduced into this Work, eſpecially as they appear not to us to be abſolutely concluſive. We muſt therefore refer the reader to his Hiſtory of Inventions. The *cinara*, *carduus*, and *ſcolymus* (ſee Scolymus in this Supplement), were in his opinion ſpecies of the *thiſtle*, of which the *roots* and young *ſhoots*, as well as the bottom of the *calyx* of the laſt, were eaten. He has proved indeed, he thinks, that the Greeks and Romans uſed the pulpy bottom of the calyx, and the tendereſt ſtalks and young ſhoots of many plants belonging to the thiſtle kind, in the ſame manner as we uſe artichokes and cardoons, but that theſe latter were unknown to them.

"It appears probable (ſays he) that the uſe of theſe thiſtles, at leaſt in Italy and Europe in general, was in the courſe of time laid aſide and forgotten, and that the artichoke, when it was firſt brought to Italy from the Levant, was conſidered as a new ſpecies of food. It is undoubtedly certain that our artichoke was firſt known in that country in the 15th century. Hermolaus Barbarus, who died in 1494, relates that this plant was firſt ſeen at Venice in a garden in 1473, at which time it was very ſcarce. About the year 1466, one of the family of Strozza brought the firſt artichokes to Florence from Naples. Politian, in a letter in which he deſcribes the diſhes he found at a grand entertainment in Italy in 1488, among theſe mentions artichokes. They were introduced into France in the beginning of the 16th century, and into England in the reign of Henry VIII."

The original country of the artichoke is unknown. Linnæus ſays that it grew wild in Narbonne, Italy, and Sicily, as the cardoon did in Crete; but our author has proved very ſufficiently, that with reſpect to both theſe facts the great botaniſt was miſinformed. The artichoke is certainly known in Perſia; but Tavernier ſays expreſsly, that it was carried thither, like aſparagus and other European vegetables of the kitchen garden, by the Carmelite and other monks; and that it was only in latter times that it became common.

CINNABAR. See CHEMISTRY in this Supplement, n° 91.

CIRCLE OF CURVATURE, or circle of equicurvature, is that circle which has the ſame curvature with a given curve at a certain point; or that circle whoſe radius is equal to the radius of curvature of the given curve at that point.

CIRCLES of Declination are great circles interſecting each other in the poles of the world.

CIRCLE of Diſſipation, in optics. See OPTICS, *Encycl.* n° 253.

CIRCLE Equant, in the Ptolemaic aſtronomy, is a circle deſcribed on the centre of the equant. Its chief uſe is to find the variation of the firſt inequality.

CIRCLES of Excurſion are little circles parallel to the ecliptic, and at ſuch a diſtance from it, as that the excurſions of the planets towards the poles of the ecliptic may be included within them; being uſually fixed at about 10 degrees.

CIRCLES of Poſition, are circles paſſing through the common interſections of the horizon and meridian, and through any degree of the ecliptic, or the centre of any ſtar, or other point in the heavens; and are uſed for finding out the ſituation or poſition of any ſtar. Theſe are uſually ſix in number, cutting the equinoctial into 12 equal parts, which the aſtrologers call the *celeſtial houſes*, and hence they are ſometimes called *circles of the celeſtial houſes*.

CIRCULAR LINES, a name given by ſome authors to ſuch ſtraight lines as are divided by means of the diviſions made in the arch of a circle; ſuch as the ſines, tangents, ſecants, &c.

CIRCULAR Parts, called, from the uſe which he firſt made of them, *Napier's* circular parts, are the five parts of a right-angled or a quadrantal ſpherical triangle; they are the two legs, the complement of the hypothenuſe, and the complements of the two oblique angles.

Concerning theſe circular parts, Napier gave a general rule in his *Logarithmorum Canonis Deſcriptio*, which is this; "The rectangle under the radius and the ſine of the middle part is equal to the rectangle under the tangents of the adjacent parts, and to the rectangle under the coſines of the oppoſite parts. The right angle or quadrantal ſide being neglected, the two ſides and the complements of the other three natural parts are called the *circular parts*, as they follow each other as it were in a circular order. Of theſe, any one being fixed upon as the middle part, thoſe next it are the adjacent, and thoſe fartheſt from it the oppoſite parts."

This rule contains within itſelf all the particular rules for the ſolution of right-angled ſpherical triangles, and they were thus brought into one general comprehenſive theorem, for the ſake of the memory; as thus, by charging the memory with this one rule alone: All the caſes of right-angled ſpherical triangles may be reſolved, and thoſe of oblique ones alſo, by letting fall a perpendicular, excepting the two caſes in which there are given either the three ſides, or the three angles. And for theſe a ſimilar expedient has been deviſed by Lord Buchan and Dr Minto, which may be thus expreſſed: "Of the circular parts of an oblique ſpherical triangle, the rectangle under the tangents of half the ſum and half the difference of the ſegments at the middle part (formed by a perpendicular drawn from an angle to the oppoſite ſide), is equal to the rectangle under the tangents of half the ſum and half the difference of the oppoſite parts." By the circular parts of an oblique ſpherical triangle are meant its three ſides and the ſupplements of its three angles. Any of theſe ſix being aſſumed as a middle part, the oppoſite parts are thoſe two of the ſame denomination with it, that is, if the middle part is one of the ſides, the oppoſite parts are the other two, and, if the middle part is the ſupplement of one of the angles, the oppoſite parts are the ſupplements of the other two. Since every plane triangle may be conſidered as deſcribed on the ſurface of a ſphere of an infinite radius, theſe two rules may be applied to plane triangles, provided the middle part be reſtricted to a ſide.

Thus it appears that two ſimple rules ſuffice for the ſolution of all the poſſible caſes of plane and ſpherical triangles. Theſe rules, from their neatneſs, and the manner in which they are expreſſed, cannot fail of engraving themſelves deeply on the memory of every one who is a little verſed in trigonometry. It is a circumſtance worthy of notice, that a perſon of a very weak memory may carry the whole art of trigonometry in his head.

CIRCULATING DECIMALS. See DECIMALS in this Supplement.

CLOCK, a machine for meaſuring time, of which a deſcription is given in the Encyclopædia. For the ſcientific principles of *clock* and *watch-making*, as well as for a ſhort account of the moſt valuable conſtructions, ſee WATCH-*Making* in this Supplement.

COACH, as we have obſerved in the Encyclopædia, is a very modern invention, if by that word be meant a covered carriage ſuſpended on ſprings. We learn, indeed, from the laborious reſearches of Profeſſor Beckmann, that coaches of ſome kind were known in the beginning of the 16th century; but they were uſed only by women of the firſt rank, for the men thought it diſgraceful to ride in them. At that period, when the electors and princes did not chooſe to be preſent at the meetings of the ſtates, they excuſed themſelves by informing the emperor that their health did not permit them

them to ride on horſeback; and it was conſidered as a point eſtabliſhed, that it was unbecoming for them to ride like women. It is certain, however, that, about the end of the 15th century, the emperor, kings, and princes, began to employ covered carriages on journeys, and afterwards on public ſolemnities.

The wedding carriage of the firſt wife of the Emperor Leopold, who was a Spaniſh princeſs, coſt, together with the harneſs, 38,000 florins. The coaches uſed by that Emperor are thus deſcribed by Kink: “In the imperial coaches no great magnificence was to be ſeen; they were covered over with red cloth and black nails. The harneſs was black, and in the whole work there was no gold. The pannels were of glaſs, and on this account they were called the *imperial glaſs coaches*. On feſtivals the harneſs was ornamented with red ſilk fringes. The imperial coaches were diſtinguiſhed only by their having leather traces; but the ladies in the imperial ſuite were obliged to be contented with carriages, the traces of which were made of ropes.” At the magnificent court of Duke Erneſt Auguſtus of Hanover, there were in the year 1681 fifty gilt coaches with ſix horſes each. So early did Hanover begin to ſurpaſs other cities in the number of its carriages. The firſt time that ambaſſadors appeared in coaches on a public ſolemnity was at the imperial commiſſion held at Erfurth in 1613 reſpecting the affair of Juliers.

In the hiſtory of France we find many proofs that at Paris, in the 14th, 15th, and even 16th centuries, the French monarchs rode commonly on horſes, the ſervants of the court on mules, and the princeſſes, together with the principal ladies, ſometimes on aſſes. Perſons of the firſt rank often ſat behind their equerry, and the horſe was often led by ſervants. Carriages, however, of ſome kind appear to have been uſed very early in France. An ordinance of Philip the Fair, iſſued in 1294 for ſuppreſſing luxury, and in which the citizens wives are forbid to uſe carriages (*cars*), is ſtill preſerved. Under Francis I. or rather about 1550, ſomewhat later, there were in Paris for the firſt time only three coaches.

The oldeſt carriages uſed by the ladies in England were known under the now forgotten name of *whirlicotes*. When Richard II. towards the end of the 14th century, was obliged to fly before his rebellious ſubjects, he and all his followers were on horſeback; his mother only, who was indiſpoſed, rode in a carriage. This, however, became afterwards ſomewhat unfaſhionable, when that monarch's queen, Ann, the daughter of the Emperor Charles IV. ſhewed the Engliſh ladies how gracefully and conveniently ſhe could ride on a ſide-ſaddle. Whirlicotes were laid aſide, therefore, except at coronations and other public ſolemnities. Coaches were firſt known in England about the year 1580, and, as Stow ſays, were introduced from Germany by Fitzallen, earl of Arundel. In the year 1598, when the Engliſh ambaſſador came to Scotland, he had a coach with him. Anderſon places the period when coaches began to be in common uſe about the year 1605. The celebrated duke of Buckingham, the unworthy favourite of two kings, was the firſt perſon who rode with a coach and ſix horſes, in 1619. To ridicule this new pomp, the earl of Northumberland put eight horſes to his carriage.

Reſpecting the progreſs of luxury with regard to coaches, the reader will find much curious information in the firſt volume of Profeſſor Beckmann's *Hiſtory of Inventions*. It is perhaps one of the moſt entertaining articles in that very learned work. The author, however, with all his labour, has not been able to aſcertain the country in which coaches hung on ſprings were firſt uſed; but he ſeems inclined to give the credit of the invention to Hungary.

COBALT (ſee Chemistry-*Index*, in this Supplement), is a valuable article to potters and dyers. To fit it for their uſe, it is firſt roaſted and freed from the foreign mineral bodies with which it is united: it is then well calcined, and ſold either mixed or unmixed with fine ſand under the name of zaffer (*zaffera*); or it is melted with ſiliceous earth and potaſhes to a kind of blue glaſs called *ſmalt*, which when ground very fine is known in commerce by the name of *powder blue*. All theſe articles, becauſe they are moſt durable pigments, and thoſe which beſt withſtand fire, and becauſe one can produce with them every ſhade of blue, are employed above all for tinging cryſtal and for enamelling; for counterfeiting opaque and tranſparent precious ſtones, and for painting and varniſhing real porcelain and earthen and potters ware. This colour is indiſpenſably neceſſary to the painter when he is deſirous of imitating the fine azure colour of many butterflies and other natural objects; and the cheaper kind is employed to give a blueiſh tinge to new-waſhed linen, which ſo readily changes to a diſagreeable yellow, though not without injury to the health as well as to the linen.

Profeſſor Beckmann, in his *Hiſtory of Inventions*, gives the following account of the paint prepared from cobalt. “About the end of the 15th century cobalt appears to have been dug up in great quantity in the mines on the borders of Saxony and Bohemia, diſcovered not long before that period. As it was not known at firſt to what uſe it could be applied, it was thrown aſide as a uſeleſs mineral. The miners had an averſion to it, not only becauſe it gave them much fruitleſs labour, but becauſe it often proved prejudicial to their health by the arſenical particles with which it was combined; and it appears even that the mineralogical name *cobalt* then firſt took its riſe. At any rate, I have never met with it before the beginning of the 16th century; and Matheſius and Agricola ſeem to have firſt uſed it in their writings. Friſch derives it from the Bohemian word *kow*, which ſignifies *metal*; but the conjecture that it was formed from *cobalus*, which was the name of a ſpirit that, according to the ſuperſtitious notions of the times, haunted mines, deſtroyed the labours of the miners, and often gave them a great deal of unneceſſary trouble, is more probable; and there is reaſon to think that the latter is borrowed from the Greek. The miners, perhaps, gave this name to the mineral out of joke, becauſe it thwarted them as much as the ſuppoſed ſpirit, by exciting falſe hopes, and rendering their labour often fruitleſs. It was once cuſtomary, therefore, to introduce into the church ſervice a prayer that God would preſerve miners and their works from *kobolts* and ſpirits.

“Reſpecting the invention of making an uſeful kind of blue glaſs from cobalt, we have no better information than that which Klotzſch has publiſhed from the papers of Chriſtian Lehmann. The former, author of an hiſtorical work reſpecting the upper diſtrict of the mines in Miſnia, and a clergyman at Scheibenberg, collected with great diligence every information that reſpected the hiſtory of the neighbouring country, and died at a great age in 1688. According to his account, the colour mills at the time when he wrote were about 100 years old; and as he began firſt to write towards the end of the thirty years war, the invention ſeems to fall about 1540 or 1560. He relates the circumſtance as follows: 'Chriſtopher Schurer, a glaſs-maker at Platten, a place which belongs ſtill to Bohemia, retired to Neudeck, where he eſtabliſhed his buſineſs. Being once at Schneeberg, he collected ſome of the beautiful coloured pieces of cobalt which were found there, tried them in his furnace; and finding that they melted, he mixed ſome cobalt with glaſs metal, and obtained fine blue glaſs. At firſt he prepared it only for the uſe of the potters; but in the courſe of time it was carried as an article of merchandiſe to Nuremberg, and thence to Holland. As painting on glaſs was then much cultivated in Holland, the artiſts there knew better how to appreciate this invention. Some Dutchmen therefore repaired to Neudeck, in order that they might learn the proceſs uſed in preparing this new paint. By great promiſes they perſuaded the inventor to remove to Magdeburg, where he alſo made glaſs from the cobalt of Schneeberg; but he again returned to his former reſidence, where he conſtructed a handmill to grind his glaſs, and afterwards erected one driven by water. At that period the colour was worth 7¼ dollars per cwt. and in Holland from 50 to 60 florins. Eight colour mills of the ſame kind, for which roaſted cobalt was procured in caſks from Schneeberg, were ſoon conſtructed in Holland; and it appears that the Dutch muſt have been much better acquainted with the art of preparing, and particularly with that of grinding it, than the Saxons; for the Elector John George ſent for two colour-makers from Holland, and gave a thouſand florins towards the enabling them to improve the art. He was induced to make this advance chiefly by a remark of the people of Schneeberg, that the part of the cobalt which dropped down while it was roaſting contained more colour than the roaſted cobalt itſelf. In a little time more colour-mills were erected around Schneeberg. Hans Burghard, a merchant and chamberlain of Schneeberg, built one, by which the eleven mills at Platten were much injured. Paul Nordhoff, a Frieſlander, a man of great ingenuity, who lived at the Zwittermill, made a great many experiments in order to improve the colour; by which he was reduced to ſo much poverty that he was at length forced to abandon that place, where he had been employed for ten years in the colour-manufactory. He retired to Annaberg, eſtabliſhed there in 1649, by the aſſiſtance of a merchant at Leipſic, a colour-manufactory, of which he was appointed the director; and by theſe means rendered the Annaberg cobalt of utility. The conſumption of this article, however, muſt have decreaſed in the courſe of time; for in the year 1659, when there were mills of the ſame kind at more of the towns in the neighbourhood of mines, he had on hand above 8000 quintals.' Thus far Lehmann."

Koſsler ſays, that the Bohemian cobalt is not ſo good as that of Miſnia, and that its colour is more like that of aſhes. We truſt, however, that the qualities of foreign cobalt ſhall ſoon be a matter of little importance to the Britiſh artiſt, as a rich mine of this mineral has lately been diſcovered near Penzance in Cornwal.

COFFEA, the *Coffee-Tree*, is a plant which has been botanically deſcribed in the Encyclopædia Britannica, where ſome account is likewiſe given of the modes of cultivating it, as well as of the qualities of its fruit. Since that account, however, was publiſhed, two works have fallen into our hands, from which we deem it our duty to make ſuch extracts as may not only correct ſome miſtakes which we had committed, but alſo communicate uſeful information to the public.

In our former article we adopted the common opinion, that the coffee produced in Arabia is ſo greatly ſuperior to that which is raiſed everywhere elſe, that it is vain to think of cultivating the plant to any extent in the Weſt India iſlands. We are happy to find that this is a vulgar error. In the year 1783, when the cultivation of coffee was not ſo well underſtood in Jamaica as at preſent, ſome ſamples from that iſland were produced in London, and pronounced by the dealers to be equal to the very beſt brought from the Eaſt. "Two of the ſamples were equal to the beſt Mocha coffee, and two more of them ſuperior to any coffee to be had at the grocers ſhops in London, unleſs you will pay the price of *picked* coffee for it, which is two ſhillings per pound more than for that which they call the *beſt* coffee. All the reſt of the ſamples were far from bad coffee, and very little inferior, if at all, to what the grocers call *beſt* coffee *."

If this be ſo, it ſurely becomes the legiſlature of Great Britain to encourage the cultivation of coffee in the Weſt Indies, eſpecially as it thrives beſt in ſoil which is not fit for the ſugar-cane, and may be raiſed in conſiderable quantities by thoſe who are not able to ſtock a ſugar plantation. The encouraging every article which increaſes the intercourſe with our colonies is increaſing our commerce. The payment for all the ſtaples of the Weſt Indies is made in our manufactures; the ſale of which muſt increaſe in proportion to the numbers that are employed in the cultivation of what is bartered for them. Our Weſt India iſlands, without draining us of ſpecie or bullion, can ſupply us with many of thoſe very articles for which we are drained in other parts of the world, and particularly with coffee.

To give a detailed account of the introduction of the coffee-tree into the Weſt Indies, would ſwell this article to very little purpoſe. According to Boerhaave, a Dutch governor was the firſt perſon who procured freſh berries from Mocha, and planted them in Batavia; and in the year 1690 ſent a plant from thence to Amſterdam, which came to maturity, and produced thoſe berries which have ſince furniſhed all that is now cultivated in the Weſt Indies.

In 1714 a plant from the garden of Amſterdam was ſent by Mr Pancras, a burgomaſter and director of the botanic garden, as a preſent to Louis XIV. which was placed in the garden at Marly. In 1718, the Dutch began to cultivate coffee in Surinam; in 1721, the French began to cultivate it at Cayenne; in 1727, at Martinico; and in 1728, the Engliſh began to cultivate it in Jamaica.

As it has been more cultivated in the French Weſt India iſlands than in the Britiſh, it may be of importance to our coloniſts to be made acquainted with the practice of the French planters. Accordingly Dr Laborie, a royaliſt of St Domingo, has lately publiſhed a volume for their inſtruction on this ſubject; in which are

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* *Moſeley's Treatiſe on Coffee.*

are many judicious obſervations, the reſult of long experience, reſpecting the ſoil fit for a coffee plantation; the various eſtabliſhments neceſſary; the cultivation of the coffee-tree through the ſeveral ſtages of its growth and duration; and the management and uſe of the negroes and cattle.

With reſpect to ſoil, it is a fact, ſays he, beyond contradiction, that low lands, and even the mountains near the champaign country, are leſs proper for the production of coffee, than lands which are high and at a diſtance from the ſea. The coffee-tree delights in a comparatively cool climate, and in an open and permeable virgin ſoil; and is hurt by the parching deſtructive air of the ſea. The ſoil on the mountains of St Domingo conſiſts generally of a bed of mould more or leſs deep; but which, for the production of coffee-trees, ought not to be leſs than four or five feet. If the declivity be gentle, the ſofteſt and moſt friable earth is preferable to all others; but in ſteep grounds a firm though not clayey ſoil, mixed with a proportion of gravel or ſmall ſtones, through which the water may find an eaſy way, is the moſt deſirable. The colour of the ground is of little conſequence, though ſuch as is ſomewhat reddiſh is generally to be preferred. With regard to expoſure, the north and weſt are the moſt eligible in low and hot ſituations, becauſe theſe expoſures are the cooleſt; and on the higheſt mountains the ſouth and eaſt are to be choſen, becauſe they are the hotteſt. On the whole, neither the higheſt nor the loweſt ſituations are the beſt, but thoſe which are conſiderably above the middle of the mountains.

Whatever be the planter's circumſtances in point of fortune, and our author thinks that he ought not to undertake a ſettlement without the command of 3000 or 4000 pounds ſterling, he ought not to ſet out with a great number of negroes. If he cannot command a plentiful ſupply of victuals from ſome contiguous plantation, ſix, or at the moſt twelve, male negroes, with one or two women, will be found ſufficient to make the firſt eſſay. After building two huts, one for the maſter or overſeer and the other for the ſlaves, they are to commence their operations by cutting away the underwood and creeping plants with the bill, and felling the trees. The trees are to be cut as low as poſſible, but the roots are to be left in the ground, becauſe they preſerve the ſoil during the firſt period of culture; and in burning this maſs of wood and ſhrubs, the only way ſometimes of clearing the ground, care muſt be taken that the fire be nowhere ſo violent as to convert the ſoil into the conſiſtence of brick, which it is very apt to do if the ſoil be clayey. Amid the coffee-trees, after they are planted, may be ſown beans, maize, and all kinds of eſculent plants, pot herbs, and roots; but particular care muſt be taken to remove from theſe plantations all creeping plants, ſuch as melons, yams, potatoes, gourds, and more eſpecially tobacco, which multiplies to a vaſt extent, and exhauſts the ground.

In St Domingo the moſt approved method of planting the coffee-tree is in ſtraight rows croſſing each other at right angles, and the diſtance between the plants is regulated by the quality and expoſure of the ground. The richer the ſoil, the expoſures being the ſame, and the cooler the expoſure, the quality of the ſoil being the ſame, the farther muſt the trees be planted aſunder. If on the north and weſt the ground be good, plant ſtill farther; but, on the contrary, if to the eaſt or ſouth it be light (which it generally is), plant ſtill nearer. Thus if it be proper on a ſouth or eaſt expoſure to plant at the diſtance of ſix feet, it will be neceſſary to plant at the diſtance of ſeven on a weſt or north expoſure, if the ground be of the ſame quality as in the other ſituations.

Though coffee, like all other vegetables, grows from the ſeed, Dr Laborie adviſes, in the forming of large plantations, to make uſe of ſaplings reared in nurſeries; and the ſituation fitteſt for a nurſery is a plain, or at leaſt a ground of gentle aſcent, where the mould is crumbly. In forming a nurſery, ſome plant the whole cherry; but our author recommends the taking off the ſkin, and waſhing the ſeparated ſeeds; in which we ſuſpect that he is miſtaken, as his practice is certainly a deviation from nature. The nurſery muſt be kept very clear of weeds, and neither corn nor any thing elſe ſown in it.

The beſt ſeaſon for tranſplanting the ſaplings is during the genial rains of April and May, when great attention is required, as the treaſures of future harveſts are at ſtake. Thoſe plants are the fitteſt for being removed which, in the language of our author, are *crowned*, or have each four little boughs; and, if the ſeeds were freſh and ſown in furrows about an inch from each other, this perfection is generally attained in the courſe of a year. The ſaplings muſt not be pulled up by force, but carefully raiſed by means of a flat, ſharp, iron ſhovel, thruſt deep under their roots; and the ſooner they are planted, after being taken up, the better.

In planting, the firſt thing to be done is to thruſt into the ground a dibble, or ſharp pointed ſtick, round which a hole is dug from nine to twelve inches in diameter, and from fifteen to eighteen in depth. Then a quantity of the mould taken out of the hole is thrown back into it, till its depth be diminiſhed about four or ſix inches; and the plant being ſupported with the left hand, in the middle of the hole, while the end of its ſtraight root, which our author calls its pivot, touches lightly the new bed, the ſurrounding mould is with the right hand thrown in, to the height of ſix inches. This being lightly preſſed down with both hands, more earth is thrown in and preſſed in the ſame manner, care being taken not to hurt, or bend, or diſplace the ſapling, which muſt be ſet ſo deep that its two inferior branches be rather below the level of the ground. On this account three or four inches of the hole are left open, which, by the time that theſe branches riſe above its margin, are filled up by the ſurrounding earth. The buſineſs is finiſhed by ſinking the ſharp-pointed ſtick at the upper margin of the hole, where it ſerves as a ſmall fence to the infant tree. In hot ſituations plantain trees are intermingled with the coffee trees for the purpoſe of ſhade and coolneſs. They are uſually placed in every fourth or ſixth row, as the trees are more or leſs diſtant, and the expoſure more or leſs hot.

To the buſineſs of planting very ſoon ſucceeds that of weeding; for there is hardly any plant to which weeds are ſo pernicious as the coffee-tree: they cauſe it to grow yellow, fade, wither, and periſh. Where the ground ſlopes much, eſpecially if the ſoil be ſoft and friable, the weeds muſt be taken up by the hand; for if they be rooted out by the hoe, the ſoil will be ſo looſened that the rains will ſweep it away. Some weeds, however, from the depth of their roots muſt be dug up; and when that is the caſe the earth muſt be carefully returned and preſſed down. If, in weeding, any ſaplings be found withered, others of the ſame ſize muſt be brought from the nurſery and planted in their ſtead, with what our author calls their clod, *i. e.* with the earth of the nurſery adhering to their roots. If any ſapling be found broken or twiſted, it muſt be cut cloſe by the ground in a ſloping direction, the cut ſurface facing the north, and it will ſoon put forth ſuckers, of which the beſt only need be preſerved. In plantations of eighteen or twenty months old trees are often found with yellow, withered leaves, of which the cauſe is ſometimes a premature load of fruit, which muſt therefore be inſtantly removed or the tree will periſh. If, after this, it begin not in a few days to recover, it is probably eaten at the roots by a large white worm reſembling a ſlug. In that caſe the tree muſt be removed, the worm taken out, and before another tree be planted in its ſtead, a large hole muſt be made in the ground, expoſed to the influence of the ſun at leaſt for a fortnight.

The natural height of the coffee tree is from 15 to 18 feet; and if left to itſelf it would have the form of moſt other trees, *i. e.* a naked trunk and a branchy head. This is prevented by what the planters call *ſtopping*; which is performed by cutting off the top of the tree when it has arrived at the proper height, which varies according to circumſtances. In the beſt ſoil and moſt genial expoſure, it is ſuffered to grow to the height of five feet, and in the worſt ſtopped at two; but under the ſame aſpect, and on ground of the ſame quality, all the trees ought to be ſtopped at the ſame height. This operation of ſtopping is very apt to make the trees put forth ſuperfluous branches, which renders them inacceſſible to the genial warmth of the ſun, and, of courſe, deficient in the powers of fructification. Theſe muſt be *plucked* away while yet tender; for if they be ſuffered to grow till it become neceſſary to cut them, a number of ſprouts ſucceed; whereas, when they are plucked, the wound ſoon cicatrizes, and nothing follows.

The ſaw and the knife, however, muſt ſometimes be uſed; for when trees grow old their heads are apt to ſpoil; ſuperfluous branches may have been left upon them through neglect; a bough may have been broken by accident; or branches may be ſpent by too great a load of fruit. In all theſe caſes recourſe muſt be had to pruning, which ſhould be performed immediately after crop, and in ſuch a manner as that the tree, when it puts forth its new branches, may ſtill have as much as poſſible its natural or former appearance. This will be accompliſhed by cutting the withered bough immediately above a knot, whence a good ſecondary branch is put forth, which may be eaſily trained into the proper ſhape. Our author directs the cut to be always made ſo as that the ſloping ſurface ſhall face the north; by which expoſure it will eſcape the injury which it would otherwiſe receive from the exceſſive heat of the ſun. This is a good advice; but it would ſtill be an improvement on it to treat the wound with Forſyth's or Hit's plaſter, which we have deſcribed elſewhere (See *Encycl.* Vol. XVIII. page 562). When the tree is completely pruned, the moſs and other excreſcences muſt be ſcraped from the trunk with a wooden knife, great care being taken not to injure the bark.

After pruning follows what is called *nipping*. This is nothing more than the removal of thoſe ſuperfluous ſmall twigs which are ſent forth from every cut ſurface in ſuch numbers as would ſoon exhauſt the tree; and it is called nipping, becauſe they are plucked away by the hand, and not cut by the knife. It is needleſs to add, that when the ground begins to be impoveriſhed, it muſt be enriched by proper manure. This is known to every huſbandman both in Europe and in the Weſt Indies; but it is not perhaps ſo generally known that the weedings, and chiefly the red ſkins of coffee, when gathered into pits, are, in proceſs of time, converted into a black mould, which our author ſays makes the very beſt manure.

"The fruit of the coffee, when perfectly ripe, appears like a ſmall oval cherry. Under a red and ſhining ſkin a whitiſh clammy luſcious pulp preſents itſelf, which generally incloſes two ſeeds. Theſe ſeeds have one ſide flat, the other hemiſpherical. The firſt is marked with a longitudinal fiſſure, and the flat ſides are applied to each other. When the ſeeds are opened, they are found covered with a white, ligneous, brittle membrane, denominated *parchment*; on the inſide of which is another ſilver-coloured membrane, exceedingly thin, and ſeeming to originate from the fiſſure of the ſeeds. Sometimes the cherry has but one ſeed or grain, which then is in the form of a ſmall egg. This is peculiar to old decayed trees, or to the extremities of ſome ſmall branches."

The buſineſs of preparation conſiſts in taking the ſeed from its covering, in drying, and in cleaning it ſo as to have every advantage at market. Our author thinks that the beſt method of preparing the coffee is to ſtrip the ſeed of its outer ſkin immediately on its being pulled, and to dry it in its parchment. The proceſs has been already deſcribed in the Encyclopædia; but we believe it to be an injudicious one. We have the authority of a very eminent botaniſt *, well acquainted with all the vegetable productions of the Weſt Indies, to ſay, that the improvement which we have there mentioned, as propoſed by Mr Miller, is greatly preferable to Dr Laborie's practice. Indeed he himſelf admits, that coffee dried in the cherry is more heavy than when dried in parchment, and that it generally has a higher flavour. Nay, he ſays expreſsly, that "if a planter wants to have coffee of the firſt quality, either for himſelf or for his friends, he muſt ſet a part a number of his oldeſt trees, and not gather the fruit till it is ripened into *dryneſs*. It is in that manner, he believes, that the Arabians in Yemen make their little harveſts; and he declares, that coffee thus nouriſhed on the tree to the laſt moment, muſt have every perfection of which it is capable." His only plauſible objection is, that the trees are ſoon exhauſted when the fruit is left ſo long upon them; but doubtleſs this exhauſtion might be retarded by proper manure.

The chemical analyſis of coffee evinces that it poſſeſſes a great portion of mildly bitter and lightly aſtringent gummous and reſinous extract; a conſiderable quantity of oil; a fixed ſalt; and a volatile ſalt.—Theſe are its medicinal conſtituent principles. The intention of torrefaction is not only to make it deliver thoſe principles, and make them ſoluble in water, but to give it a property it does not poſſeſs in the natural ſtate of the berry. By the action of fire, its leguminous taſte and

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* *Dr Wright.*

the aqueous part of its mucilage are deſtroyed ; its ſaline properties are created and diſengaged, and its oil is rendered empyreumatic.—From thence ariſes the pungent ſmell, and exhilarating flavour, not found in its natural ſtate.

The roaſting of the berry to a proper degree requires great nicety : Du Four juſtly remarks, that the virtue and agreeableneſs of the drink depend on it, and that both are often injured in the ordinary method. Bernier ſays, when he was at Cairo, where it is ſo much uſed, he was aſſured by the beſt judges, that there were only two people in that great city, in the public way, who underſtood the preparing it in perfection. If it be under-done, its virtues will not be imparted, and in uſe it will load and oppreſs the ſtomach :—If it be overdone, it will yield a flat, burnt, and bitter taſte, its virtues will be deſtroyed, and in uſe it will heat the body, and act as an aſtringent.

Fourteen pounds weight of raw coffee is generally reduced, at the public roaſting houſes in London, to eleven pounds by the roaſting ; for which the dealer pays ſeven pence half-penny, at the rate of five ſhillings for every hundred weight. In Paris, the ſame quantity is reduced to ten pounds and an half. But the roaſting ought to be regulated by the age and quality of the coffee, and by nicer rules than the appearance of the fumes, and ſuch as are uſually practiſed : therefore the reduction muſt conſequently vary, and no exact ſtandard can be aſcertained. Beſides, by mixing different ſorts of coffee together, that require different degrees of heat and roaſting, coffee has ſeldom all the advantages it is capable of receiving to make it delicate, grateful, and pleaſant. This indeed can be effected no way ſo well as by people who have it roaſted in their own houſes, to their own taſte, and freſh as they want it for uſe. The cloſer it is confined at the time of roaſting, and till uſed, the better will its volatile pungency, flavour, and virtues, be preſerved.

The mode of preparing this beverage for common uſe differs in different countries, principally as to the additions made to it.—But though that is generally underſtood, and that taſte, conſtitution, the quality of the coffee, and the quantity intended to be drunk, muſt be conſulted, in regard to the proportion of coffee to the water in making it—yet there is one material point, the importance of which is not well underſtood, and which admits of no deviation.

The preſervation of the virtues of coffee, particularly when it is of a fine quality, and exempt from rankneſs, as has been ſaid, depends on carefully confining it after it has been roaſted ; and not powdering it until the time of uſing it, that the volatile and ethereal principles, generated by the fire, may not eſcape. But all this will ſignify nothing, and the beſt materials will be uſeleſs, unleſs the following important admonition is ſtrictly attended to ; which is, that after the liquor is made, it ſhould be bright and clear, and entirely exempt from the leaſt cloudineſs or foul appearance, from a ſuſpenſion of any of the particles of the ſubſtance of the coffee.

There is ſcarcely any vegetable infuſion or decoction whoſe effects differ from its groſs origin more than that of which we are ſpeaking. Coffee taken in ſubſtance cauſes oppreſſion at the ſtomach, heat, nauſea, and indigeſtion : conſequently a continued uſe of a preparation of it, in which any quantity of its ſubſtance is contained, beſides being diſguſting to the palate, muſt tend to produce the ſame indiſpoſitions. The reſiduum of the roaſted berry, after its virtues are extracted from it, is little more than an earthy calx, and muſt therefore be injurious.

The want of attention to this circumſtance has been the cauſe of many of the complaints againſt coffee, and of the averſion which ſome people have to it ; and it is from this conſideration that coffee ſhould not be prepared with milk inſtead of water, nor ſhould the milk be added to it on the fire, as is ſometimes the caſe, for economical dietetic purpoſes, where only a ſmall quantity of coffee is uſed, as the tenacity of the milk impedes the precipitation of the grounds, which is neceſſary for the purity of the liquor, and therefore neither the milk nor the ſugar ſhould be added until after it is made with water in the uſual way, and the clarification of it is completed (A).—The milk ſhould be hot when added to the liquor of the coffee, which ſhould alſo be hot, or both ſhould be heated together, in this mode of uſing coffee as an article of ſuſtenance.

If a knowledge of the principles of coffee, founded on examination and various experiments, added to obſervations made on the extenſive and indiſcriminate uſe of it, cannot authoriſe us to attribute to it any particular quality unfriendly to the human frame ; if the unerring teſt of experience has confirmed its utility, in many countries, not excluſively productive of thoſe inconveniences, habits, and diſeaſes, for which its peculiar properties ſeem moſt applicable—let thoſe properties be duly conſidered ; and let us reflect on the ſtate of our atmoſphere, the food and modes of life of the inhabitants, and the chronical infirmities which derive their origin from theſe ſources, and it will be evident what ſalutary effects might be expected from the general dietetic uſe of coffee in Great Britain.

COFFER-DAMS, or *Batardeaux*, in bridge-building, are encloſures formed for laying the foundation of piers, and for other works in water, to exclude the ſurrounding water, and ſo prevent it from interrupting the workmen.

COLCHESTER, the chief town in Eſſex, is deſcribed in the Encyclopædia Britannica ; but the deſcription is in many reſpects erroneous. The following account of it was ſent to us by an obliging correſpondent, who is deſirous that the place of his nativity may be accurately deſcribed in this Supplement.

Colcheſter is pleaſantly ſituated upon an eminence, gradually riſing on the ſouth ſide of the river Colne. It is the ancient *Colonia Camulodunum*, from which word Colonia, both the town and the river Colne received their names. The Saxons called it *Colneceaſter*. That it flouriſhed under the Romans, ſeveral buildings full of their bricks, and innumerable quantities of coin

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(A) It is not to coffee alone that this reflection is confined ; every article we uſe as a diluter demands the ſame attention. Malt liquors, particularly ſmall beer, which in this reſpect is much neglected, ought always to be carefully fined. The fæculent matter entangled by the mucilage of the malt is hurtful to digeſtion, and detrimental to health.

dug up in and about it, fully evince. In the year 1763, a curious teſſellated or moſaic pavement was found in the garden of the late Mr Barnard, ſurgeon in the High Street, now the property of Mr John Wallis, about three feet under the ſurface of the earth. The emperor Conſtantine the Great was born here, his mother Helen being daughter of Cool, governor or king of this diſtrict under the Romans. She is ſaid to have found out the croſs of Chriſt at Jeruſalem; and on that account the arms of this town are a croſs regulee between three ducal coronets, two in chief and one in baſe, the coronet in baſe paſſing through the croſs.

The walls wherewith the town was encompaſſed are ſtill tolerably entire on the ſouth, eaſt, and weſt ſides, but much decayed on the north ſide: they are generally about nine feet thick. By a ſtatute of King Henry VIII. this town was made the ſee of a ſuffragan biſhop.

This town is the moſt noted in England for making of baize; it is alſo of ſpecial note for candying the eringo roots, and for oyſters.

In the concluſion of the civil war 1648, this town ſuffered a ſevere ſiege of ten weeks; and the beſieged making a very reſolute defence, the ſiege was turned into a blockade, wherein the garriſon and inhabitants ſuffered the utmoſt extremity of hunger, being reduced to eat horſe-fleſh, dogs, and cats, and were at laſt obliged to ſurrender at diſcretion, when their two valiant chief officers, Sir Charles Lucas and Sir George Liſle, were ſhot under the caſtle walls in cold blood. Colcheſter is a borough by preſcription, and under that right ſends two members to parliament, all their charters being ſilent upon that head. The charter was renewed in 1763. The town is now governed by a mayor, recorder, 12 aldermen, 18 aſſiſtants, and 18 common-council men. Quarter-ſeſſions are held here four times in the year.

The famous abbey gate of St John is ſtill ſtanding, and allowed to be a ſurpriſing, curious, and beautiful piece of Gothic architecture, great numbers of perſons coming from remote parts to ſee it. It was built, together with the abbey, in 1097, and Gudo, ſteward to King William Rufus, laid the firſt ſtone.

St Ann's chapel, ſtanding at the eaſt end of the town, is valuable in the eſteem of antiquarians as a building of great note in the early days of Chriſtianity, and made no ſmall figure in hiſtory many centuries paſt. It is now pretty entire.

St Botoph's priory was founded by Ernulphus in the reign of Henry I. in the year 1110. It was demoliſhed in the wars of Charles I. by the parliament army under Sir Thomas Fairfax. The ruins ſtill exhibit a beautiful ſketch of ancient maſonry, much admired by the lovers of antiquities. The caſtle is ſtill pretty entire, and is a magnificent ſtructure, in which great improvements have of late been made. Here is an excellent and valuable library.

The markets, which are on Wedneſday and Saturday, are very well ſupplied with all kinds of proviſions. There are no leſs than ſix diſſenting meeting-houſes in this town. Colcheſter is 51 miles from London. It had 16 pariſh churches, in and out of the walls, but now only 12 are uſed, the reſt being damaged at the ſiege in 1648.

COLOURS. See Pigments in this Supplement.

Accidental Colours, a name given to a very curious optical phenomenon, which was firſt, we believe, attended to by Buffon. That philoſopher wrote a ſhort paper on it, which was publiſhed in the Memoirs of the Academy of Sciences for the year 1743.

If a perſon look ſtedfaſtly and for a conſiderable time at a ſmall *red* ſquare painted upon *white* paper, he will at laſt obſerve a kind of green-coloured border ſurround the red ſquare. If he now turn his eyes to ſome other part of the paper, he will ſee an imaginary ſquare of a delicate green bordering on blue, and correſponding exactly in point of ſize with the red ſquare. This imaginary ſquare continues viſible for ſome time, and indeed does not diſappear till the eye has viewed ſucceſſively a number of new objects. It is to this imaginary ſquare that the improper name of *accidental colour* has been given. If the ſmall ſquare be *yellow*, the imaginary ſquare or accidental colour is blue: the accidental colour of green is red; of blue, yellow; of white, black; and on the contrary, that of black is white.

The firſt perſon, as far as we know, who gave a ſatisfactory explanation of theſe phenomena was Profeſſor Scherffer of Vienna, whoſe diſſertation, tranſlated by Mr Bernoulli, has been publiſhed in the 26th volume of the Journal de Phyſique.

In order to underſtand theſe phenomena, let us recollect, in the firſt place, that light conſiſts of ſeven rays, namely, red, orange, yellow, green, blue, indigo, violet; that whiteneſs conſiſts in a mixture of all theſe rays: and that thoſe bodies which reflect but very little light are black. Thoſe bodies that are of any particular colour, reflect a much greater quantity of the rays which conſtitute that particular colour than of any other rays. Thus red bodies reflect moſt red rays; green bodies, moſt green rays, and ſo on.

Let us recollect, in the ſecond place, that when two impreſſions are made at the ſame time upon any of our organs of ſenſation, one of which is ſtrong and the other weak, we only perceive the former. Thus if we examine by the priſm the rays reflected by a red roſe, we ſhall find that they are of four kinds; namely red, yellow, green, and blue. In this caſe, the impreſſion made by the red rays makes that made by the others quite inſenſible. For the ſame reaſon, when a perſon goes from broad day light into an ill-lighted room, it appears to him at firſt perfectly dark, the preceding ſtrong impreſſion rendering him for ſome time incapable of feeling the weaker impreſſion.

With the aſſiſtance of theſe two remarks, it will not be difficult to explain the phenomena of accidental colours. When a perſon conſiders attentively for ſome time a white ſquare lying on any black ſubſtance (paper for inſtance), it is evident that the part of the retina on which the white ſquare is painted, receives a ſtronger impreſſion than any other part; at leaſt the greateſt number of rays ſtrike upon it. A weaker impreſſion, therefore, will act on it with much leſs force than upon the reſt of the retina. Conſequently, when the eye is turned from the white ſquare to ſome other part of the black paper, a ſquare is perceived of the ſame ſize with the white ſquare, and much blacker than any other part of the paper: this is evidently in conſequence of the weaker impreſſion made by the rays reflected by the black paper upon that part of the eye previouſly fatigued by the copious reflection from the white ſquare. For the very ſame reaſon, if, after looking for a ſufficient

cient time at a white ſquare lying on a black ground, we turn our eyes upon a ſheet of white paper, we perceive a very well defined black ſquare. In this caſe, the part of the retina already fatigued is not ſo ſenſible to the rays reflected by the white paper as the other parts of it which have not been fatigued. The reaſon then that *black* is the accidental colour of white is ſufficiently evident.

On the contrary, when we look a ſufficient time at a black ſquare lying upon a white ground, if we turn our eyes to any other part of the white paper, or even upon black paper, we ſhall perceive a ſmall ſquare anſwering to the black ſquare, and much brighter than any other part of the paper: evidently becauſe that part of the retina on which the black ſquare was painted being leſs fatigued is more ſuſceptible of impreſſions than any other part of the eye. Thus we ſee why the accidental colour of black is white, and why that of white on the contrary is black. Theſe facts, indeed, have been long known, and they have been generally explained in this manner.

When a perſon has looked for a ſufficient time at a red ſquare placed on a ſheet of white paper, and then turns his eyes to another part of the paper, that part of the retina on which the red was painted being fatigued, the red rays reflected from the white paper ceaſe to make any ſenſible impreſſion on it, and conſequently there will be ſeen upon the white paper a ſquare ſimilar to the red ſquare, and the colour of which is that which would reſult from the mixture of all the rays of light except the red. In general, therefore, the *accidental colour* is the colour which reſults from the mixture of all the rays of light, thoſe rays excepted which are the ſame with the primitive colour.

Now, in order to diſcover the accidental colours, let us recollect the manner which Newton employed to determine the colour which reſults from the mixture of ſeveral others, the ſpecies and quantity of which are known. He did it by dividing the circumference of a circle, ſo that the arches are to one another in the proportion of a ſtring ſhortened by degrees, in order to ſound one after another the notes of an octave; which is nearly the proportion that the different rays occupy when light is decompoſed by means of the priſm. Or ſuppoſe the circumference of the circle, as uſual, divided into 360 degrees, the different rays, according to Benvenut, ſhould occupy the following arches:

Red, - - - - -	45°
Orange, - - - -	27
Yellow, - - - - - -	48
Green, - - - - -	60
Blue, - - - - -	60
Indigo, - - - - -	40
Violet, - - - - -	80

Let us now compare the action of colours on one another with that of different weights; and for that purpoſe let us ſuppoſe each colour concentrated in the centre of gravity of its arch. In order to find the colour reſulting from any mixture, we have only to find the common centre of gravity of the arches which repreſent the different colours: The colour reſulting from the mixture will be that of the arch to which the common centre of gravity approaches neareſt. And if that common centre of gravity is not in the ſtraight line which joins the centre of the circle, and the centre of gravity of the arch to which it is moſt contiguous, the reſulting colour will approach more or leſs to the colour of the contiguous arch towards which the line, paſſing through the centre of the circle, and the common centre of gravity of the arches, falls. And farther, the reſulting colour will be more or leſs deep according to the diſtance of the common centre of gravity from the centre of the circle.

In the caſe under conſideration at preſent, namely, to determine the different accidental colours, the application of this method is remarkably eaſy; becauſe only one of the ſeven primitive colours is excluded, and conſequently the ſix colours from the mixture of which we wiſh to know the reſulting colour are all contiguous. For it is evident, that the ſum of the ſix arches, repreſenting theſe ſix colours, will be divided into two equal parts by the line which paſſes through the centre of the circle and their common centre of gravity; and that if the ſame line be produced till it reaches the circumference of the circle on the other ſide, it will alſo divide the arch repreſenting the ſeventh or omitted colour into two equal parts. Let us ſuppoſe, for inſtance, that the violet is omitted, and that we wanted to know the colour reſulting from the mixture of the other ſix colours, we have only to biſect the arch repreſenting the violet, and from the point of ſection to draw a diameter to the circle, the arch of the circle oppoſite to the violet through which the diameter paſſes will indicate the colour of the mixture. The arch repreſenting the violet being 80°, let us take the half of it, which is 40°, and let us add to it 45° for the red, 27° for the orange, and 48° for the yellow, we ſhall have 160°, which wants 20° of half the circumference of the circle. If now we add the 60° for the green, the ſum total will be 220°, conſiderably more than half the circumference; conſequently the common centre of gravity is neareſt the green arch; but it falls 10° nearer the yellow than the ſtraight line which joins the centre of the circle and the centre of gravity of the green arch. Hence we ſee that the reſulting colour will be green, but that it will have a ſhade of yellow.

It is evident, then, that the accidental colour of violet muſt be green with a ſhade of yellow; and this is actually the caſe, as any one may convince himſelf by making the experiment.

Suppoſe, now, we wanted to know the accidental colour of *green*, or, which is the ſame thing, the colour reſulting from the mixture of all the primitive rays except the green. The green arch is 60°, the half of which is 30°; if to this we add 60° for the blue arch, and 40° for the indigo arch, we ſhall have 130°, or 50° degrees leſs than a ſemicircle. If to this we add the violet arch, which is 80°, we ſhall have 30° more than the ſemicircle; conſequently the common centre of gravity falls neareſt the violet, and it is 10° nearer the red arch than is the centre of gravity of the violet arch. Hence we know that the accidental colour of green will be violet or purple, with a ſhade of red: And experiment confirms this.

Buffon obſerved that the accidental colour of blue was reddiſh and pale. Let us ſee whether we ſhall obtain the ſame reſult from our method. Let us ſuppoſe that Buffon employed a light blue. In that caſe, if to 30, the half of the blue arch, we add 60 for the green, 48 for the yellow, and 27 for the orange, we ſhall have 165°, or 15° leſs than half the circumference of the circle:

circle: Conſequently the common centre will fall neareſt the red arch, but within 15° of the orange. The accidental colour muſt therefore be red, with a ſhade of orange; or, which is the ſame thing, it muſt be a pale red.

In the ſame manner we may diſcover, that the accidental colour of indigo is yellow, inclining a good deal to orange; and that the accidental colour of indigo and blue together is orange, with a ſtrong ſhade of red. Both of which correſpond accurately with experiment.

It would be eaſy to indicate, in the ſame manner, the accidental colour of any primitive colour, if what has been ſaid were not ſufficient to explain the cauſe of accidental colours, and to ſhow that their phenomena correſpond exactly, both with the Newtonian theory of optics, and with what we know to be laws of our ſenſations in other particulars.

From the theory above given, which is that of Profeſſor Scherffer, the following conſequences may be deduced: 1. The accidental colour of a red ſquare, lying upon a white or a black ground, ought to be blackiſh, if we caſt our eyes upon a red coloured ſurface. 2. If the ſurface upon which we look at a red ſquare be itſelf coloured, if it be yellow, for inſtance, the white paper upon which we afterwards caſt our eyes will appear blue, with a green ſquare in it correſponding to the original red ſquare. And, in general, we ought to perceive the accidental colour of the ground on which the ſquare is placed, as well as the ſquare itſelf. 3. If while we are looking at the little ſquare we change the ſituation of the eye, ſo that its image ſhall occupy a different place on the retina, when we turn our eyes to the white paper we ſhall ſee two ſquares, or at leaſt one unlike the figure of the original one. 4. If the white paper on which we look be farther diſtant than the little ſquare was, the imaginary ſquare will appear conſiderably larger than the true one. 5. If while we are looking at the little ſquare, we gradually make the eye approach to it, without altering its ſituation, the imaginary ſquare will appear with a pale border. Theſe, and many other conſequences that might eaſily be deduced, will be found to take place conſtantly and accurately, if any one chooſes to put them to the teſt of experiment; and therefore may be conſidered as a complete confirmation of the theory given above of the cauſe of accidental colours.

There is another circumſtance reſpecting accidental colours which deſerves attention. If we continue looking ſtedfaſtly at the little ſquare longer than is neceſſary, in order to perceive its accidental colour, we ſhall at laſt ſee its border tinged with the accidental colour of the ground on which the ſquare is lying. For inſtance, if a white ſquare be placed upon blue paper, its border becomes yellow; if upon red paper, it becomes green; and it becomes reddiſh upon green. In like manner, the border of a yellow ſquare becomes greeniſh upon a red ground, and that of a red ſquare on a green ground becomes purple.

The cauſe of this phenomenon ſeems to depend upon the contraction and extenſion of the image of the ſquare painted on the retina. We know for certain, that the diameter of the pupil changes during our inſpecting the ſquare; at firſt it becomes leſs, and afterwards increaſes. And though we cannot ſee what paſſes in the bottom of the eye, we can ſcarcely doubt that ſimilar movements are going on there, if we attend to the changes that are continually taking place in the border of our little ſquare; ſometimes it is large, ſometimes ſmall; at one time it diſappears altogether, and the next moment makes its appearance again.

There is another phenomenon connected with accidental colours, which it is not ſo eaſy to explain; namely, that if we look at theſe little ſquares for a very long time, till the eye is very much fatigued, their accidental colours will appear even after we ſhut our eyes. The very ſame thing takes place if we attempt to look at a very luminous object; as the ſun, for inſtance. Profeſſor Scherffer thinks that this may be partly owing to the light which ſtill paſſes through the eye-lids. That ſome light paſſes through the eye-lids is evident, becauſe when we look towards a ſtrong light with our eye-lids ſhut, we ſee diſtinctly their colour, derived from the blood-veſſels with which they are filled; and if we paſs our finger before our eyes, we ſee the ſhadow of the finger though our eye-lids be ſhut, provided our eyes be turned towards the window. But that this light is not ſufficient to explain the phenomenon in queſtion is evident from this circumſtance, that the ſame accidental colours make their appearance though we go immediately into the darkeſt place. Perhaps we have accounted for the phenomenon elſewhere (See Metaphysics, *Encycl.* n° 54.) We paſs over the other conjectures of Profeſſor Scherffer, which are exceedingly ingenious, but not ſufficiently ſupported by facts to be admitted.

COLUMBA Noachi, *Noah's Dove*, a ſmall conſtellation in the ſouthern hemiſphere, conſiſting of 10 ſtars.

COMAR, or Khomar, a Zemindar's demeſne of land.

COMBUSTION is an operation of nature, which, though of the higheſt importance, ſeems not to have attracted much of the attention of philoſophers previous to the ſeventeenth century. Since that period indeed, the labours of Bacon and Boyle, and Hooke and Mayow, together with thoſe of Stahl and Lavoiſier, have thrown much light on the ſubject; as the reader will find by conſulting the articles Chemistry both in this Supplement and in the Encyclopædia. The theory of Lavoiſier is by far the moſt rational that has yet been offered to the public, and places its author in the firſt ranks of philoſophy. He corrects the errors of his predeceſſors, and has advanced before them one very important ſtep; but, as we have elſewhere obſerved, many new ſteps are ſtill wanting to render his theory of combuſtion complete. It explains indeed, in a ſatisfactory manner, why, during the proceſs of combuſtion, the burning body gradually waſtes away; but it gives no explanation of the conſtant emiſſion of heat and light, though a circumſtance as worthy of attention as the waſting of the body.

The emiſſion of light and heat the French chemiſts ſeem indeed to have conſidered as of no importance; for rather than acknowledge that the theory of their juſtly admired and ill-fated aſſociate is incomplete, they have choſen to give a new meaning to the word *combuſtion;* and to make it ſignify the *combination of a body with oxygen*, whether during that proceſs light and heat be evolved or not. Surely ſuch conduct is unphiloſophical; and yet our own chemiſts, with a ſervility which ill becomes the countrymen of Bacon and Newton,

ton, have, for the moſt part, acquieſced in this abſurd definition of combuſtion.

From the claſs of idolaters of the ſcience of the *great nation* muſt be excepted Dr Thomſon, the author of the article CHEMISTRY in this Supplement. Senſible that *combuſtion*, in the ſenſe uſually affixed to that word, denotes a phenomenon very different from many of thoſe which are included under the term in its new acceptation, he acknowledges the theory of Lavoiſier to be defective; but influenced by that diffidence which is the inſeparable attendant on the ſpirit of true philoſophy, he has not ventured to complete it in the article to which we have referred. He has indeed formed a theory of his own, and ſubmitted it to public diſcuſſion; but, with great propriety, gives it no place in his Syſtem of the Science, till it ſhall have undergone the examination of other chemiſts.

The conductor of this work, however, perſuaded that, while gratifying his readers in general, he ſhall not injure his friend's fame, embraces with pleaſure the opportunity afforded him, by a new edition, of laying before them a conciſe view of this very ingenious theory.

Dr Thomſon, then, admitting the truth and accuracy of the Lavoiſerian theory as far as it proceeds, divides the bodies which occupy the attention of chemiſts into, 1. *Combuſtibles*; 2. *Supporters of combuſtion*; and, 3. *Incombuſtiblts*.

The COMBUSTIBLES, or thoſe bodies which, in common language, are ſaid to *burn*, may be divided into, 1. *Simple* combuſtibles; 2. *Compound* combuſtibles; and, 3. Combuſtible *oxides*. *Simple* combuſtibles are, *ſulphur*, *phoſphorus*, *carbon*, *hydrogen*, and all the *metals*, except perhaps *gold*, *ſilver*, and *mercury*. *Compound* combuſtibles conſiſt of compounds formed by the ſimple combuſtibles uniting together two and two; and combuſtible *oxides* are compoſed of one or more ſimple combuſtibles combined with a doſe of *oxygen*. Theſe oxides may be arranged under two heads: viz. thoſe which containing only a *ſingle baſe* combined with oxygen, may therefore be termed *ſimple* combuſtible *oxides*; and thoſe which containing *more than one baſe*, may therefore be termed *compound* combuſtible oxides. The ſimple combuſtible oxides are only four in number; namely, *oxide of ſulphur*, *oxide of phoſphorus*, *charcoal*, and *carbonic oxide gas*. All the ſimple combuſtible oxides are by combuſtion converted into *acids*. The compound combuſtible oxides include by far the greater number of combuſtible bodies; for almoſt all the animal and vegetable ſubſtances belong to them, and the double baſe is uſually *carbon* and *hydrogen*.

The SUPPORTERS *of combuſtion* are a ſet of bodies which are not of themſelves, ſtrictly ſpeaking, capable of undergoing combuſtion, but which are abſolutely neceſſary for the proceſs. All the ſupporters known at preſent are ſix; viz. 1. *Oxygen gas*; 2. *Air*; 3. *Gaſeous oxide of azot*; 4. *Nitrous gas*; 5. *Nitric acid*; and, 6. *Oxy-muriatic acid*. There are other ſubſtances, to be mentioned afterwards, to which the author gives the name of *partial ſupporters*; but *all* ſupporters contain one common principle, namely *oxygen*.

The INCOMBUSTIBLE BODIES are neither capable of undergoing combuſtion themſelves, nor of ſupporting the combuſtion of bodies that are. Of courſe, they are not immediately connected with combuſtion; but they are noticed here, becauſe ſome of the alkalies and earths, which belong to this claſs, poſſeſs certain properties in common with combuſtibles, and are capable of exhibiting phenomena ſomewhat analogous to combuſtion; phenomena which the author deſcribes under the title of *ſemi-combuſtion*.

From the preceding obſervations it is obvious, that, in every caſe of combuſtion, there muſt be preſent a *combuſtible* and a *ſupporter*; and Lavoiſier aſcertained beyond a doubt, that, during the proceſs, the combuſtible always unites with the oxygen of the ſupporter. This new compound our author calls *a product of combuſtion*; and maintains that every ſuch product is either *water*, or an *acid*, or a *metallic oxide*. He admits, indeed, that other bodies ſometimes make their appearance during combuſtion; but affirms that theſe, upon examination, will be found neither to be products, nor to have undergone combuſtion.

But though the combination of the combuſtible with oxygen be a conſtant part of combuſtion, yet the facility with which combuſtibles burn is not in proportion to their apparent affinity for that gas. Phoſphorus, for inſtance, burns more readily than charcoal; yet charcoal is capable of abſtracting oxygen from phoſphorus. The combuſtible oxides take fire more readily than ſome of the ſimple combuſtibles. Thus, charcoal burns more eaſily than carbon or diamond; and alcohol, ether, and oils, which are all compound combuſtible oxides, are exceedingly combuſtible; whereas the metals, which are ſimple combuſtibles, do not burn, when air is the ſupporter, but at a very high temperature. This facility of burning combuſtible oxides is probably owing to the weak affinity by which their particles are united; and to the ſame cauſe, viz. the inferiority of the coheſion of heterogeneous particles, is to be attributed the fact, that ſome of the *compound ſupporters* occaſion combuſtion in circumſtances when the combuſtibles would not be acted on by *ſimple ſupporters*.

None of the *products* of combuſtion are themſelves combuſtible, in the uſual and proper acceptation of that word. This, however, is not owing to their being ſaturated with oxygen, for ſeveral of them are capable of combining with an additional doſe of it; but during this new combination no caloric nor light is ever emitted, and the compound formed differs eſſentially from a mere *product* of combuſtion, being by the additional doſe of oxygen converted into a *ſupporter*.

When the *ſupporters*, thus formed by the combination of oxygen with *products*, are made to ſupport combuſtion, they do not loſe *all* their oxygen, but only the *additional doſe* which conſtituted them ſupporters. Of courſe they are again reduced to their original ſtate of products of combuſtion; and as they owe their properties as ſupporters, not to the whole of the oxygen which they contain, but to the additional doſe, the author calls them *partial ſupporters*.

All the partial ſupporters with which we are acquainted contain a metallic baſis; for metallic oxides are the only products at preſent known capable of combining with an additional doſe of oxygen. The following oxides, which are products of combuſtion, combined each with an additional doſe of oxygen, are *partial ſupporters*: 1. Red oxide of iron; 2. Yellow oxide of gold; 3. White oxide of ſilver; 4. Red oxide of mercury; 5. Arſenic acid; 6. Red and brown oxides of lead; 7. Black oxide of manganeſe; 8. Acidulous oxide of antimony? 9. White oxide of tin.

Thus it appears that ſeveral of the products of combuſtion are capable of combining with oxygen; and hence it follows that the incombuſtibility of products is not owing to their want of affinity for oxygen, but to ſome other cauſe.

Though no *mere product* of combuſtion is capable of *ſupporting* combuſtion, this is not occaſioned by any want of affinity for combuſtible bodies; for ſeveral of theſe products are capable of combining with an additional doſe of their baſes. By this combination, however, they loſe their properties as products, and are converted into *combuſtibles;* whence it follows that the proceſs muſt differ eſſentially from that of combuſtion. Thus ſulphuric acid, a *product* of combuſtion, by combining with an additional doſe of ſulphur or its oxide, is converted into *ſulphurous acid;* a ſubſtance which, from many of its properties, Dr Thomſon concludes to be *combuſtible.* Thus alſo phoſphoric acid, a product of combuſtion, is capable of combining with phoſphorated hydrogen, and forming *phoſphorous acid*, a combuſtible body. When this laſt acid is heated in contact with a ſupporter, it undergoes combuſtion; but it is only the additional doſe of the combuſtible which burns, and the whole is converted into phoſphoric acid. Hence we ſee that it is not the whole baſis of theſe compounds that is combuſtible, but merely the additional doſe; and therefore the compounds themſelves may be termed *partial combuſtibles*, to indicate, that *part* only of the baſe is capable of undergoing combuſtion. Now, ſince the products of combuſtion are capable of combining with oxygen, but never exhibit the phenomena of combuſtion, except when they are in the ſtate of partial combuſtibles, combuſtible bodies muſt contain ſome principle, which they loſe during combuſtion, and to which they owe their combuſtibility; for after they have loſt it, they unite to oxygen without exhibiting the phenomena of combuſtion.

Though the *products* of combuſtion are not capable of *ſupporting* combuſtion, they not unfrequently part with their oxygen juſt as ſupporters do, give it out to combuſtibles, and convert them into products; but during this proceſs no heat nor light is ever evolved. Water, for inſtance, gives out its oxygen to iron, and converts it into *black oxide*, a product; and ſulphuric acid gives out its oxygen to phoſphorus, and converts it into phoſphoric acid. Thus we ſee that the oxygen of products is capable of converting combuſtibles into products, juſt as the oxygen of ſupporters; but during the combination of the laſt only are heat and light emitted. The oxygen of ſupporters, then, contains ſomething which the oxygen of products wants.

Whenever the whole of the oxygen is abſtracted from products, the combuſtibility of their baſe is reſtored as completely as before combuſtion; but no ſubſtance is capable of abſtracting the whole of oxygen, except a *combuſtible* or a *partial combuſtible*; and when this is done, the combuſtible or partial combuſtible loſes its own combuſtibility by the proceſs, and is converted into a product.

From theſe facts, which have been all eſtabliſhed by Stahl, Lavoiſier, and our author, it follows that the products of combuſtion may be formed without actual combuſtion: but in theſe caſes a *new combuſtible* is always evolved. The proceſs is merely an interchange of combuſtibility; for the combuſtible is converted into a product only by means of a product. Both the oxygen and the baſe of the product having undergone combuſtion, have loſt ſomething which is eſſential to combuſtion. The proceſs is merely a double decompoſition. The product yields its oxygen to the combuſtible, while, at the ſame time, the combuſtible gives out ſomething to the baſe of the product. The combuſtibility of that baſe, then, is reſtored by the loſs of its oxygen, and by the reſtoration of ſomething which it receives from the other combuſtible thus converted into a product.

No *ſupporter* can be produced by combuſtion, or by any equivalent proceſs. Now as all the ſupporters, except oxygen gas, conſiſt of oxygen combined with a baſe, it follows as a conſequence, that oxygen may combine with a baſe, without loſing that ingredient, whatever it is, which gives occaſion to combuſtion. The mere act of combination of oxygen with a baſe, therefore, is by no means the ſame with combuſtion.

Several of the ſupporters and partial ſupporters are capable of combining with combuſtibles, without undergoing decompoſition, or exhibiting the phenomena of combuſtion. In this manner the yellow oxide of gold, and the white oxide of ſilver, combine with ammonia; the red oxide of mercury with oxalic acid; and oxy-muriatic acid with ammonia. Thus alſo nitre and oxy-muriat of potaſh may be combined, or at leaſt intimately mixed with ſeveral combuſtible bodies, as in gunpowder, &c. In all theſe compounds the oxygen of the ſupporter retains each the ingredients proper to itſelf, which render them ſuſceptible of combuſtion; and hence the compound is ſtill combuſtible. They burn indeed with amazing facility, not only when heated, but when triturated or ſtruck ſmartly with a hammer; and have received, in conſequence, the name of *detonating* or *fulminating* bodies.

Such are the properties of the combuſtibles, the ſupporters, and the products; and ſuch the phenomena which they exhibit when made to act upon each other. If we compare together the *ſupporters* and the *products*, we ſhall find that they reſemble each other in ſeveral reſpects. Both of them contain oxygen as an eſſential part; both are capable of converting combuſtibles into products; and of both ſeveral combine with combuſtibles and with additional doſes of oxygen. But they differ widely from each other in the phenomena which accompany their action on combuſtibles. The ſupporters convert theſe bodies into products; and at the ſame time combuſtion, or the emiſſion of light and heat, takes place; whereas the products convert combuſtibles into products without any ſuch emiſſion. Now as the ultimate change produced upon combuſtibles by both theſe ſets of bodies is the ſame, and as the ſubſtance which combines with the combuſtibles is in both caſes the ſame, namely oxygen, we muſt conclude that this oxygen in the ſupporters contains ſomething which the oxygen of the products wants; ſomething which ſeperates during the paſſage of the oxygen from the ſupporter to the combuſtible, and occaſions the combuſtion, or emiſſion of fire, which accompanies this paſſage. The oxygen of ſupporters, then, contains ſome ingredient

dient which the oxygen of products wants. Many circumſtances concur to render it probable that this ingredient is CALORIC.

The *combuſtibles* and the *products* alſo reſemble each other in ſeveral reſpects. Both of them contain the ſame or a ſimilar baſe; both frequently combine with combuſtibles, and likewiſe with oxygen: but they differ eſſentially in the phenomena which accompany their combination with oxygen. In the one caſe, *fire* is emitted; in the other, not. If we recollect that no ſubſtance but a combuſtible is capable of reſtoring combuſtibility to the baſe of a product, and that at its doing ſo, it always loſes its own combuſtibility; and if we recollect farther, that the baſe of the product does not exhibit the phenomenon of combuſtion even when it combines with oxygen—we cannot avoid concluding, that all combuſtibles contain an ingredient which they loſe when converted into products, and that this loſs contributes to the fire which makes its appearance during the converſion. Many circumſtances concur to render it probable that this ingredient is LIGHT.

If we ſuppoſe that the oxygen of *ſupporters* contains *caloric* as an eſſential ingredient, and that *light* is a component part of all *combuſtibles*, the phenomena of combuſtion, numerous and intricate as they are, admit of an eaſy and obvious explanation. The component parts of the oxygen of ſupporters are two; namely, 1. A *baſe*; and, 2. *Caloric*. The component parts of combuſtibles are likewiſe two; namely, 1. A *baſe*; and, 2. *Light*. During combuſtion the baſe of the oxygen combines with the baſe of the combuſtible, and forms the product; while at the ſame time the caloric of the oxygen combines with the light of the combuſtible, and the compound flies off in the form of fire. Thus combuſtion is a double decompoſition; the oxygen and combuſtible divide themſelves each into two portions, which combine in pairs; the one compound is the *product*, and the other the *fire*, which eſcapes. Hence the reaſon that the oxygen of products is unfit for combuſtion: It wants its *caloric*. Hence the reaſon that combuſtion does not take place when oxygen combines with products, or with the baſe of ſupporters: Theſe bodies contain no *light*. The caloric of the oxygen of courſe is not ſeparated, and no *fire* appears. Hence alſo the reaſon why a combuſtible alone can reſtore combuſtibility to the baſe of a product. In all ſuch caſes a double decompoſition takes place. The oxygen of the product combines with the baſe of the combuſtible, while the light of the combuſtible combines with the baſe of the product."

Such is the theory of Dr Thomſon, propoſed to the public* under the humble title of *Remarks on Combuſtion*. As the author completely eſtabliſhes the facts on which his reaſoning reſts, we can conceive to it but one plauſible objection. Why is not the caloric of the oxygen ſeparated when that gas combines with bodies deſtitute of light? That there is caloric emitted on many occaſions, when no light *appears* with it, is incontrovertible; but perhaps the matter of light is chemically combined with all bodies which emit heat, though it never flies off but when the heat is great. If this be a fact, and it is not improbable, the theory before us ſeems to be eſtabliſhed; for it not only completes the theory of Lavoiſier, but affords an eaſy ſolution to ſome phenomena which have been thought inconſiſtent with that theory.

In the year 1793, the aſſociated Dutch chemiſts drew the attention of philoſophers to a curious phenomenon which accompanies the formation of ſome of the ſulphurets. When eight parts of copper, iron, lead, tin, or zinc filings, and three parts of flowers of ſulphur, are mixed together in a glaſs receiver, and the veſſel placed upon burning coals, the mixture melts, a kind of exploſion takes place, it becomes ſuddenly red hot, and a glow, like that of a piece of red hot charcoal fanned with bellows, rapidly pervades the whole. When this diſappears, the mixture is found in the ſtate of ſolid ſulphuret of copper, or iron, &c. The experiment ſucceeds whether the veſſel be filled with air, or with azotic or hydrogen gas, or even with water or mercury. What is ſingular in this experiment is the glowing *red heat*, or the emiſſion of fire, which accompanies the combination of the ſulphur and metal. This emiſſion being the ſame which takes place during combuſtion, the proceſs has been conſidered as a combuſtion, and ſtated as ſuch, by the German chemiſts, as an objection to Lavoiſier's theory. But our author ſhews that no objection can be urged from this experiment againſt the truth of that theory as far as it goes; and that all the phenomena are fully explained by the additions which he has made to it. Thus, we have only to recollect, 1. That the ſulphur is in a melted ſtate, and therefore contains caloric as an ingredient; 2. That the metals which produce the phenomenon contain light as an eſſential ingredient; and, 3. That the ſulphuret produced is always in a ſolid ſtate—and the explanation is ſimple and obvious. The *ſulphur* combines with the *baſe* of the metal, while the *caloric*, to which the ſulphur owed its fluidity, combines with the *light* of the metal, and the compound flies off under the form of *fire*.

Thus the proceſs is exactly the ſame with combuſtion, excepting what regards the product. The melted ſulphur acts the part of the *ſupporter*, while the metal occupies the place of the *combuſtible*. The firſt furniſhes caloric, the ſecond light, while the baſes of both combine together. Hence we ſee that the baſe of ſulphurets (and the ſame thing holds of ſome phoſphurets) reſembles the baſe of products in being deſtitute of light, the formation of theſe bodies exhibiting the ſeparation of fire like *combuſtion*; but the product, differing from a product of combuſtion in being deſtitute of oxygen, our author propoſes to diſtinguiſh the proceſs by the title of *ſemi-combuſtion*, to indicate that it poſſeſſes one half of the characteriſtic marks of combuſtion, but is deſtitute of the other half.

COMPASS, or MARINER'S STEERING COMPASS, is an inſtrument of ſo great value, that every improvement of it, propoſed by men of ſcience or of experience, is entitled to notice. We ſhall therefore lay before our readers ſome obſervations on the defects of the compaſs in common uſe, which have fallen into our hands ſince the article in the Encyclopædia was publiſhed. The firſt is by Captain O'Brien Drury of the royal navy, and relates entirely to the needle.

" Experience (ſays this officer) ſhews us, that the needle of a compaſs, as well as all other magnets, whether artificial or real, perpetually loſes ſomething of its

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* *Nicholſon's Journal*, vol. ii. ſecond ſeries.

magnetic powers, which often produces a difference exceeding a point; and I am well convinced that the great errors in ſhip-reckonings proceed more frequently from the incorrectneſs of the compaſs than from any other cauſe.

"Steel cannot be too highly tempered for the needle of a ſea-compaſs, as the more it is hardened the more permanent is the magnetiſm it receives; but, to preſerve the magnetiſm, and conſequently the polarity of the needle, I recommend to have the needle caſed with thin, well-poliſhed, ſoft iron; or elſe to have it armed at the poles with a bit of ſoft iron. I have found, from many experiments, that the caſed needle preſerved its magnetiſm in a much more perfect degree than the needle not caſed; and I have ſometimes thought that the magnetic power of the caſed needle had inreaſed, while the magnetic power of the uncaſed and unarmed needle always loſes of its polarity."

This is not an opinion taken up at random, but is the reſult of what appears to have been a fair and judicious experiment; for our author placed a caſed needle, an armed needle, and one without either caſe or armour, in a room for three months; each having at that time preciſely the ſame direction, and nearly the ſame degree of force. At the expiration of the three months, he found that the caſed needle and the armed needle had not in the leaſt changed their direction; but the other had changed two degrees, and had loſt very conſiderable of its magnetic power. If there was any change in either of the other needles, it was too inconſiderable to be perceived.

Theſe obſervations ſeem to be new, and may tend to the improvement of the compaſs. But it is not with reſpect to the needle only that this inſtrument is defective. Mr Bernard Romans of Penſacola well obſerves, that, on another account, the heavieſt braſs compaſſes now in uſe are by no means to be relied on in a hollow or high ſea. This is owing to the box hanging in two braſs rings, confining it to only two motions, both vertical and at right angles with each other; by which confinement of the box, upon any ſuccuſſion, more eſpecially ſudden ones, the card is always put into too much agitation, and, before it can well recover itſelf, another jerk prevents its pointing to the pole; nor is it an extraordinary thing to ſee the card unſhipped by the violence of the ſhip's pitching.

All theſe inconveniences are remedied to the full by giving the box a vertical motion at every degree and minute of the circle, and compounding theſe motions with a horizontal one of the box as well as of the card. By this unconfined diſpoſition of the box, the effects of the jerks on the card are avoided, and it will always very ſteadily point to the pole. "Experience (ſays our author) has taught me, that the card not only is not in the ſmalleſt degree affected by the hollow ſea, but that, in all the violent ſhocks and whirlings the box can receive, the card lies as ſtill as if in a room unaffected by the leaſt motion.

"Lately a compaſs was invented and made in Holland, which has all theſe motions. It is of the ſize of the common braſs compaſſes; the bottom of the braſs box, inſtead of being like a bowl, muſt be raiſed into a hollow cone, like the bottom of a common glaſs bottle; the vertex of the cone muſt be raiſed ſo high as to leave but one inch between the card and the glaſs; the box muſt be of the ordinary depth, and a quantity of lead muſt be poured in the bottom of the box, round the baſe of the cone; this ſecures it on the ſtile whereon it traverſes.

"This ſtile is firmly fixed in the centre of a ſquare wooden box, like the common compaſs, except that it requires a thicker bottom. The ſtile muſt be of braſs, about ſix inches long, round, and of the thickneſs of one-third of an inch; its head blunt, like the head of a ſewing-thimble, but of a good poliſh: the ſtile muſt ſtand perpendicular. The inner vertex of the cone muſt alſo be well poliſhed; the vertical part of the cone ought to be thick enough to allow of a well-poliſhed cavity, ſufficient to admit a ſhort ſtile, proceeding from the centre of the card whereon it traverſes. The compaſs I ſaw was ſo conſtructed; but I ſee no reaſon why the ſtile might not proceed from the centre of the vertex of the cone, and ſo be received by the card the common way. The needle muſt be a magnetic bar, blunt at each end; the glaſs and cover are put on in the common way."

A compaſs of this kind was ſubmitted to our author's examination by the captain of a ſloop of war, who aſſured him, that in a hard gale, which laſted ſome days, there was no other compaſs of the ſmalleſt ſervice. Mr Romans was ſatiſfied that the officer did not praiſe the apparatus more than it deſerved; and we feel ourſelves ſtrongly inclined to be of the ſame opinion.

It muſt not be concealed, however, that the ingenious Mr Nicholſon ſeems to think very differently of all ſuch contrivances. In a paper publiſhed in the ninth number of his valuable Journal, he labours to prove, that the compaſs is very little diſturbed by tilting the box on one ſide, but very much by ſudden horizontal changes of place; that a ſcientific proviſion againſt the latter is therefore the chief requiſite in a well made inſtrument of this kind; and that no other proviſion is requiſite or can eaſily be obtained, than good workmanſhip according to the common conſtruction, and a proper adjuſtment of the weight with regard to the centres or axes of ſuſpenſion. The ſame author is of opinion, that it would greatly improve the compaſs to make the needle flat and thin, and to ſuſpend it, not, as is moſt commonly done, with its flat ſide, but with its edge uppermoſt; for it being a well-known fact, that ſoft ſteel loſes its magnetiſm ſooner than hard, it is obvious, that unleſs both ſides of a needle be equally hard (which is almoſt impoſſible if they be diſtant from each other), the magnetic power will, in proceſs of time, deviate towards the harder ſide.

The Chineſe COMPASS has ſome advantages over the European compaſs, from which it differs with reſpect to the length of the needle, and the manner in which it is ſuſpended. In the compaſs of China, the magnetic needle is ſeldom above an inch in length, and is leſs than a line in thickneſs. It is poiſed with great nicety, and is remarkably ſenſible, or, in other words, points ſteadily towards the ſame portion of the heavens. This ſteadineſs is accompliſhed by the following contrivance: "A piece of thin copper is ſtrapped round the centre of the needle. This copper is rivetted by its edges to the upper part of a ſmall hemiſpherical cup, of the ſame metal, turned downwards. The cup ſo inverted ſerves as a ſocket to receive a ſteel pivot riſing from a cavity made into a round piece of light wood or cork, which thus forms the compaſs-box. The ſurfaces of the ſocket and pivot, intended to meet each other, are perfectly poliſhed, to avoid, as much as poſſible, all friction. The cup has a proportionably broad margin, which, beſide adding to its weight, tends, from its horizontal poſition, to keep the centre of gravity, in all ſituations of the compaſs, nearly in coincidence with the centre of ſuſpenſion. The cavity, in which the needle is thus ſuſpended, is in form circular, and is little more than ſufficient to remove the needle, cup, and pivot. Over this cavity is placed a thin piece of tranſparent talc, which prevents the needle from being affected by any motion of the external air; but permits the apparent motion of the former to be eaſily obſerved. The ſmall and ſhort needle of the chineſe has a material advantage over thoſe of the uſual ſize in Europe, with regard to the inclination or dip towards the horizon; which, in the latter, requires that one extremity of the needle ſhould be made ſo much heavier than the other as will counteract the magnetic attraction. This being different in different parts of the world, the needle can only be accurately true at the place for which it had been conſtructed. But in ſhort and light needles, ſuſpended after the Chineſe manner, the weight below the point of ſuſpenſion is more than ſufficient to overcome the magnetic power of the dip or inclination in all ſituations of the globe; and therefore ſuch needles will never deviate from their horizontal poſition."

COMPLEMENT, in general, is what is wanting, or neceſſary, to complete ſome certain quantity or thing.

Arithmetical COMPLEMENT, is what a number or logarithm wants of unity or 1 with ſome number of cyphers. It is beſt found by beginning at the left hand ſide, and ſubtracting every figure from 9, except the laſt, or right hand figure, which muſt be ſubtracted from 10. So, the arithmetical comp. of the log. 9·5329714,
by ſubtracting from 9's, &c. is 0·4670286.

The arithmetical complements are much uſed in operations by logarithms, to change ſubtractions into additions, which are more conveniently performed, eſpecially when there are more than one of them in the operation.

COMPLEMENT, in aſtronomy, is uſed for the diſtance of a ſtar from the zenith; or the arc contained between the zenith and the place of a ſtar which is above the horizon. It is the ſame as the complement of the altitude, or co-altitude, or the zenith diſtance.

COMPLEMENT *of the Courſe*, in navigation, is the quantity which the courſe wants of 90°, or 8 points, viz. a quarter of the compaſs.

COMPLEMENT *of the Curtain*, in fortification, is that part of the anterior ſide of the curtain which makes the demigorge.

COMPLEMENT *of the Line of Defence*, is the remainder of that line, after the angle of the flank is taken away.

COMPLEMENTS *of a Parallelogram*, or *in a Parallelogram*, are the two leſſer parallelograms, made by drawing two right lines parallel to each ſide of the given parallelogram, through the ſame point in the diagonal.

COMPLEMENT *of Life*, a term much uſed, in the doctrine of life annuities, by De Moivre; and, according to him, it denotes the number of years which a given life wants of 86, this being the age which he conſidered as the utmoſt probable extent of life. So 56 is the complement of 30, and 30 is the complement of 56.

COMPOSITION OF PROPORTION, according to the 15th definition of the 5th book of Euclid's Elements, is when, of four proportionals, the ſum of the firſt and ſecond is to the ſecond, as the ſum of the third and fourth is to the fourth.

COMPOSITION *of Ratios*, is the adding of ratios together: which is performed by multiplying together their correſponding terms, viz. the antecedents together, and the conſequents together, for the antecedent and conſequent of the compound ratio; like as the addition of logarithms is the ſame thing as the multiplication of their correſponding numbers. Or, if the terms of the ratios be placed fraction-wiſe, then the addition or compoſition of the ratios is performed by multiplying the fractions together.

COMPOUND INTEREST. See ALGEBRA, *Encycl.* and *Compound* INTEREST in this *Supplement*.

CONCEPTION, a city of Chili in South America, was viſited in 1786 by the celebrated, though unfortunate, navigator La Perouſe, who gives an account of ſome particulars relating to it very different from what we have given of it under the article CONCEPTION, *Encycl.* So far are the Spaniards from living in ſecurity with reſpect to the Indians, that, according to him, they are under continual alarms of being attacked by thoſe bold and enterpriſing ſavages. "The Indians of Chili (ſays he) are no longer thoſe Americans who were inſpired with terror by European arms. The increaſe of horſes, which are diſperſed through the interior of the immenſe deſerts of America, and that of oxen and ſheep, which has alſo been very great, have converted theſe people into a nation of Arabs, in every thing reſembling thoſe who inhabit the deſerts of Arabia. Conſtantly on horſeback, they conſider an excurſion of two hundred leagues as a very ſhort journey. They march accompanied by their flocks; feed upon their fleſh and milk, and ſometimes upon their blood; and cover themſelves with their ſkins, of which they make helmets, cuiraſſes, and bucklers. All their old cuſtoms are laid aſide. They no longer feed upon the ſame fruits, nor wear the ſame dreſs; but have a more ſtriking reſemblance to the Tartars, or to the inhabitants of the banks of the Red Sea, than to their anceſtors, who lived two centuries ago. So deciſive an influence has the introduction of two domeſtic animals had upon the manners of that once timid people. It is eaſy to conceive what formidable enemies they muſt now be to the Spaniards; for ſuppoſing them defeated in battle, how is it poſſible to follow them in ſuch long excurſions? How is it poſſible to prevent aſſemblages, which bring together in a ſingle point nations ſcattered over 400 leagues of country, and thus form armies of 30,000 men?"

Of theſe people M. Rollin, ſurgeon-major of the frigate *la Buſſale*, gives the following phyſiological particulars: "They are, in general (ſays he), of lower ſtature, and leſs robuſt, than Frenchmen, though they endure with great courage the fatigues of war and all its attendant privations. There is a great ſameneſs in the phyſiognomy of moſt individuals. The face is larger and rounder than that of Europeans. The features are more ſtrongly marked. The eyes are ſmall, dull, black, and deeply ſeated. The forehead is low; the eyebrows black and ſhaggy; the noſe ſhort and flattened; the cheek-bones high; the lips thick; the mouth wide;

and the chin diminutive. The women are ſhort, ill-made, and with diſguſting countenances. Both men and women bore their noſe and ears, which they adorn with glaſs or mother-of-pearl trinkets. The colour of their ſkin is a reddiſh brown: That of their nails is ſimilar, but not ſo deep. The hair of both is black, coarſe, and very thick. The men have little beard; but their arm-pits and parts of ſex are well furniſhed with hair, which parts, in moſt of the women, have none."

The military governor of Conception, who was an Iriſhman, returned, while M. de la Perouſe was there, from the frontiers of the Spaniſh ſettlements, where he had juſt concluded a glorious peace with the Indians. This peace was highly neceſſary to the people of his government, whoſe diſtant habitations were expoſed to the inroads of ſavage cavalry, whoſe practice it is to maſſacre the men and children, and to make the women priſoners. This amiable man, whoſe name was *Higguins* (probably *Higgins*), had ſucceeded in gaining the good-will of theſe ſavages, and thereby rendered the moſt ſignal ſervice to the nation that had adopted him. For while the Indians and Spaniards are at variance, an alliance with the former by any of the maritime powers of Europe would become ſo formidable to the latter, as to induce them, for fear of their lives, to abandon their ſettlements in Chili, and retire to Peru. This was clearly ſeen by *Monneron* the engineer on the expedition, who, with the true ſpirit of a Frenchman, pointed out to his government the method of wreſting from its moſt faithful ally one of the moſt valuable provinces of the Spaniſh empire.

La Perouſe deſcribes the common people of Conception as much addicted to thieving, and the women as exceedingly eaſy of acceſs. "They are a degenerated and mongrel race (ſays he); but the inhabitants of the firſt claſs, the true bred Spaniards, are polite and obliging in the extreme. The biſhop was a man of great ſenſe, of agreeable manners, and of a charity of which the Spaniſh prelates afford frequent examples." He was a Creole, and had never been in Europe. Of the monks our author gives a very different character. "The misfortune (ſays he) of having nothing to do, the want of family ties, the profeſſion of celibacy, without being ſeparated from the world, and their living in the convenient retirement of their cells, has rendered, and could not fail to render, them the greateſt profligates in America. Their effrontery is inconceivable. I have ſeen ſome of them ſtay till midnight at a ball; aloof, indeed, from the good company, and ſeated among the ſervants. Theſe ſame monks gave our young men more exact information than they could get elſewhere, concerning places with which prieſts ought to have been acquainted only in order to interdict the entrance."

M. de la Perouſe repreſents that part of Chili, which is called *the Biſhopric of Conception*, as one of the moſt fertile countries in the univerſe. Corn yields ſixty to one; the vineyards are equally productive; and the plains are covered with innumerable flocks, which, tho' left to themſelves, multiply beyond all imagination. Yet this colony is far from making the progreſs that might be expected from a ſituation ſo favourable to an increaſe of population. The influence of the government inceſſantly counteracts the climate and the ſoil. Prohibitory regulations exiſt from one end of Chili to the other; and this kingdom, of which the productions, if carried to their higheſt pitch, would feed the half of Europe; of which the wool would ſuffice for the manufactures of Great Britain and France, even when manufactures flouriſhed in the latter country; and of which the cattle, if ſalted down, would produce an immenſe revenue—is entirely deſtitute of commerce, and its inhabitants ſunk in ſloth and indolence. Unleſs, therefore, Spain change its ſyſtem entirely, Chili will never reach that pitch of proſperity which might be expected from its ſituation and fertility. For the latitude and longitude of Conception, ſee *Encycl.*

CONDORCET (Jean-Antoine Nicolas Caritat de), was born at Ribemont in Picardy, the 17th of September 1743, of a noble and very ancient family. At the age of 15 he was ſent to ſtudy philoſophy at the college of Navarre, and had the good fortune to fall into the hands of an able profeſſor, who has ſince diſtinguiſhed himſelf by his geometrical works. The young Condorcet had no reliſh for the buſineſs of the firſt courſe, for the quibbles of ontology and pneumatology, and all the wretched appendages of ſchool metaphyſics: But in the following year, his ſtudies, being directed to the mathematical and phyſical ſciences, were entirely congenial to his taſte; and though there were upwards of 120 ſcholars, he diſtinguiſhed himſelf above them all. At Eaſter he held a public theſis, at which Clairaut, D'Alembert, and Fontaine, aſſiſted. He now returned home, but continued to cultivate geometry. To enjoy more opportunities of improvement, he removed in 1762 to Paris; where he attended the chemical courſe of Macquer and Beaumé, and frequented the literary ſocieties which D'Alembert had formed at the houſe of Mademoiſelle de Leſpinaſſe.

In 1765, when only 22 years old, he publiſhed a work on the Integral Calculus, which diſcovered vaſt extent and originality of views. Condorcet was already numbered with the foremoſt mathematicians in Europe. "There was not (ſays La Lande) above ten of that claſs; one at Peterſburgh, one at Berlin, one at Baſle, one at Milan, and five or ſix at Paris; England, which had ſet ſuch an illuſtrious example, no longer produced a ſingle geometer that could rank with the former." It is mortifying to us to confeſs that this remark is but too much founded in truth. We doubt not but there are in Great Britain at preſent mathematicians equal in profundity and addreſs to any who have exiſted ſince the illuſtrious Newton; but theſe men are not known to the learned of Europe, becauſe they keep their ſcience to themſelves. They have no encouragement, from the taſte of the nation, to publiſh any thing in thoſe higher departments of geometry which have ſo long occupied the attention of the mathematicians on the continent.

In 1767 Condorcet publiſhed his ſolution of the problem of three bodies; and in the following year, the firſt part of his Analytical Eſſays; in which he entered very profoundly into thoſe arduous queſtions. He was received into the academy on the 8th of March 1769; and from that time till 1773 he enriched their annual volumes with memoirs on infinite ſeries, on partial and finite differences on equations of condition, and on other objects of importance in the higher calculus. It muſt be regretted, that he indulged ſpeculation perhaps to exceſs; the methods that he propoſes for integration

gration are ſometimes of a nature ſo extremely general, as to refuſe to be accommodated to practice. Proſecuting thoſe reſearches for ſeveral years longer, he compoſed an ample Treatiſe on the Integral Calculus, in five parts, compriſing the doctrines and their application. It was afterwards copied out for the preſs in 1785 by Keralio, formerly governor to the Infant of Parma. Only 128 pages were printed; but the manuſcript ſtill exiſts; as does that of an elementary Treatiſe on Arithmetic. It is to be hoped that both of theſe will yet be given to the public.

His attention was not, however, entirely abſorbed in thoſe recondite ſtudies. He publiſhed about this time an anonymous pamphlet, intitled *A Letter to a Theologian;* in which he replied with keen ſatire to the attacks made by the author of the *Three Centuries of Literature* againſt the philoſophical ſect. "But (ſubjoins the prudent La Lande) he puſhed the matter ſomewhat too far; for, admitting the juſtneſs of his ſyſtem, it was more prudent to confine within the circle of the initiated thoſe truths which are dangerous for the multitude, who cannot replace by ſound principles what they would loſe of fear, of conſolation, and of hope." Condorcet was now leagued with the atheiſts; and *La Lande*, who wiſhes well to the ſame ſect, cenſures not his principles, but only regrets his raſhneſs. He was indeed, as Mr Burke obſerved, a fanatic atheiſt and furious democratic republican.

On the 10th of June 1773 he was made ſecretary of the academy of ſciences; and that important truſt he diſcharged through the reſt of his life with great ability and uncommon reputation. The duties of his office required him to write the lives of the deceaſed academicians, which he performed with diligence, judgment, and univerſal applauſe: And what ſpecies of compoſition is capable of being rendered ſo extenſively uſeful as biography? In the moſt inſinuating form it conveys inſtruction; and, beſtowing vitality and action on the rules of conduct and on the leſſons of virtue, it fires the breaſt with the nobleſt emulation. The life of a philoſopher muſt alſo include a portion of the hiſtory of ſcience. We there trace the ſucceſſive ſteps which led to diſcoveries, and learn to eſtimate the value of thoſe acquiſitions by the efforts that were made, and the obſtacles that were ſurmounted. The literati of France have long excelled in the compoſition of *Eloges:* but thoſe of Condorcet are of a very ſuperior caſt. Replete with information and genuine ſcience, they maintain a dignified impartiality, and diſplay vigour of imagination, with boldneſs and energy of ſtyle. The intrepidity (ſay his Panegyriſts) with which he uttered the ſentiments of truth and of freedom, could not have been expected from the mouth of an academician under an abſolute monarchy. It could not, indeed, till the preſent eventful age, have been expected under any government whatever; for what he called the ſentiments of truth were the dogmas of debaſing irreligion, which would not have been permitted in the far-famed republics of Greece and Rome; and what he dignified with the appellation of the principles of freedom, experience has ſhown to have been the immediate ſource of anarchy, out of which has ſprung a deſpotiſm, the heavieſt under which any people have groaned ſince the creation of the world.

Beſides the eloges, which properly belonged to his province, Condorcet publiſhed in a ſeparate volume the lives of thoſe *ſavants*, who, having died before the renewal of the academy in 1699, did not fall in with the plan of Fontenelle. The ſuppreſſion of the hiſtory of the academy, or the regular abſtracts of the printed memoirs, which he effected in 1783, afforded him more leiſure. In 1787 appeared, yet without a name, his account of Turgot; an ineſtimable piece, which, in developing the beneficial views of a virtuous and enlightened miniſter, exhibits the neateſt abſtract of the principles of political economy that is extant in any language. Nearly about the ſame time he compoſed that elegant life which is prefixed to the ſplended edition of the works of Voltaire. Condorcet had been elected member of the *Academie Françaiſe* in 1782; and his reputation as a fine writer was ſo well eſtabliſhed, that bookſellers were ſolicitous to cover their undertakings with the ſanction of his name. He promiſed an additional volume to the tranſlation of Euler's Letters to a German Princeſs; but it was never finiſhed. The part which was printed, amounting to only 112 pages, contains the elements of the calculation of probabilities, and a curious plan of a dictionary, in which objects ſhould be arranged by their qualities merely. A new tranſlation of Smith's celebrated *Wealth of Nations* was likewiſe announced with the notes of Condorcet, tho' he was never heartily engaged about it. On equally ſlight grounds, his name was lent to the *Bibliotheque de l'Homme Public;* and the facility of his temper laid him but too open, at this period, to ſuch diſingenuous arts. Indeed diſingenuous arts ſeem to be the natural offspring of the preſent philoſophy of France; for the tricks played by Voltaire to his bookſellers, which are well known, would in this country have ſunk into diſgrace the greateſt genius that ever lived; and the attempt of Diderot to cheat the late empreſs of Ruſſia, by ſelling to her, at an immenſe price, a library, which he pretended to be one of the moſt valuable in Europe, when he poſſeſſed not perhaps one hundred volumes, was diſingenuity ingrafted on impudence. But to return from this ſhort digreſſion.

Theſe literary purſuits did not entirely ſeduce Condorcet from more profound ſtudies. At the inſtigation of Turgot, he ſought to apply analyſis to queſtions of politics and morality. His firſt Memoir on Probabilities was read to the academy in 1781. He afterwards extended his reſearches to the conſideration of elections, ſales, and ſucceſſions; and digeſting thoſe remarks and calculations into a ſyſtematic ſhape, he publiſhed in 1785 a quarto volume, containing the elements of a new and important ſcience.

It is eaſy to conceive the intereſt that Condorcet would take in the ſucceſs of the revolution. Aware of the prodigious influence of newſpapers, he contributed largely to the *Journal de Paris*, and the *Chronique*, which acquired great celebrity from the elegance of his pen; and not very long before his death, he began, in concert with the famous Sieyes, a Journal of Social Inſtruction. In 1791 he wrote a pamphlet in favour of republican government, which procured him a ſeat in the Legiſlative Aſſembly, and the academy permitted him ſtill to retain the office of ſecretary. He drew up a manifeſto on the ſubject of the war menaced by the crowned heads; and a very ample report on public inſtruction, which has in part been lately adopted by the councils of France. He was an early member of the

Jacobin club, that active inſtrument of the revolution: but perceiving the progreſſive ferocity of its meaſures, he forſook it in March 1792.

On the 13th of Auguſt, when the king was conducted to the temple, Condorcet was named by the Aſſembly to draw up a juſtificatory memorial addreſſed to all Europe. At the diſſolution of that Aſſembly, he was choſen deputy to the National Convention, and for ſome time acted a diſtinguiſhed part in its deliberations. He was at the head of the committee appointed to prepare the plan of a republican conſtitution. But, in the meanwhile, the faction of the Mountain, with a peculiar energy of character, was rapidly acquiring ſtrength. The report of the committee was coldly received—was even treated with contempt; and, on the 31ſt of May 1793, Robeſpierre completely triumphed.

During the conteſt between the Mountain and the Briſſotines, Condorcet maintained a cautious ſilence. For eight months he hardly ſpoke in the Convention; and ſeems to have been ſingularly wary in not riſking an opinion on any party queſtion. At length he was ſo far rouſed by the indignities which the legiſlative body daily endured, that he propoſed the diſſolution of the Convention, and the calling of a new one. This probably exaſperated the Mountain to ſuch an exceſs, that in a ſubſequent inſurrection his printing-office was deſtroyed. He was not, however, included in the liſt of proſcribed deputies; nor was he one of the members who ſigned the famous proteſt againſt the proceedings on the 31ſt of May. See REVOLUTION (*Encycl.*), n° 159.

But though he could conquer every ſentiment of friendſhip, and ſtifle every indignant ſenſation at the deſtruction of his party, his vanity as an author propelled him to a fatal exertion. When the conſtitution of 1793 was accepted, he publiſhed *An Addreſs to all French Citizens;* reprobating the extreme rapidity and want of conſideration with which it had been framed and accepted, and detailing the numerous acts of violence by which the prevailing party in the Convention had eſtabliſhed their influence. This raſh act placed him in the power of the Mountain: Chabot denounced the publication, and moved for a decree of accuſation againſt Condorcet; which was immediately granted.

He eſcaped from the arreſt, and concealed himſelf nine months in the houſe of a woman in Paris, who, though ſhe knew him only by name, had the generoſity to riſk her life, and ſuſtain all the inconveniences ariſing from her harbouring ſuch a gueſt. At length a domiciliary viſit was threatened, and he was obliged to quit his aſylum. He had the good fortune, though unprovided with a paſſport or civic card, to eſcape through the barrier; when he went to the country-houſe of a friend on the plain of Mont-Rouge. Unfortunately his friend was at Paris, and not expected to return in leſs than three days; during which the fugitive was obliged to wander about, expoſed to hunger, cold, ſuſpenſe, and the pain ariſing from a wound in his foot. At length his friend returned into the country, and found him; but conſidering it dangerous to take him to his houſe in the day-time, requeſted him to wait till night, when he would receive and conceal him. Condorcet, on that day which his friend had fixed as the end of his miſeries, forgot the dictates of prudence, and went to an inn at Chemars, where he ordered an amelette. His ſqualid appearance, dirty cap, torn clothes, leanneſs, and voracity, fixed the attention of a municipal officer, who aſked him whence he came, whither he was going, and if he had a paſſport? His confuſion at theſe interrogatories betrayed him, and he was inſtantly apprehended. He was confined that night in a dungeon, and in the morning was found dead. He always carried about him a doſe of poiſon, with which he terminated his life, to avoid a trial before the revolutionary tribunal, and ſhun the *gradual approach* of inevitable deſtruction.

Thus miſerably periſhed a philoſopher, whoſe "genius (ſays Madame Roland) was equal to the comprehenſion of the vaſteſt ſubjects; but he had no other characteriſtic beſides fear. It may be ſaid of his underſtanding, combined with his perſon, that it was a fine eſſence abſorbed in cotton. No one could ſay of him, that in a feeble body he diſplayed great courage; for his heart and his conſtitution were equally weak. After having deduced a principle, or demonſtrated a fact, in the Aſſembly, he would give a vote decidedly oppoſite; overawed by the thunder of the tribunes, armed with inſults, and prodigal of threats."

It was during the period of his concealment at Paris, uncertain of a day's exiſtence, that he wrote his Sketch of the Progreſs of the Human Mind; a production which undoubtedly diſplays genius, though it contains ſome of the moſt extravagant paradoxes that ever fell from the pen of a philoſopher. Among other wonderful things, the author inculcates the poſſibility, if not the probability, that the nature of man may be improved to abſolute perfection in body and mind, and his exiſtence in this world protracted to immortality. So firmly does he ſeem to have been perſuaded of the truth of this unphiloſophical opinion, that he ſet himſelf ſeriouſly to conſider how men ſhould conduct themſelves when the population ſhould become too great for the quantity of food which the earth can produce; and the only way which he could find for counteracting this evil was, to check population by promiſcuous concubinage and other practices, with an account of which we will not ſully our pages. Yet we are told by La Lande, that this ſketch is "only the outline of a great work, which, had the author lived to complete it, would have been conſidered as a monument erected to the *honour* of human nature!!!" La Lande, indeed, ſpeaks of the author in terms of high reſpect; and his abilities are certainly unqueſtionable: but what ſhall we think of the morals of that man, who firſt purſued with malicious reports, and afterwards hired ruffians to aſſaſſinate *, the old Duke of Rochefoucalt, in whoſe houſe he had been brought up; by whom he had been treated as a ſon; and at whoſe ſolicitation Turgot created for him a lucrative office; and by the power of the court raiſed him to all his eminence? There is a living Engliſh writer, who has laboured hard to prove that gratitude is a crime. Condorcet muſt ſurely have held the ſame opinion; and therefore could not blame thoſe low-born tyrants who paſſed againſt him what we muſt think an unjuſt decree of accuſation; for it was in ſome degree to his writings that thoſe tyrants were indebted for their power.

About the end of the year 1786, Condorcet married Marie-Louiſe Sophie de Grouchy, whoſe youth, wit, and beauty, were leſs attractive in the eyes of a philo-

ſopher

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* *Jour. de Phyſ.* Nov. 1792.

ſopher than the tender and courageous anxiety with which ſhe watched the couch, and aſſuaged the ſufferings, of the ſon of the preſident du Paty, who had been bitten by a mad dog. This union, however, we are told, was fatal to his repoſe ; it tempted him into the dangerous road of ambition ; and the idea of providing for a wife and daughter induced him to ſeek for offices which once he would have deſpiſed.

CONFERVA JUGALIS (ſee CONFERVA, *Encycl.*) is introduced here merely on account of a curious circumſtance reſpecting it, which was communicated, not long ago, to the Philomatic Society at Paris. Citizens Charles and Romain Coquebert having collected ſome of this *Conferva* in the neighbourhood of Paris, aſcertained, by means of an excellent microſcope, conſtructed by Nairne and Blunt, that, in this ſpecies, there are male and female filaments, which unite by an actual copulation ; that certain globules contained in the male filaments paſs into the interior part of the female filaments ; and that by this union there are formed in the latter ſeeds, or, if we may uſe the expreſſion, ſmall *ova*, which reproduce the ſpecies. This is the firſt inſtance, in the vegetable kingdom, of a reproduction abſolutely analogous to that which we find among animals.—*Philoſophical Magazine*, N° 3.

May this fact be depended on ? We queſtion not, in the ſlighteſt degree, the veracity of the editor of the very reſpectable miſcellany from which we have copied it ; but we confeſs ourſelves inclined to admit the phyſiological diſcoveries of citizen philoſphers with great heſitation. The fact, if real, is certainly curious, and may lead to important concluſions; and we therefore recommend an inveſtigation of its truth to our botanical readers.

CONGELATION. See CHEMISTRY in this Supplement, n° 280—283.

CONTAGION (ſee *Encycl.*) is a ſubject on which much has been written to very little purpoſe. Of all the attempts which have been made to account for it, there is not one that can be thought ſatisfactory. This, however, is not perhaps a matter of great importance, if a method could only be diſcovered to ſtop the progreſs of contagion where it is known to have place. Among the many benefits which may be reaped from the late diſcoveries in chemiſtry, even this deſideratum promiſes to be one ; and we ſurely need not add one of the greateſt. Dr James Carmichael Smyth, phyſician extraordinary to his Majeſty, ſuggeſted, in the year 1795 or 1796, a proceſs for determining the effect of the nitric acid in deſtroying contagion ; and experiments, according to his directions, were made on board the *Union* and other ſhips at Sheerneſs.

The Union was an hoſpital ſhip, and the experiment on board her was conducted by Mr Menzies, late ſurgeon to his Majeſty's ſloop Diſcovery, and by Mr Baſſan, ſurgeon of the Union; and when it is conſidered that freſh contagion was daily pouring into the hoſpital from the Ruſſian veſſels, which were at that time lying in the Downs, and which had brought with them a ſpecies of fever that might in every ſenſe of the word be termed an epidemy, it will be allowed, that the ſucceſs which attended it was ſuch that it cannot be too generally known.

The wards were extremely crowded, and the ſick of every deſcription lay in cradles, promiſcuouſly arranged, to the number of nearly two hundred ; of which about one hundred and fifty were in different ſtages of the above malignant fever, which was extremely contagious, as appeared evident from its rapid progreſs and fatal effects among the attendants on the ſick and the ſhip's company.

The utenſils and materials provided for the proceſs were the following: A quantity of fine ſand, about two dozen quart earthen pipkins, as many common teacups, ſome long ſlips of glaſs to be uſed as ſpatulas, a quantity of concentrated vitriolic (ſulphuric) acid, and a quantity of pure nitre (nitrat of potaſh).

The proceſs was conducted in the following manner: *1ſt*, All the ports and ſcuttles were ſhut up ; the ſand, which had been previouſly heated in iron pots, was then ſcooped out into the pipkins by means of an iron ladle; and in this heated ſand, in each pipkin, a ſmall tea-cup was immerſed, containing about half an ounce of the ſulphuric acid, to which, after it had acquired a proper degree of heat, an equal quantity of nitrat of potaſh in powder was gradually added, and the mixture ſtirred with a glaſs ſpatula till the vapour aroſe from it in conſiderable quantity (A). The pipkins were then carried through the wards by the nurſes and convaleſcents, who kept walking about with them in their hands, occaſionally putting them under the cradles of the ſick, and in every corner where any foul air was ſupected to lodge. In this manner they continued fumigating, until the whole ſpace between decks was fore and aft filled with the vapour, which appeared like a thick haze.

The vapour at firſt excited a good deal of coughing among the patients, which gradually ceaſed as it became more generally diffuſed through the wards ; part of this effect, however, was to be attributed to the inattention of thoſe who carried the pipkins, in putting them too near the faces of the ſick; which cauſed them to inhale the ſtrong vapour as it immediately iſſued from the cups.

The body-clothes and bed-clothes of the ſick were as much as poſſible expoſed to the nitrous vapour during the fumigation ; and all the foul linen removed from them was immediately immerſed in a tub of cold water, afterwards carried on deck, rinſed out, and hung up till nearly dry, and then fumigated before it was taken to the waſh-houſe : a precaution extremely neceſſary in every caſe of infectious diſorder. Due attention was alſo paid to cleanlineſs and ventilation.

It took about three hours to fumigate the ſhip. In about an hour after, the vapour having entirely ſubſided, the ports and ſcuttles were thrown open for the admiſſion of freſh air. It could plainly be perceived that

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(A) That the fumes of the mineral acids poſſeſſed the property of ſtopping contagion was proved by Morveau as far back as the year 1773, who, by means of the fumes of muriatic acid extricated from the muriat of ſoda (ſea ſalt) by the ſulphuric acid, purified the air of the cathedral of Dijon, which had been ſo much infected by exhumations that they were obliged to abandon the building. See CHEMISTRY, n 426. in this *Suppl.*

that the air of the hoſpital was greatly ſweetened even by this firſt fumigation. The proceſs was repeated again next morning; and the people employed, being now better acquainted with it, were more expert, and finiſhed the whole in about an hour's time. In an hour afterwards, the vapour having entirely ſubſided, the freſh air was freely admitted into the hoſpital as before. Fewer pipkins were employed for the evening fumigations than for thoſe of the mornings, as the freſh air could not be admitted ſo freely after the former as the latter.

The pleaſing and immediate effect of the fumigation in deſtroying the offenſive and diſagreeable ſmell, ariſing from ſo many ſick crowded together, was now very perceptible, even to the nurſes and attendants; the conſequence of which was, that they began to place ſome degree of confidence in its efficacy, and approached the cradles of the infected with leſs dread of being attacked with the diſorder: ſo that the ſick were better attended, and the duty of the hoſpital was more regularly and more cheerfully performed. In ſhort, a pleaſing gleam of hope ſeemed now to caſt its cheering influence over that general deſpondency, which was before evidently pictured in every countenance, from the dread and horror each individual naturally entertained of being, perhaps, the next victim to the malignant powers of a virulent contagion.

It is a remarkable fact, that from the 26th of November 1795, when the fumigation was firſt reſorted to, till the 25th of December, not a perſon on board was attacked with the fever, though, in the three months preceding, more than one-third of all the people in the ſhip had been ſeized with the diſtemper, and of theſe more than one in four were carried off by it; and the probability is, that the ſickneſs and mortality would have gone on, increaſing in proportion to the diffuſion of the contagion, and to the increaſing deſpondency of the people, who conſidered themſelves as ſo many devoted victims.

The advantage of the fumigation was not felt by the ſhip's company and attendants alone, whom it preſerved from the baneful effects of the fever: the ſick and convaleſcents derived almoſt an equal benefit from it. The ſymptoms of the diſeaſe were meliorated, and loſt much of their malignant appearance; and the advantage of a pure air, and free from ſtench, to convaleſcents, may be readily conceived.

Great confidence is always dangerous. It proved ſo on the preſent occaſion. On the 17th of December they imagined themſelves ſo ſecure, that they diſcontinued the cuſtom of fumigating morning and evening, thinking that once a day was ſufficient. On the 25th, one of the nurſes ſuffered a ſlight attack; and on the 26th, a marine, who, for a week before, had been in a ſtate of intoxication, was ſeized with the fever, of which he died. Theſe two accidents gave immediate alarm: they returned again to the practice of fumigating twice a-day; and from that time to the extermination of the diſorder, there was not an inſtance of a perſon ſuffering from contagion on board the ſhip.

The ſucceſs of the experiment was not confined to the Union: the power of the nitrous vapour to deſtroy contagion was equally diſplayed on board the Ruſſian ſhips in which it was employed. The ſafety, too, with which it may be employed, in any ſituation, without inconvenience or riſk of fire, is another great recommendation in its favour.

From the deſcription that has been given of the proceſs, no perſon can be at any loſs in reſorting to the ſame kind of fumigation. It is only neceſſary to obſerve, for the ſake of thoſe who may not be verſant in chemical purſuits, that the ingredients ought to be pure, and that metal veſſels or rods muſt not be employed. Any kind of metal getting among the ingredients would cauſe the vapour to be very noxious inſtead of ſalutary. The fumes that riſe ſhould be white; if they are of a red colour, there is reaſon to ſuſpect the purity of the ingredients.

The importance of this diſcovery need not be inſiſted on: it is equally applicable to every ſpecies of putrid contagion, even to the plague itſelf. It ſhould therefore be uſed in all hoſpitals and pariſh workhouſes; and ſhould be conſtantly reſorted to by the proprietors of all large works, on the firſt appearance of infectious diſeaſe among the people employed in them:—Indeed, it ſhould be employed even as a preventive in all ſituations where a number of people, from the nature of their buſineſs, are obliged to be crowded together, or where, from local circumſtances, there are reaſons for ſuſpecting that the purity of the air is injured by noxious exhalations or other cauſes. If there be any circumſtances in which its utility may be called in queſtion, it can only be in caſes of inflammatory diſeaſes; for in ſuch ſuperoxygenation has been found hurtful.

CONTRA-HARMONICAL *Proportion*, that relation of three terms, in which the difference of the firſt and ſecond is to the difference of the ſecond and third, as the third is to the firſt. Thus, for inſtance, 3, 5, and 6, are numbers contra-harmonically proportional; for 2 : 1 : : 6 : 3.

CONTRA-Mure, in fortification, is a little wall built before another partition wall, to ſtrengthen it, ſo that it may receive no damage from the adjacent buildings.

COOPER, an artificer who makes coops, caſks, tubs, or barrels, *i. e.* all kinds of wooden veſſels bound together by hoops. See *Encycl.*

The art of the cooper appears to be of great antiquity, and to have very ſoon attained to all the perfection which it poſſeſſes at preſent. This being the caſe, it is obvious that we can communicate no inſtruction to the cooper himſelf, and, on the ſubject of his art, very little that could be intereſting to our other readers. In the *Encyclopedie Methodique* there is a long and verboſe account of the tools or inſtruments employed by the cooper; of the kinds of timber proper for the different kinds of caſks; of the methods of preparing the wood for his various purpoſes; of the manner in which he ought to *hold the plane* when dreſſing the ſtaves; and of the time when it is proper to put the ſtaves together, or, in other words, to mount the caſk. From this detail we ſhall extract ſuch particulars as appear to us to be leaſt generally known, though perhaps of no great importance in themſelves.

Notwithſtanding the antiquity of the art of *caſk-building*, there are ſome countries in which even now it is wholly unknown; and others where, though it is ſufficiently known, yet, from the ſcarcity of wood or ſome other cauſe, earthen veſſels, and ſkins lined with pitch, are preferred to wooden barrels for the holding and tranſporting of liquors. The Latin word *dolium*, which we tranſlate "a caſk," was employed by the Romans to denote earthen veſſels uſed for this purpoſe; though the word *dolare*, from which it is derived, applies very well to our caſks, which are compoſed of ſeveral pieces of wood hewn from the ſame tree, and fitted by planes before they be joined together. We are indeed certain that caſks of the ſame kind with our own were in uſe among the Romans before the Chriſtian era; for both Varro and Columella, in treating of the rural economy of their days, ſpeak of veſſels formed of ſeveral ſtaves of wood bound together by circles or hoops. The merit of having invented ſuch veſſels is given by Pliny to certain people who lived at the foot of the Alps, and who in his days lined their caſks with pitch.

At what period the fabrication of caſks was introduced into Britain is unknown to us, though it is probable that we derived the art from the French, who might have it from the Romans.

We need hardly inform any of our readers, that a caſk has the appearance of two truncated cones joined at their baſes, or that the part where the junction appears to be made being the moſt capacious, or that of which the diameter is the largeſt, is vulgarly called the belly of the caſk. Theſe cones, however, were they completed, would not be regular, but rather *conoids*, being formed of pieces of timber, or ſtaves, which are not ſtraight lines as in the cone, but are curved from the vertex to the baſe.

In chooſing his wood, if he can have a choice, the cooper prefers old and thick and ſtraight trees, from which he hews thin planks to be formed into ſtaves; and in France, where this art is practiſed on a large ſcale, the winter months are allotted for the preparation of the ſtaves and bottoms, and the ſummer for putting them together or mounting the caſk. The author of the article in the *Encyclopedie Methodique* directs the cooper, when dreſſing the ſtaves with the plane, to cut the wood always acroſs; a practice which we doubt not is proper, though we think it would not be eaſy to aſſign the reaſon of it. Plaining is the moſt laborious and difficult part of the work; and there are but few coopers who plane quickly, and at the ſame time well. In ſhops where the work is diſtributed into parts, plaining is reckoned a great object; and in France, before the revolution, a good plainer gained from three ſhillings and threepence ſterling to four ſhillings and three farthings a-day.

In forming the ſtaves, it muſt never be forgotten that each is to conſtitute part of a double conoid; that it muſt therefore be broadeſt at the middle, becoming gradually, though not in ſtraight lines, narrower towards the extremities; that the outſide acroſs the wood muſt be wrought into the ſegment of a circle; and that the ſtave muſt be thickeſt near the middle, growing thinner, by very gentle degrees, towards the ends. To adjuſt accurately theſe different curves (for even the *narrowing* of the ſtaves muſt be in a curve) to the ſize and intended ſhape of the caſk, would require either great experience, or a larger portion of mathematical ſcience than we have reaſon to think that many coopers poſſeſs. With reſpect to the inſide of the ſtave, it is of little conſequence whether it be rounded into the ſegment of a circle or not, and therefore the cooper very ſeldom takes that trouble.

The ſtaves being all dreſſed and ready to be arranged in a circular form, it might be thought neceſſary, in order to make the ſeams tight, to trim the thin edges, which are to be joined together, in ſuch a manner as that a ray paſſing from the outſide of the caſk through a ſeam to the centre, ſhould touch the contiguous ſtaves from the exterior to the interior ſide; in other words, that the thin edges ſhould be ſloped as the archſtones of a bridge are ſloped, ſo that the contiguous ſtaves may be brought into firm contact throughout the whole joint. This, however, is not the practice of the cooper. With great propriety he brings the contiguous ſtaves into contact at their inner ſurfaces only; ſo that by driving the hoops hard, he can make the joints much cloſer than he could poſſibly have done had the edges of the ſtaves been ſo ſloped as to permit them to touch each other throughout before being drove together by the compreſſion of the hoops. This, together with giving to the ſtaves the proper curvature, ſeems to be the only part of the cooper's work which deſerves the name of art; for the driving of the hoops and the forming of the bottoms could certainly be accompliſhed by any carpenter, we had almoſt ſaid by any man, though he had never ſeen a hoop driven or a bottom formed.

In many parts of Scotland, inſtead of ale or beer mugs, they uſe ſmall hooped wooden veſſels, of which the ſtaves are feather-edged or dove-tailed into one another. This, as the ſtaves are of different colours, increaſes the beauty of the veſſel, and to a ſuperficial obſerver appears to be an ingenious contrivance; but it adds nothing to the ſtrength or tightneſs of the ſeam, and cannot be attended with the ſmalleſt difficulty. We think, indeed, that in a large caſk or tub it would prove injurious to the ſeam; for either theſe dove-tails muſt be very thin ſlips raiſed from the interior edges of the ſtaves, which in many caſes could not be done if the wood were thoroughly ſeaſoned; or if they be cut out like inverted wedges, the contiguous ſtaves muſt be brought into contact from the interior to the exterior ſide previous to the driving of the hoops; and in that caſe, as we have ſeen, the ſeams could not be made completely tight.

COPERNICUS (Nicolaus), the reſtorer, if not the inventor, of the true ſyſtem of the ſun, holds ſo conſpicuous a place in the republic of ſcience, that every man of a liberal education muſt be intereſted both in the events of his life and in the hiſtory of his diſcoveries. Accordingly, in the Encyclopædia, we have given a ſhort ſketch of his hiſtory, as well as an account of what led him to ſuppoſe the ſun placed in the centre of our ſyſtem (ſee COPERNICUS, and ASTRONOMY, n° 22. *Encycl.*) Since theſe articles were publiſhed, Dr Adam Smith's *Eſſays on Philoſophical Subjects* have been given to the world; and in that which is intitled *The Hiſtory of Aſtronomy*, we have an account of Copernicus's diſcoveries, ſo much more perſpicuous and ſatisfactory than any thing which we have elſewhere ſeen on the ſubject, that we are perſuaded our readers will be pleaſed to meet with it here.

"The confuſion (ſays Dr Smith) in which the old hypotheſis repreſented the heavenly bodies, was, as Copernicus himſelf tells us, what firſt ſuggeſted to him the deſign of forming a new ſyſtem, that theſe, the nobleſt works of Nature, might no longer appear devoid of that harmony and proportion which diſcover themſelves in her meaneſt productions. What moſt of all diſſatisfied him was, the notion of the equalizing circle, which, by repreſenting the revolutions of the celeſtial ſpheres as equable only, when ſurveyed from a point that was different from their centres, introduced a real inequality into their motions; contrary to that moſt natural, and indeed fundamental idea, with which all the authors of aſtronomical ſyſtems, Plato, Eudoxus, Ariſtotle, even Hipparchus and Ptolemy themſelves, had hitherto ſet out, that the real motions of ſuch beautiful and divine objects muſt neceſſarily be perfectly regular, and go on in a manner as agreeable to the imagination as the objects themſelves are to the ſenſes. He began to conſider, therefore, whether, by ſuppoſing the heavenly bodies to be arranged in a different order from that in which Ariſtotle and Hipparchus had placed them, this ſo much ſought for uniformity might not be beſtowed upon their motions. To diſcover this arrangement, he examined all the obſcure traditions delivered down to us, concerning every other hypotheſis which the ancients had invented for the ſame purpoſe. He found, in Plutarch, that ſome old Pythagoreans had repreſented the earth as revolving in the centre of the univerſe, like a wheel round its own axis; and that others, of the ſame ſect, had removed it from the centre, and repreſented it as revolving in the ecliptic like a ſtar round the central fire. By this central fire he ſuppoſed they meant the ſun; and though in this he was very widely miſtaken, it was, it ſeems, upon this interpretation that he began to conſider how ſuch an hypotheſis might be made to correſpond to the appearances. The ſuppoſed authority of thoſe old philoſophers, if it did not originally ſuggeſt to him his ſyſtem, it ſeems at leaſt to have confirmed him in an opinion which, it is not improbable, he had before-hand other reaſons for embracing, notwithſtanding what he himſelf would affirm to the contrary.

“ It then occurred to him, that if the earth was ſuppoſed to revolve every day round its axis, from weſt to eaſt, all the heavenly bodies would appear to revolve, in a contrary direction, from eaſt to weſt. The diurnal revolution of the heavens, upon this hypotheſis, might be only apparent; the firmament, which has no other ſenſible motion, might be perfectly at reſt; while the ſun, the moon, and the five planets, might have no other movement beſide that eaſtward revolution which is peculiar to themſelves. That, by ſuppoſing the earth to revolve with the planets round the ſun, in an orbit, which comprehended within it the orbits of Venus and Mercury, but was comprehended within thoſe of Mars, Jupiter, and Saturn, he could, without the embarraſſment of epicycles, connect together the apparent annual revolutions of the ſun, and the direct, retrograde, and ſtationary appearances of the planets; that while the earth really revolved round the ſun on one ſide of the heavens, the ſun would appear to revolve round the earth on the other; that while ſhe really advanced in her annual courſe, he would appear to advance eaſtward in that movement which is peculiar to himſelf. That, by ſuppoſing the axis of the earth to be always parallel to itſelf, not to be quite perpendicular, but ſomewhat inclined to the plane of her orbit, and conſequently to preſent to the ſun, the one pole when on the one ſide of him, and the other when on the other, he would account for the obliquity of the ecliptic; the ſun's ſeemingly alternate progreſſion from north to ſouth, and from ſouth to north, the conſequent change of the ſeaſons, and different lengths of days and nights in the different ſeaſons.

“ If this new hypotheſis thus connected together all theſe appearances as happily as that of Ptolemy, there were others which it connected together much better. The three ſuperior planets, when nearly in conjunction with the ſun, appear always at the greateſt diſtance from the earth, are ſmalleſt, and leaſt ſenſible to the eye, and ſeem to revolve forward in their direct motion with the greateſt rapidity. On the contrary, when in oppoſition to the ſun, that is, when in their meridian about midnight, they appear neareſt the earth, are largeſt, and moſt ſenſible to the eye, and ſeem to revolve backwards in their retrograde motion. To explain theſe appearances, the ſyſtem of Ptolemy ſuppoſed each of theſe planets to be at the upper part of their ſeveral epicycles in the one caſe, and at the lower in the other. But it afforded no ſatisfactory principle of connection, which could lead the mind eaſily to conceive how the epicycles of thoſe planets, whoſe ſpheres were ſo diſtant from the ſphere of the ſun, ſhould thus, if one may ſay ſo, keep time to his motion. The ſyſtem of Copernicus afforded this eaſily, and like a more ſimple machine, without the aſſiſtance of epicycles, connected together, by fewer movements, the complex appearances of the heavens. When the ſuperior planets appear nearly in conjunction with the ſun, they are then in the ſide of their orbits, which is almoſt oppoſite to, and moſt diſtant from, the earth, and therefore appears ſmalleſt and leaſt ſenſible to the eye. But as they then revolve in a direction which is almoſt contrary to that of the earth, they appear to advance forward with double velocity; as a ſhip that ſails in a contrary direction to another, appears from that other to ſail both with its own velocity and the velocity of that from which it is ſeen. On the contrary, when thoſe planets are in oppoſition to the ſun, they are on the ſame ſide of the ſun with the earth, are neareſt it, moſt ſenſible to the eye, and revolve in the ſame direction with it; but as their revolutions round the ſun are ſlower than that of the earth, they are neceſſarily left behind by it, and therefore ſeem to revolve backwards; as a ſhip which ſails ſlower than another, though it ſails in the ſame direction, appears from that other to ſail backwards. After the ſame manner, by the ſame annual revolution of the earth, he connected together the direct and retrograde motions of the two inferior planets, as well as the ſtationary appearances of all the five.

“ Thus far did this new account of things render the appearances of the heavens more completely coherent than had been done by any of the former ſyſtems. It did this, too, by a more ſimple and intelligible, as well as more beautiful machinery. It repreſented the ſun, the great enlightener of the univerſe, whoſe body was alone larger than all the planets taken together, as eſtabliſhed immoveable in the centre, ſhedding light and heat on all the worlds that circulated around him in one uniform direction, but in longer or ſhorter periods, according to their different diſtances. It took away the diurnal revolution of the firmament, whoſe rapidity,

upon

upon the old hypotheſis, was beyond what even thought could conceive. It not only delivered the imagination from the embarraſſment of epicycles, but from the difficulty of conceiving theſe two oppoſite motions going on at the ſame time, which the ſyſtem of Ptolemy and Ariſtotle beſtowed upon all the planets ; I mean, their diurnal weſtward, and periodical eaſtward revolutions. The earth's revolution round its own axis took away the neceſſity for ſuppoſing the firſt, and the ſecond was eaſily conceived when by itſelf. The five planets, which ſeem, upon all other ſyſtems, to be objects of a ſpecies by themſelves, unlike to every thing to which the imagination has been accuſtomed, when ſuppoſed to revolve along with the earth round the ſun, were naturally apprehended to be objects of the ſame kind with the earth, habitable, opaque, and enlightened only by the rays of the ſun. And thus this hypotheſis, by claſſing them in the ſame ſpecies of things, with an object that is of all others the moſt familiar to us, took off that wonder and uncertainty which the ſtrangeneſs and ſingularity of their appearance had excited ; and thus far, too, better anſwered the great end of philoſophy.

“ Neither did the beauty and ſimplicity of this ſyſtem alone recommend it to the imagination ; the novelty and unexpectedneſs of that view of nature which it opened to the fancy, excited more wonder and ſurpriſe than the ſtrangeſt of thoſe appearances, which it had been invented to render natural and familiar, and theſe ſentiments ſtill more endeared it. For though it is the end of philoſophy to allay that wonder which either the unuſual or ſeemingly disjointed appearances of Nature excite, yet ſhe never triumphs ſo much as when, in order to connect together a few, in themſelves perhaps inconſiderable objects, ſhe has, if I may ſay ſo, created another conſtitution of things, more natural indeed, and ſuch as the imagination can more eaſily attend to, but more new, more contrary to common opinion and expectation, than any of thoſe appearances themſelves. As in the inſtance before us, in order to connect together ſome ſeeming irregularities in the motions of the planets, the moſt inconſiderable objects in the heavens, and of which the greater part of mankind have no occaſion to take any notice during the whole courſe of their lives, ſhe has, to talk in the hyperbolical language of Tycho Brahé, moved the earth from its foundations, ſtopt the revolution of the firmament, made the ſun ſtand ſtill, and ſubverted the whole order of the univerſe.

“ Such were the advantages of this new hypotheſis, as they appeared to its author when he firſt invented it. But though that love of paradox, ſo natural to the learned, and that pleaſure which they are ſo apt to take in exciting, by the novelty of their ſuppoſed diſcoveries, the amazement of mankind, may, notwithſtanding what one of his diſciples tells us to the contrary, have had its weight in prompting Copernicus to adopt this ſyſtem ; yet when he had completed his Treatiſe of Revolutions, and began coolly to conſider what a ſtrange doctrine he was about to offer to the world, he ſo much dreaded the prejudice of mankind againſt it, that, by a ſpecies of continence of all others the moſt difficult to a philoſopher, he detained it in his cloſet for thirty years together. At laſt, in the extremity of old age, he allowed it to be extorted from him, but died as ſoon as it was printed, and before it was publiſhed.”

This noble theory, however, being repugnant to the prejudices of habit and education, was at firſt coldly received, or utterly rejected, by every claſs of men. The aſtronomers alone favoured it with their notice, though rather as a convenient hypotheſis than an important truth. By the vulgar it was conſidered as a chimera, belied by the cleareſt evidence of our ſenſes ; while the learned beheld it with diſdain, becauſe it militated againſt the fanciful diſtinctions and the vague erroneous tenets of the Peripatetic philoſophy, which no one had ventured to call in queſtion ; and it is amuſing to obſerve with what dexterity the Copernicans, ſtill uſing the ſame weapons, endeavoured to parry the blows of their antagoniſts. Its real merits and blemiſhes appear to have been overlooked by both parties. Brahé framed a ſort of intermediate ſyſtem ; but this Daniſh aſtronomer was more remarkable for his patience and ſkill in obſerving the heavens, than for his talents of philoſophical inveſtigation. Towards the commencement of the 16th century, a new order of things emerged. The ſyſtem of Copernicus became generally known and daily made converts. Its reception alarmed the ever-watchful authority of the church, rouſed her jealouſy, and at length provoked her vindictive artillery. The *ultima ratio theologorum* was pointed at the head of the illuſtrious Galileo, whoſe elegant genius diſcovered the laws of motion, extended the ſcience of mechanics, and added luſtre and ſolidity to the true ſyſtem of the univerſe. From the ſtorms of perſecution Copernicus himſelf had been exempted only by a timely death.

COPPER, one of the metals ; for the properties of which, ſee CHEMISTRY *Index* in this Supplement.—The Chineſe have a metal which they call *pe-tung*, but which Sir George Staunton denominates

White Copper. This metal has a beautiful ſilver-like appearance, and a very cloſe grain. It takes a fine poliſh, and many articles of neat workmanſhip, in imitation of ſilver, are made of it. An accurate analyſis has determined it to conſiſt of copper, zinc, a little ſilver ; and in ſome ſpecimens a few particles of iron and of nickel have been found. From this account it would appear that white copper is not an artificial mixture of metals, but is found native in the mine. Yet in the very ſame page and paragraph, Sir George proceeds to ſay that Dr Gallan was informed at Canton, that the artiſts, in making their pe-tung, reduce the copper into as thin ſheets or laminæ as poſſible, which they make red-hot, and increaſe the fire to ſuch a pitch as to ſoften in ſome degree the laminæ, and to render them ready almoſt to flow. In this ſtate they are ſuſpended over the vapour of their pureſt tu-te-nag or zinc, placed in a ſubliming veſſel over a briſk fire. The vapour thus penetrates the heated laminæ of the copper, ſo as to remain fixed with it, and not to be eaſily diſſipated or calcined by the ſucceeding fuſion it has to undergo. The whole is ſuffered to cool gradually, and is then found to be of a brighter colour, and of a cloſer grain, than when prepared in the European way. Surely this is not the white copper, which conſiſts of copper, zinc, ſilver, iron, and nickel.

CORK is the exterior bark of a tree which has been deſcribed in the Encyclopædia. When the tree is about 15 years old it is fit to be barked, and this can be done ſucceſſively for eight years. The bark always grows up again, and its quality improves as the age of the tree increaſes. It is commonly ſinged a little over a ſtrong fire or glowing coals, or laid to ſoak a certain time in water; after which it is placed under ſtones in order to be preſſed ſtraight. We were wont to procure the greater part of our cork from the Dutch, who brought it principally from France; but they imported ſome alſo from Portugal and Spain.

This tree, as well as the uſes to which its bark is put, was known to the Greeks and the Romans; by the former of whom it was called φελλος. and by the latter *ſuber*. By the Romans, as we learn from Pliny, it was even employed to ſtop veſſels of every kind; but its application to this uſe ſeems not to have been very common till the invention of glaſs bottles, of which Profeſſor Beckmann finds no mention before the 15th century.

In later times, ſome other vegetable productions have been found which can be employed inſtead of cork for the laſt-mentioned purpoſe. Among theſe is the wood of a tree common in South America, particularly in moiſt places, which is called there *monbin* or *monbain*, and by botaniſts *ſpondias lutea*. This wood is brought to England in great abundance for that uſe. The ſpongy root of a North American tree, known by the name of *nyſſa*, is alſo uſed for the ſame end, as are the roots of liquorice, which, on that account, is much cultivated in Sclavonia, and exported to other countries.

CORNUA Ammonis, in natural hiſtory, are foſſil ſhells, of which a pretty full account is given in the Encyclopædia. See Cornu *Ammonis* and Snake-*Stones*. It was obſerved in the laſt of theſe articles, that few, if any, of theſe ſhells are known in their recent ſtate, or as occupied by the living animal; but ſome authors have aſſerted, on the authority of Linnæus, that *ammonites*, with ſhells ſimilar to all the varieties of the foſſil ones, are yet found alive in the depth of the ſea. We are much inclined to embrace this opinion; but it has been controverted by *M. de Lamanon*, who accompanied *La Perouſe* on his voyage of diſcovery, by ſuch arguments as we know not how to anſwer. This unfortunate naturaliſt (ſee Lamanon in this Supplement) allows that there are ſtill in the ſea living *cornua ammonis*; but he thinks that they are in very ſmall numbers, and materially different from the greater part of the foſſil ones. According to him, theſe laſt ought to be conſidered as a race, formerly the moſt numerous of all, of which, either there are no deſcendants, or thoſe deſcendants are reduced to a few degenerate individuals. That there are no living animals with ſhells of the very ſame kind with ſome of the foſſil *cornua ammonis*, the following obſervations he conſiders as a ſufficient proof.

" The foſſil ſhells are very light and thin, whereas the ſhells of thoſe animals that live in very deep water are always thick and ponderous; beſides, the form of the foſſil cornua ammonis points out to us, in ſome meaſure, the organization of the animal which inhabited it. The celebrated Juſſieu proved, in 1721, that there exiſted a very cloſe analogy between the ammonite and nautilus (a). It is well known that the nautilus, by filling or emptying a part of its ſhell, has the power of remaining ſtationary in any depth it pleaſes: the ſame was doubtleſs the caſe with the ammonite; and if this ſpecies ſtill abounds in the ſea, it would ſurely be occaſionally diſcovered by ſailors.

" The waves alſo would throw fragments of it on the ſhore; fiſhermen might ſometimes entangle it in their nets; or, at leaſt, there would be fragments ſticking to the lead of the ſounding line when aſcertaining great depths. It may alſo be added, that if the ammonites never quitted the abyſs of the ſea, thoſe which are found petrified would not be conſtantly met with on the ſame level, and in the ſame bed, as thoſe ſhell-fiſh that only inhabit the ſhallows. There are, however, found in Normandy, Provence, Touraine, and a multitude of other places, ammonites mixed with turbines, buccina (whelks), and other littoral ſhells. They are found, beſides, at every degree of elevation from below the level of the ſea to the ſummits of the higheſt mountains. Analogy alſo leads us to ſuppoſe, that Nature, who has given eyes to the nautilus, has not refuſed them to the ammonite: now what uſe could theſe be of if they remained confined to thoſe depths which the light is unable to penetrate?

" The extinction of the ancient race of ammonites is therefore an eſtabliſhed fact, which no rational ſuppoſition can deſtroy; and this fact is undoubtedly the moſt ſurpriſing of any that is preſented to us in the hiſtory of aquatic animals. The diſcovery of a few living ſpecies of cornua ammonis does not deſtroy the truth of this, for theſe ammonites are very different from thoſe which are found petrified. They are extremely rare, and cannot be looked up to as the repreſentatives of the old ammonites, ſo varied in their ſpecies, and the number of which in the ancient ocean was probably far more conſiderable than that of all the other ſhells beſides."

To every univolve ſhell, rolled in a ſpiral, ſo as that a horizontal plane will divide it into two equal parts, formed of united ſpirals, and bearing a certain proportion to each other, our author gives the name of an *ammonite*. " I thought it abſolutely neceſſary (ſays he) to aſcertain the preciſe meaning of the term *ammonite*, previous to deſcribing that which I found during our voyage round the world. The form of this is almoſt orbicular, the long diameter being to the ſhort one as three lines to two lines and three quarters. The firſt ſpire is by far the largeſt, occupying nearly half of the longitudinal diameter. The ſummit is placed at the diſtance of about two-thirds of this diameter; it is terminated on the right ſide by a very ſmall knob viſible only through a magnifier, thus differing from the ammonite of Rimini, which beſides is microſcopical and celled, the inſide of this which we are now ſpeaking of being entirely plain. The number of ſpiral circumvolutions is four and a half; they are equally convex on both ſides, and are fixed on a plane, dividing the ſhell into

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(a) There are, however, ſome ſtriking internal differences: firſt, the partitions in the ſhell of the nautilus are more curved than thoſe of the ammonite: ſecondly, the ammonite wants the ſmall hole which communicates from one cell to the other.

into two equal parts: there is on each ſide a kind of boſs formed by the increaſe of the perpendicular diameter of the ſpires, in proportion as they recede from the centre. The ſurface is ſmooth; the back is armed with a flat, even, brittle creſt, as thin as paper, ſurrounding it on every ſide like a ruff: it is about half a line broad, extends over the ſummit of the ſpires, and ſerves to join them together. The mouth of the ſhell is nearly triangular; its edges project in the form of lips, and are rounded at the border. I have often found this ammonite encloſed in the ſtomach of the bonetta (ſcomber pelamis, Linn.), caught in the South Sea, between the tropics, where no bottom was found with a line of more than two hundred fathoms. Theſe ſhells were covered with a black clayey mud. Their ſize varies from one to four lines acroſs; they are conſequently the largeſt living ammonites that have yet been diſcovered."

It is well known for what purpoſe the modern philoſophers of France have been ſo indefatigable in the ſtudy of natural hiſtory; and there can be little doubt but that it is to ſerve the ſame purpoſe that Lamanon thus reaſons for the deſtruction of the ancient race of ammonites in ſome univerſal convulſion of the world. But ſuppoſing his arguments concluſive, they affect not the truth of the Jewiſh and Chriſtian ſcriptures. It is nowhere ſaid in the Bible, that the *matter* of this globe was brought into being at the moment when Moſes repreſents the Creator as beginning to reduce the chaos into order; and it is more than inſinuated that there will be a *new earth* after the preſent ſyſtem of things ſhall be diſſolved. That *new* earth will certainly be ſtored with ſome kind of inhabitants; and could it be demonſtrated that there was an *old* earth, previous to the era of the Moſaic coſmogany, inhabited by creatures rational and irrational, and that the foſſil *cornua ammonis* make part of the wreck of that ſyſtem, the cauſe of revelation would remain uninjured. "Moſes, as a real philoſopher * has well obſerved, writes the hiſtory, not of this globe through all its revolutions, but of the race of Adam."

This ſecret attack, therefore, made by Lamanon againſt that religion of which he once profeſſed to diſcharge the duties of a prieſt, is nothing more than *telum imbelle ſine ictu*. Yet it may be worth ſome naturaliſt's while to enquire, whether, though feeble, it has been fairly made. We confeſs that our own ſuſpicions of unfair dealing are ſtrong; for when a man of ſcience contradicts himſelf in the courſe of two pages, the blunder muſt be attributed to ſome other ſource than mere inadvertency. M. de Lamanon wiſhes to prove, among other things, that the ancient ammonites did not inhabit great depths of the ſea; and that Linnæus was miſtaken when he ſuppoſed that in great depths they may ſtill be found. Yet he himſelf tells us, that he frequently caught ammonites in the South Sea, where no bottom was to be found with a line of *more than* 200 *fathoms;* and to put it beyond a doubt that the animals had been at that bottom, he informs us, that their ſhells were covered with a *black clayey mud*. It is true theſe ammonites were but ſmall; while of 300 varieties of foſſil ammonites which he mentions, ſome, he ſays, have been found ten feet in circumference. But is it certain that theſe large ſhells were real *cornua ammonis?* If they agree not exactly with our author's deſcription of the ſhell of the ammonite (a fact into which we have had no opportunity of inquiring), his arguments for the extinction of the ancient race are groſs ſophiſms, unworthy of a man either of ſcience or of candour.

CORRECTION-HOUSE is a priſon where idle vagrants are compelled to work, and where perſons guilty of certain crimes ſuffer puniſhment and make reparation to the public. Of the former kind of *correction houſes*, perhaps enough has been ſaid in the Encyclopædia under the title WORK-*Houſe*; but of the latter very little will be found in that work under the titles BRIDEWELL and IDLENESS.

Perhaps houſes of correction, as means of puniſhment, are not, in this country, employed ſo frequently as juſtice and expediency ſeem to require. In the opinion of Dr Paley, whoſe opinions are always worthy of attention, it is one of the greateſt defects of the laws of England (and we may ſay the ſame thing of the laws of Scotland), that "they are not provided with any other puniſhment than that of death, ſufficiently terrible to keep offenders in awe. Tranſportation, which is the puniſhment ſecond in the order of ſeverity, anſwers the purpoſe of example very imperfectly; not only becauſe exile is in reality a ſlight puniſhment to thoſe who have neither property, nor friends, nor regular means of ſubſiſtence at home, but becauſe the puniſhment, whatever it be, is unobſerved and unknown. A tranſported convict *may* ſuffer under his ſentence, but his ſufferings are removed from the view of his countrymen; his miſery is unſeen; his condition ſtrikes no terror into the minds of thoſe for whoſe warning and admonition it was intended. This chaſm in the ſcale of puniſhment produces alſo two farther imperfections in the adminiſtration of penal juſtice; of which the firſt is, that the ſame puniſhment is extended to crimes of very different characters and malignancy; and the ſecond, that puniſhments, ſeparated by a great interval, are aſſigned to crimes hardly diſtinguiſhable in their guilt and miſchief."

Perhaps this chaſm might be properly filled up by houſes of correction under judicious management, which might likewiſe promote another important purpoſe, better than the puniſhments in common uſe.

The end of puniſhment is twofold, *amendment* and *example*. In the firſt of theſe, the *reformation* of criminals, little has ever been effected, and little indeed ſeems practicable by the puniſhments known to the laws of Britain. From every ſpecies of puniſhment inflicted among us, from impriſonment and exile, from pain and infamy, malefactors return more hardened in their crimes, and more inſtructed. The caſe we think would often be different when they returned to the world from a well-regulated houſe of correction. As experience is the only ſafe guide in matters of legiſlation and police, we ſhall lay before our readers *M. Thouin*'s account of the houſe of correction at Amſterdam, which ſeems to corroborate our opinion.

The Amſterdam correction houſe, from the employment of the priſoners confined in it, is called the *raſping-houſe*, and is deſtined to the reception of thoſe malefactors whoſe crimes do not amount to a capital offence. Their puniſhment cannot ſo properly be denominated ſolitary confinement as a ſequeſtration from ſociety during a limited term of years. The building is ſituated in a part of the ſuburbs to the north-eaſt of the city.

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* *Profeſſor Robiſon of Edinburgh.*

The exterior has nothing remarkable, either with reſpect to form or extent. It is detached from the ſtreet by a ſpacious court, which contains the keeper's lodge, together with apartments for the different ſervants belonging to the eſtabliſhment. Over the gate, which opens from this court into the priſon, are placed two ſtatues, as large as life, repreſenting two men in the act of ſawing a piece of logwood.

The inner court is in the form of a ſquare, round which are arranged the apartments of the priſoners, together with the neceſſary warehouſes. One part of the ground ſtory is divided into different chambers; the other ſerves as a depot for the logwood, and the implements employed in its preparation.

The keeper, whoſe countenance, contrary to the general cuſtom of perſons of his profeſſion, was ſtrongly indicative of urbanity and gentleneſs, introduced M. Thouin into an apartment where two priſoners were at work in ſawing a large log of Campeachy wood. The ſaw is compoſed of four blades joined together, with very ſtrong, large, and ſharp teeth, which make a ſciſſure in the wood of nearly two inches in breadth. The operation is repeated, till the pieces become too ſmall to undergo the ſaw, when they are ground in mills peculiarly conſtructed for this purpoſe.

This employment requires an extraordinary exertion of ſtrength, and is at firſt a ſevere penance even to robuſt perſons; but habit, addreſs, and practice, ſoon render it eaſy; and the priſoners in a ſhort time become competent to furniſh, without painful exertion, their weekly contingent of 200 lb. weight of ſawed pieces. After completing this taſk, they even find time to fabricate a variety of little articles in wood and ſtraw, which they ſell to thoſe who viſit the priſon, or diſpoſe of, by means of agents, in the town.

M. Thouin next inſpected three apartments of different dimenſions, which opened into the inner court. The one was inhabited by four, the ſecond by ſix, and the third by ten priſoners. The furniture of the rooms conſiſted in hammocks, with a matraſs, a blanket, and a coverlid to each, tables, chairs, and ſtools, glaſs, &c. earthen veſſels, and various other articles of convenience. Every thing in theſe apartments was diſtinguiſhed by neatneſs and propriety; and notwithſtanding the number of inhabitants allotted to each, was fully adequate to the dimenſions of the rooms; the ſenſes were not offended with any diſagreeable ſcent, and the air was in every reſpect as pure and wholeſome as the ſurrounding atmoſphere.

In an obſcure part of the building are a number of cells, in which formerly thoſe priſoners who revolted againſt the proper ſubordination of the place, or ill-treated their comrades, were confined for a few days. But the keeper aſſured M. Thouin that theſe cells had not been made uſe of for upwards of 10 years. They are dark gloomy dungeons, with only a ſmall aperture for the admiſſion of light and air. The ſuppreſſion of this barbarous and coercive puniſhment does honour to the humanity of government.

The ſtore rooms are filled with various kinds of wood for the purpoſes of dyeing; as the haemotoxylum campechianum, the morus tinctoria, the caeſalpinia ſappan, &c. They are all exotics, with the exception of the Evonymus Europæus. The warehouſes were not of ſufficient extent to contain the quantity of wood, which was depoſited in piles in different parts of the court.

The priſoners, amounting to 76 in number, were uniformly habited in coarſe woollens; wear very good ſtockings, large leather ſhoes, white ſhirts, and caps or hats. They are, by the rules of the houſe, obliged to frequent ablutions, which greatly contribute to the preſervation of their health. There was only one ſick perſon amongſt them; and, what is not a little remarkable, almoſt all the priſoners had formerly lived in large commercial towns; very few villagers were amongſt them. They had all been ſentenced to impriſonment for theft; but it depends upon themſelves, by reformation and good behaviour, to ſhorten the term of their confinement, which many of them frequently do.

The keeper, whoſe humanity to the unfortunate perſons committed to his care entitles him rather to the title of their protector than their gaoler (and M. Thouin informs us, that the priſoners generally called him by no other name than *father*), aſſiſts them with his counſels and friendly admonitions. He regiſters every week, in a book appropriated to this purpoſe, both the inſtances of good and bad behaviour, which is annually ſubmitted to the examination of the magiſtracy, who, from this report, abridge or prolong the term of confinement, according to the degree of indulgence which each priſoner appears to merit. Caſes frequently happen where a malefactor, condemned to an impriſonment of eight years, by his good behaviour procures his enlargement at the expiration of four; and ſo in proportion for a ſhorter term. But great attention is paid to diſcriminate between actual reform and hypocritical artifice.

The reward of good behaviour is not, however, confined to, or withheld till, the period of actual liberation. Their reſtoration to ſociety is preceded by a progreſſive amelioration of their lot. Their work is gradually rendered leſs laborious, they are accommodated with ſeparate apartments, and employed in the ſervices of domeſtic economy. The keeper even entruſts them with commiſſions beyond the precincts of the priſon; and ſcarce a ſingle inſtance has occurred of their abuſing this indulgence. By this prudent management, a conſiderable ſaving is effected in the expence of the eſtabliſhment, at the ſame time that it tends to wear away prejudice, and to initiate the priſoners by gradual advances into the reciprocal duties of ſocial life.

M. Thouin made particular inquiries whether it was cuſtomary for perſons after their diſcharge to be confined a ſecond and third time, as is but too often the caſe in many countries, for a repetition of their offence. He was informed, that ſuch inſtances very rarely occur; but the caſe is not without precedent, as he obſerved in the perſon of a young Jew, who was then in the raſping-houſe for the third time. The caſe of this man is ſomewhat extraordinary. During the period of his detention, he always conforms, with the moſt ſcrupulous obſervance, to the rules of the place, and gives general ſatisfaction by his exemplary conduct. But ſuch, as he himſelf avowed to our traveller, is his conſtitutional propenſity to thieving, that no ſooner is the term of his impriſonment elapſed, than he returns with redoubled ardour to his lawleſs courſes. It is not ſo much for the ſake of plunder, as to gratify his irreſiſtible impulſe, that he follows this vicious life; and M. Thouin adds, that he recounted his different exploits with as much exultation and triumph as a veteran diſplays when rehearſing his warlike atchievements.

Another ſalutary regulation in this inſtitution, from which the beſt conſequences reſult, is the indulgence granted to the priſoners of receiving the viſits of their wives and miſtreſſes twice every week. Proper care, however, is taken to guard againſt the introduction of diſeaſe; and the ladies, in one ſenſe, purchaſe their admiſſion by giving a trifling ſum of money at the gate, which becomes the perquiſite of the aged priſoners, whoſe wants are of a different nature from their youthful comrades. Thus the pleaſures of one claſs contribute to the comforts of the other; and the entrance money, trifling as it is, keeps away a croud of idle vagabonds, who have no acquaintance with the priſoners. The ladies at their viſits are permitted to eat and drink with their lovers; and when the converſation becomes too animated for a third perſon to be preſent, the reſt of the company obligingly take the hint, and leave them to enjoy a *tete-a-tete.*—By this prudent regulation, many hurtful conſequences attendant on a total ſecluſion from female ſociety are guarded againſt.

M. Thouin concludes his account with obſerving, that the raſping-houſe at Amſterdam bears a greater reſemblance to a well-ordered manufactory than to a priſon. It were to be wiſhed that all ſimilar inſtitutions were conducted upon a ſimilar plan (A).

So ſays our author: But though we have admitted experience to be the only ſafe guide in regulating inſtitutions of this kind, we cannot help thinking that the plan is ſuſceptible of improvement. We do not ſee the propriety of locking up four, ſix, or ten thieves in the ſame apartment. The uncommon attention to cleanlineſs, which diſtinguiſhes all ranks among the Dutch, may indeed prevent the room from having an offenſive ſcent; but what can prevent ſuch a number of unprincipled perſons from corrupting each other in Holland, as we know that they do in Great Britain? The introduction of females of looſe character to felons ſuffering puniſhment for their offences in a priſon, is a practice which we truſt will be approved only by philoſophers of the French ſchool. The Britiſh philoſopher, whom we have already quoted with approbation, is of opinion, and we heartily agree with him, that "of reforming puniſhments, none promiſes ſo much ſucceſs as that of ſolitary impriſonment, or the confinement of criminals in ſeparate apartments. This improvement of the Amſterdam houſe of correction would augment the terror of the puniſhment, would ſeclude the criminal from the ſociety of his fellow-priſoners, in which ſociety the worſe are ſure to corrupt the better; would wean him from the knowledge of his companions, and from the love of that turbulent pernicious life in which his vices had engaged him; would raiſe up in him reflections on the folly of his choice, and diſpoſe his mind to ſuch bitter and continued penitence, as might produce a laſting alteration in the principles of his conduct."

In ſome houſes of correction, the priſoners are ſubjected to the diſcipline of flagellation at ſtated intervals. We will not take it upon us to ſay that this puniſhment is never proper; but we are fully convinced that it is not often ſo; and that flagellation, if it can at all produce any good effect, muſt be adminiſtered in private. It is obſerved by Fielding, who well underſtood human nature, that faſting is the proper puniſhment of profligacy, not any puniſhment that, like flagellation, is attended with ſhame. Puniſhment (ſays he) that deprives a man of all ſenſe of honour, never will contribute to make him virtuous; and we believe it is generally admitted by the gentlemen of the army, that a ſoldier who has ſuffered the puniſhment of whipping ſeldom proves good for any thing.

COURTESEY OF SCOTLAND. See LAW (*Encycl.*), Part III. ſect. ix. § 28.

COWRY-SHELLS, the loweſt money in ſome parts of the Eaſt. See MONEY (*Encycl.*), where they are called *laris.*

CRANE, in mechanics, a machine uſed for raiſing or lowering great weights. For the principles on which theſe machines act, ſee DYNAMICS in this *Supplement*, and likewiſe MECHANICS, *Encycl.* where deſcriptions are given of ſeveral very powerful cranes.

The crane in common uſe is employed with ſome danger to thoſe who work it; and therefore a machine of this kind, acting upon a ſimple and certain principle, by which the men walking in the wheel can lower goods with ſafety as well as expedition, has long been conſidered as a great deſideratum in mechanics. Repeated premiums have been offered by the *Society for the Encouragement of Arts* to induce ingenious men to attempt the invention of ſuch a machine; and various have been the contrivances for accompliſhing ſo deſirable a purpoſe. A clergyman, who ſubſcribes E. C. we ſuppoſe as the initials of his name, propoſes, through the medium of the Repertory of Arts, to accompliſh it merely by introducing the action of a worm or ſcrew into the crane.

Whenever a worm of two threads is introduced into a machine, all retrograde motion is ſtopped, unleſs that worm receive its reaction from the firſt moving force; for, powerfully as a worm acts upon a wheel, a wheel has no power upon a worm, whatever force may be applied to it. Suppoſe, then, the firſt motion in a crane were given by a worm upon the axis of the wheel in which the man walks, the man would have perfect command of the machine, to raiſe or lower the goods at pleaſure, with the remoteſt poſſibility of being overpowered by the deſcending weight.

"Were I to conſtruct (ſays the author) a crane upon this principle, I would have the axis of the wheel in which the man walks, and the axis of the worm, in ſeparate parts, and occaſionally united by a coupling-box. When goods were to be raiſed, the two axes ſhould be connected; when lowered, they might be diſunited, and the worm turned by a winch, which would be done much more expeditiouſly that way than by the wheel. For the reaſons before ſuggeſted, the deſcent of the weight could be accelerated or ſtopped at pleaſure, at the diſcretion of the perſon turning the winch.

"This contrivance might be not inconveniently applied

(A) We do not know that M. Thouin's journal of his travels has been yet publiſhed. Extracts from it have been inſerted into the *Decade*, a periodical publication at Paris, whence this account of the *Amſterdam houſe of correction* was firſt copied into the Monthly Magazine for June 1798.

plied to a crane already erected upon the common principle: Let there be a wheel put upon any convenient axis in the machine as it now ſtands; upon this let there lie a worm, that can be thrown in or out of gear at pleaſure; and let the lever by which it is done lie within reach of the man's hand in the wheel. The goods being faſtened to the crane, and raiſed off the floor of the warehouſe ready for letting down, the man puts the worm into gear, leaves the wheel, and lets the goods down by the winch. Provided it can be conveniently done, it would be adviſable to throw the wheel in which the man walks out of gear when the winch is made uſe of; this, however, I ſhould apprehend, would not be a matter of abſolute neceſſity."

Our author is aware of two objections which may be urged againſt the introduction of a worm into a crane in the manner which he propoſes. The firſt ariſes from the ſlowneſs of the motion produced by the turning of a ſcrew, which he conſiders as unworthy of regard; becauſe the neceſſary ſpeed is to be gained by the firſt pair of wheels and the diameter of the barrel of the windlaſs.

To the ſecond, ariſing from the ſuppoſed greater friction between a worm and wheel, he replies, that as the friction between the teeth of two wheels (if not formed on the true epicycloidal principle) muſt, while it laſts, be greater than between a worm and wheel for the ſame ſpace of time, it ſeems no unreaſonable ſuppoſition that the aggregate of friction will, in the two caſes, nearly balance each other; eſpecially if it be taken into the account, that to obtain the power of one worm and wheel, there will be, in moſt caſes, required two pair of wheels, and two additional axes—all which will add to the friction. But, granting the balance of friction to be againſt the action of the worm, the power to overcome it is greater in proportion than to overcome the friction of two wheels.

Mr James Whyte of Chevening, in the county of Kent, whoſe improvement in the conſtruction of pullies has, with due reſpect, been noticed elſewhere *, gives, in *the Tranſactions of the Society for the Encouragement of Arts*, &c. the following deſcription of a new crane for wharfs:

Plate XX.

A (fig. 1.), a circular inclined plane, moving on a pivot underneath it, and carrying round with it the axis E. A perſon walking on this plane, and preſſing againſt the lever B, throws off the gripe D, by means of an iron rod C; and thus admits the plane and its axis to move freely, and raiſe the weight G by the coiling of the rope F round the axis E.

To ſhew more clearly the conſtruction and action of the lever and gripe, a plan of the circular inclined plane, with the lever and gripe, is added (ſee fig. 2.), where B repreſents the lever, D the ſpring or gripe. In this plan, when the lever B is in the ſituation in which it now appears, the ſpring or gripe D preſſes againſt the periphery of the plane, as ſhewn by the double line, and the machine cannot move; but when the lever B is preſſed out to the dotted line H, the gripe is alſo thrown off to the dotted line I, and the whole machine left at liberty to move. One end of a rope or cord, of a proper length, is fixed near the end of the lever B, and the other end made faſt to one of the uprights, ſerving to prevent the lever moving too far when preſſed by the man.

The properties of this crane, for which the premium of 40 guineas was adjudged by the ſociety to the inventor, are as follows:

1. It is ſimple, conſiſting merely of a wheel and axle. 2. It has comparatively little friction, as is obvious from the bare inſpection of the figure. 3. It is durable, as is evident from the two properties above mentioned. 4. It is ſafe; for it cannot move but during the pleaſure of the man, and while he is actually preſſing on the gripe-lever. 5. This crane admits of an almoſt infinite variety of different powers; and this variation is obtained without the leaſt alteration of any part of the machine. If, in unloading a veſſel, there ſhould be found goods of every weight, from a few hundreds to a ton and upwards, the man that does the work will be able ſo to adapt his ſtrength to each as to raiſe it in a ſpace of time proportionate to its weight; he walking always with the ſame velocity as nature and his greateſt eaſe may teach him.

It is a great diſadvantage in ſome cranes, that they take as long time to raiſe the ſmalleſt as the largeſt weight, unleſs the man who works them turn or walk with ſuch velocity as muſt ſoon tire him. In other cranes, perhaps, two or three different powers may be procured; to obtain which, ſome pinion muſt be ſhifted, or freſh handle applied or reſorted to. In this crane, on the contrary, if the labourer find his load ſo heavy as to permit him to aſcend the wheel without its turning, let him only move a ſtep or two toward the circumference, and he will be fully equal to the taſk. Again, if the load be ſo light as ſcarcely to reſiſt the action of his feet, and thus to oblige him to run through ſo much ſpace as to tire him beyond neceſſity, let him move laterally towards the centre, and he will ſoon feel the place where his ſtrength will ſuffer the leaſt fatigue by raiſing the load in queſtion. One man's weight applied to the extremity of the wheel would raiſe upwards of a ton; and it need not be added, that a ſingle-ſheaved block would double that power. Suffice it to ſay, that the ſize may be varied in any required *ratio*; and that this wheel will give as great advantage at any point of its plane as a common walking-wheel of equal diameter, as the inclination can be varied at pleaſure, as far as expediency may require. It may be neceſſary to obſerve, that what in the figure is the frame, and ſeems to form a part of the crane, muſt be conſidered as a part of the houſe in which it is placed; ſince it would be moſtly unneceſſary ſhould ſuch cranes be erected in houſes already built. With reſpect to the horizontal part, by walking on which the man who attends the gib occaſionally aſſiſts in raiſing the load, it is not an eſſential part of this invention, where the crane is not immediately contiguous to the gib, although, where it is, it would be certainly very convenient and economical.

Crane is alſo a popular name for a ſyphon, employed in drawing off liquors.

CROSS, *in ſurveying*, is an inſtrument conſiſting of a braſs circle, divided into four equal parts by two lines croſſing each other in the centre. At each extremity of theſe lines is fixed a perpendicular ſight, with ſmall holes below each ſlit, for the better diſcovering of diſtant objects. The croſs is mounted on a ſtaff or ſtand, to fix it in the ground, and is very uſeful for meaſuring ſmall pieces of land, and taking offſets, &c.

Cross-ſtaff, or ***Fore-ſtaff***, is a mathematical inſtrument

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* See *Mechanics*, n° 27. *Encycl.*

CHIMNEY PLATE XX.

Fig. 3.

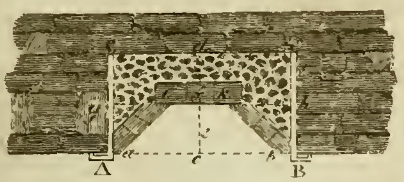


Fig. 5.

Fig. 8.

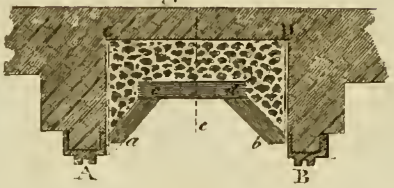


Fig. 4.

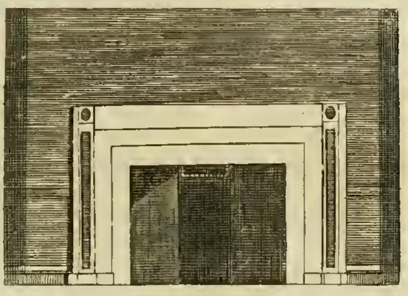


Fig. 7.

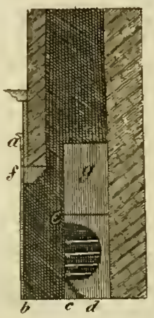
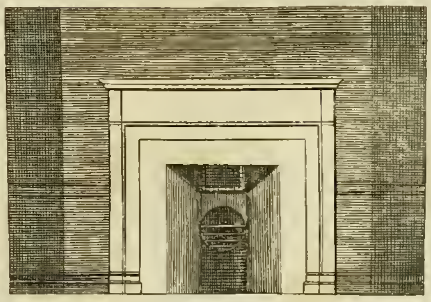


Fig. 6.



Scale 1 2 3 4 5 *of Feet*

CRANE

Fig. 1.

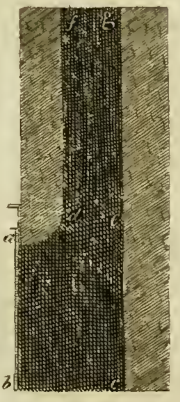


Fig. 1.

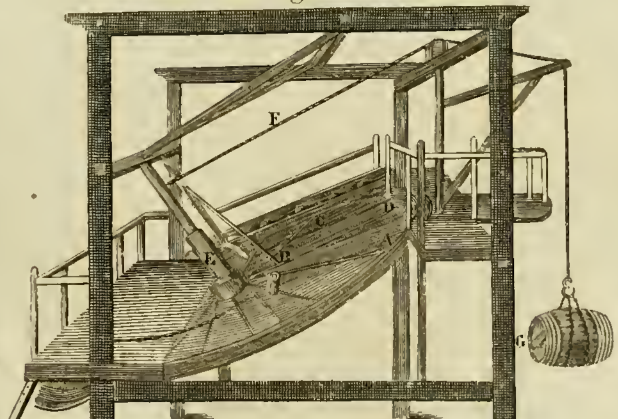
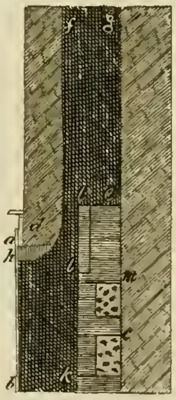


Fig. 2.



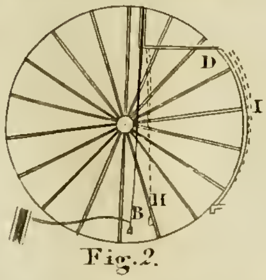


Fig. 2.

of box or pear-tree, conſiſting of a ſquare ſtaff of about three feet long, having each of its faces divided like a line of tangents, and having four croſs pieces of unequal lengths to fit on the ſtaff, the halves of theſe being as the radii to the tangent lines on the faces of the ſtaff.—The inſtrument was uſed in taking the altitudes of the celeſtial bodies at ſea.

CROWN, in aſtronomy, a name given to two conſtellations, the ſouthern and the northern.

Crown, in geometry, a plane ring included between two parallel or concentric peripheries of unequal circles.

Crown-Poſt, is a poſt in ſome buildings ſtanding upright in the middle between two principal rafters; and from which proceed ſtruts or braces to the middle of each rafter. It is otherwiſe called a *king-poſt*, or *king's-piece*, or *joggle-piece*.

La CRUZ, an excellent harbour on the north-weſt coaſt of America, diſcovered by the Spaniards in 1779. They were introduced into it by a paſſage which they called *Bucarelli's Entrance*, and which they placed in 55° 18′ N. Lat. and 139° 15′ W. Long. from the meridian of Paris. There is no good reaſon to queſtion the exactneſs of the latitude of this paſſage as laid down by the Spaniards; but the editor of Perouſe's voyage juſtly concludes, from the ſurvey made by our celebrated navigator Captain Cook on the coaſts adjacent to the entrance of Bucarelli, that this entrance is about 135° 20′ to the weſt of Paris, or very nearly 133° weſt of Greenwich.

The Spaniards were not long in the harbour of *La Cruz* before they received a viſit from the inhabitants in its neighbourhood. Bartering took place. The Indians gave their peltry, and various trifles, for glaſs beads, bits of old iron, &c. By this traffic the Spaniards were enabled to gain a ſufficiently exact knowledge of their genius, of their offenſive and defenſive arms; of their manufactures, &c.

Their colour is a clear olive; many among them have, however, a perfectly white ſkin: their countenance is well proportioned in all its parts. They are robuſt, courageous, arrogant, and warlike.

They clothe themſelves in one or two undreſſed ſkins (with the fur apparently); theſe are the ſkins of otters, of ſea-wolves, of benades (a ſpecies of deer), of bears, or other animals, which they take in hunting. Theſe dreſſes cover them from the neck to the middle of the leg; there are, however, many among them who wear boots of ſmooth ſkin, reſembling Engliſh boots, only that thoſe of the Indians open before, and are laced tight with a ſtring. They wear hats woven from the fine bark of trees, the form of which reſembles that of a funnel or a cone. At the wriſts they have bracelets of copper or iron, or for want of theſe metals the fins of whales; and round the neck, necklaces of ſmall fragments of bones of fiſhes and other animals, and even copper collars of the bigneſs of two fingers. They wear in their ears pendants of mother-of-pearl, or flat pieces of copper, on which is emboſſed a reſin of a topaz colour, and which are accompanied with jet beads. Their hair is long and thick, and they make uſe of a comb to hold it together in a ſmall queue from the middle to the extremity; a narrow ribbon of coarſe linen, woven for this purpoſe, ſerves as a ligament. They wear alſo as a covering a kind of ſcarf, woven in a particular manner, ſomething more than a yard and a half long, and about half a yard broad, round which hangs a fringe ſomething more than half a quarter of a yard deep, of which the thread is regularly twiſted.

The women give proofs of their modeſty and decency by their dreſs. Their phyſiognomy is agreeable, their colour freſh, their cheeks vermilioned, and their hair long; they plait it together in one long treſs. They wear a long robe of a ſmooth ſkin tied round the loins, like that of a nun; it covers them from the neck as low as the feet; the ſleeves reach down to the wriſts. Upon this robe they put divers ſkins of otters or other animals to defend themſelves from the inclemency of the weather. Better dreſſed, many of them might diſpute charms with the moſt handſome Spaniſh women; but diſſatisfied with their natural charms, they have recourſe to art, not to embelliſh, but to disfigure themſelves. All the married women have a large opening in the under lip, and this opening or orifice is filled up by a piece of wood cut in an oval ſhape, of which the ſmalleſt diameter is almoſt an inch; the more a woman is advanced in years, the more this curious ornament is extended: it renders them frightful, the old women eſpecially, whoſe lip, deprived of its wonted ſpring, and dragged by the weight of this extraordinary jewel, neceſſarily hangs in a very diſagreeable manner. The girls wear only a copper needle, which croſſes the lip in the place where the ornament is intended hereafter to be placed.

Theſe Indians in war make uſe of cuiraſſes and ſhoulder pieces of a manufacture like that of the whalebone ſtays among the Europeans. Narrow boards or ſcantlings form, in ſome ſort, the woof of the texture, and threads are the warp: in this manner the whole is very flexible, and leaves a free uſe to the arms for the handling of weapons. They wear round the neck a coarſe and large gorget which covers them as high as below the eyes, and their head is defended by a morion, or ſkull-piece, uſually made of the head of ſome ferocious animal. From the waiſt downwards, they wear a kind of apron, of the ſame contexture as their cuiraſs. Laſtly, a fine ſkin hangs from their ſhoulders down to the knee. With this armour they are invulnerable to the arrows of their enemies; but thus armed, they cannot change poſition with ſo much agility as if they were leſs burdened.

Their offenſive arms are arrows; bows, of which the ſtrings are woven like the large cords of our beſt muſical inſtruments; lances, four yards in length, tongued with iron; knives, of the ſame metal, longer than European bayonets, a weapon, however, not very common among them; little axes of flint, or of a green ſtone, ſo hard that they cleave the moſt compact wood without injury to their edge.

The pronunciation of their language is extremely difficult; they ſpeak from the throat, with a movement of the tongue againſt the palate. The little uſe the women make of the inferior lip greatly injures the diſtinctiveneſs of their language. The Spaniards could neither pronounce nor write the words which they heard.

From the vivacity of ſpirit in theſe Indians, and from their attention amply to furniſh the market eſtabliſhed in the harbour, it may be concluded that they are pretty laborious. They continually brought ſtuffs well woven and ſhaded by various colours, the ſkins of land and ſea wolves, of otters, bears, and other ſmaller animals;

mals; of theſe ſome were raw, and others dreſſed. There were to be found at this market alſo coverlets of coarſe cloth, ſhaded with white and brown colours, very well woven, but in ſmall quantities: large ribbons of the ſame linen which might match with that of the Spaniſh officers mattreſſes; ſkeins of thread ſuch as this cloth was made of; wooden plates or bowls neatly worked; ſmall boats, or canoes, painted in various colours, the figures of which repreſented heads with all their parts; frogs in wood, nicely imitated, which opened like tobacco boxes, and which they employed to keep their trinkets in: boxes made of ſmall planks, of a cubical form, being three quarters of a yard on each ſide, with figures well drawn, or carved on the outſide, repreſenting various animals; the covers fabricated like Flanders etwees, with rabbeted edges, formed ſo as to ſhut into the body of the box; animals in wood, as well thoſe of the earth as of the air; figures of men of the ſame material, with ſkull-caps repreſenting the heads of various fierce animals; ſnares and nets for fiſhing; copper collars for the neck, and bracelets of iron for the wriſt, but which they would not part with except at a very high price; beak-like inſtruments, from which they drew ſounds as from a German flute. The principal officers took ſuch of theſe merchandizes as were moſt agreeable to them, and left the remainder to the ſhips crews.

As the Indians diſcovered that the Spaniards were very dainty in their fiſh, they did not let them want for choice: the greateſt abundance was in ſalmon, and a ſpecies of ſole or turbot three yards and a quarter long, broad and thick in proportion; cod and pilchards were alſo brought to market, and fiſhes reſembling trout. From all this it may be inferred, that this gulf is full of fiſh; the banks too are covered with ſhells.

The quantity of mother-of-pearl that theſe Indians cut to pieces for making ear-rings awakened the curioſity of the Spaniards: they tried to diſcover whether theſe people had not in their poſſeſſion, or whether their country did not produce pearls, or ſome precious ſtones: their reſearches were fruitleſs; they only found ſome ſtones which they judged to be metallic, and which they carried on board, not having the neceſſary means for extracting the metal they might contain.

Theſe Indians feed upon fiſh, freſh or dry, boiled or roaſted; herbs and roots which their mountains yielded them, and particularly that which in Spain is called ſea parſley; and, laſtly, upon the fleſh of animals which they take in hunting: the productions of the chaſe are undoubtedly abundant, ſeeing the number of dogs they keep for this purpoſe.

Theſe Indians appeared to the Spaniards to worſhip the ſun, the earlieſt and moſt natural of all idolatrous worſhip; and they paid a decent reſpect to the remains of their dead. Don Maurelle, one of the Spaniſh officers, in an expedition round the gulf, found in two iſlands three dead bodies laid in boxes of a ſimilar form to thoſe which have been deſcribed above, though conſiderably larger, and decked in their furs. Theſe biers were placed in a little hut upon a platform, or raiſed floor, made of the branches of trees.

The country is very hilly, the mountains are lofty, and their ſlope extends almoſt every where to the ſea. The ſoil, limeſtone; it is nevertheleſs covered with an impenetrable foreſt of tall fir trees, very large and very ſtrait. As theſe trees cannot ſtrike very deep into the earth, the violence of the wind often tears them up by the roots: they rot and become a light mould, upon which grows a buſhy thicket; and in this are found nettles, camomile, wild celery, aniſe, a ſpecies of cabbage, celandine, elder, wormwood, ſorrel; and without doubt there are other plants along the rivers.

The Spaniards ſaw ducks, gulls, divers, kites, ravens, geeſe, ſtorks, gold-finches, and other little birds unknown to them.

The commerce between the Spaniards and the Indians was quite undiſturbed; and ſo deſirous were the latter to obtain iron, cloth, and other ſtuffs, that they ſold their children for broken iron hoops and other wares. The Spaniards in this manner bought three young lads, one from five to ſix years old, another of four, and the third from nine to ten, not to make ſlaves, but Chriſtians of them; they hoped beſides to derive uſeful information from them as to the nature of the country and its inhabitants. Theſe youths were ſo contented in being with the Spaniards, that they hid themſelves when their parents came on board, from the apprehenſion of being again reſtored to them. Two young girls were alſo purchaſed with the ſame view; one very ugly, ſeven years of age; the other younger, better made, but ſickly, and almoſt at the gates of death.

At the full and change of the moon, the ſea riſes in the harbour of La Cruz ſeventeen feet three inches Engliſh; it is then high water at a quarter after 12 at noon: the loweſt tides are fourteen feet three inches; the night tides exceed by one foot nine inches thoſe of the day.

CRYSTAL,
CRYSTALLIZATION,
and
Rock-Crystal.
} See Crystal and Crystallization, *Encycl.* and Chemistry-*Index* in this Supplement.

CUBIC Hyperbola, is a figure expreſſed by the equation $xy^2 = a$, having two aſymptotes, and conſiſting of two hyperbolas, lying in the adjoining angles of the aſymptotes, and not in the oppoſite angles, like the Apollonian hyperbola; being otherwiſe called by Newton, in his *Enumeratio Linearum Tertii Ordinis*, an hyperboliſmus of a parabola; and is the 65th ſpecies of thoſe lines according to him.

Cubic Parabola, a curve of the ſecond order, having two infinite legs tending contrary ways. The curve of this parabola cannot be rectified even by means of the conic ſections.

CULLEN (Dr William) was a man to whom phyſical ſcience is ſo deeply indebted, that it has often ſtruck us with wonder that no account of him has yet been given to the public, which deſerves to be claſſed with Britiſh biography. We know, indeed, that a life of him has been written by an eminent phyſician well qualified and ſtrongly inclined to do juſtice to the merits of his revered preceptor; but that life has been withheld from us by him who has certainly the beſt right to conſider himſelf as the guardian of the Doctor's fame, and who, we have been told, is to enlarge and publiſh it himſelf. In this ſtate of things our readers muſt pardon us for laying before them a very imperfect account of this eminent man, to whom we were ourſelves almoſt ſtrangers. There is a character of him in the periodical publication called *The Bee*, which we ſhall

ſhall appropriate to our own uſe, we are perſuaded, with the entire approbation of its author, though ſometimes we may expreſs our ſuſpicions that his praiſe is exaggerated.

Dr William Cullen was born in Lanarkſhire, in the weſt of Scotland, 11th December 1712. His father was for ſome time chief magiſtrate of the town of Hamilton; but though a very reſpectable man, his circumſtances were not ſuch as to permit him to lay out much money on the education of his ſon. William therefore, after ſerving an apprenticeſhip to a ſurgeon apothecary in Glaſgow, went ſeveral voyages to the Weſt Indies as a ſurgeon in a trading veſſel from London: but of this employment he tired, and ſettled himſelf, at an early period of life, as a country ſurgeon in the pariſh of Shotts, where he ſtaid a ſhort time practiſing among the farmers and country people, and then went to Hamilton with a view to practiſe as a phyſician, having never been fond of operating as a ſurgeon.

While he reſided near Shotts, it chanced that Archibald Duke of Argyle, who at that time bore the chief political ſway in Scotland, made a viſit to a gentleman of rank in that neighbourhood. The Duke was fond of literary purſuits, and was then particularly engaged in ſome chemical reſearches, which required to be elucidated by experiment. Eager in theſe purſuits, his Grace, while on this viſit, found himſelf much at a loſs for the want of ſome ſmall chemical apparatus, which his landlord could not furniſh: but happily recollecting young Cullen in the neighbourhood, he mentioned him to the Duke as a perſon who could probably furniſh it. He was accordingly invited to dine; was introduced to his Grace,—who was ſo much pleaſed with his knowledge, his politeneſs, and addreſs, that he formed an acquaintance which laid the foundation of all Dr Cullen's future advancement.

The name of Cullen by this time became familiar at every table in that neighbourhood; and thus he came to be known, by character, to the Duke of Hamilton, who then reſided, for a ſhort time, in that part of the country: and that nobleman having been ſuddenly taken ill, the aſſiſtance of young Cullen was called in; which proved a fortunate circumſtance in ſerving to promote his advancement to a ſtation in life more ſuited to his talents than that in which he had hitherto moved.

The character of the Douglaſſes, of which name the family of Hamilton now forms a principal branch, has always been ſomewhat of the ſame ſtamp with that of the riſing Cullen. Genius, benevolence, frankneſs, and conviviality of diſpoſition, have been, with them in general, very prominent features; and if to that be added a ſpirit of frolic and diſſipation, theſe will be accounted as only natural conſequences of thoſe youthful indulgences that ſpring from an exceſs of wealth at an early period of life, and the licence allowed to people of elevated rank. The Duke was therefore highly delighted with the ſprightly character and ingenious converſation of his new acquaintance. Receiving inſtruction from him in a much more pleaſing, and an infinitely eaſier way than he had ever before obtained, the converſation of Cullen proved highly intereſting to his Grace.—No wonder then that he ſoon found means to get his favourite Doctor, who was already the eſteemed acquaintance of the man through whoſe hands all preferments in Scotland were obliged to paſs, appointed to a place in the univerſity of Glaſgow, where his ſingular talents for diſcharging the duties of the ſtation he now occupied ſoon became very conſpicuous (A).

During his reſidence in the country, however, ſeveral important incidents occurred, that ought not to be paſſed over in ſilence. It was during this time that was formed a connection in buſineſs in a very humble line between two men, who became afterwards eminently conſpicuous in much more exalted ſtations. William, afterwards Doctor, Hunter, the famous lecturer on anatomy in London, was a native of the ſame part of the country; and not being in affluent circumſtances more than Cullen, theſe two young men, ſtimulated by the impulſe of genius to proſecute their medical ſtudies with ardour, but thwarted by the narrowneſs of their fortune, entered into a copartnery buſineſs as ſurgeons and apothecaries in the country. The chief end of their contract being to furniſh the parties with the means of proſecuting their medical ſtudies, which they could not ſeparately ſo well enjoy, it was ſtipulated, that one of them alternately ſhould be allowed to ſtudy in what college he inclined, during the winter, while the other ſhould carry on the buſineſs in the country for their common advantage. In conſequence of this agreement, Cullen was firſt allowed to ſtudy in the univerſity of Edinburgh for one winter; but when it came to Hunter's turn next winter, he, preferring London to Edinburgh, went thither. There his ſingular neatneſs in diſſecting, and uncommon dexterity in making anatomical preparations, his aſſiduity in ſtudy, his mildneſs of manner, and pliability of temper, ſoon recommended him to the notice of Dr Douglaſs, who then read lectures upon anatomy and midwifery there; who engaged Hunter as an aſſiſtant, and whoſe chair he afterwards filled with ſo much honour to himſelf and ſatisfaction to the public.

Thus was diſſolved, in a premature manner, a copartnery perhaps of as ſingular a kind as is to be found in the annals of literature: nor was Cullen a man of that diſpoſition to let any engagement with him prove a bar to his partner's advancement in life. The articles were freely departed from by him; and Cullen and Hunter ever after kept up a very cordial and friendly correſpondence; though, it is believed, they never from that time had a perſonal interview.

During the time that Cullen practiſed as a country ſurgeon and apothecary, he formed another connection of a more permanent kind, which, happily for him, was not diſſolved till a very late period of his life. With

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(A) It was not, however, ſolely to the favour of theſe two great men that Cullen owed his literary fame. He was recommended to the notice of men of ſcience in a way ſtill more honourable to himſelf. The diſeaſe of the Duke of Hamilton having reſiſted the effect of the firſt applications, Dr Clarke was ſent for from Edinburgh; and he was ſo much pleaſed with every thing that Cullen had done, that he became his eulogiſt upon every occaſion. Cullen never forgot this; and when Clarke died, gave a public oration in his praiſe in the Univerſity of Edinburgh; which, it is believed, was the firſt of the kind in this country.

the ardour of diſpoſition he poſſeſſed, it cannot be ſuppoſed he beheld the fair ſex with indifference. Very early in life he took a ſtrong attachment to an amiable woman, a Miſs Johnſton, daughter to a clergyman in that neighbourhood, nearly of his own age, who was prevailed on to join with him in the ſacred bonds of wedlock, at a time when he had nothing elſe to recommend him to her except his perſon and diſpoſitions; for as to riches and poſſeſſions he had little of theſe to boaſt of. She was beautiful, had great good ſenſe, equanimity of temper, an amiable diſpoſition, and elegance of manners, and brought with her a little money, which, though it would be accounted nothing now, was ſomething in thoſe days to one in his ſituation in life. After giving to him a numerous family, and participating with him the changes of fortune which he experienced, ſhe peacefully departed this life in ſummer 1786.

In the year 1746, Cullen, who had now taken the degree of doctor in phyſic, was appointed a lecturer in chemiſtry in the univerſity of Glaſgow: and in the month of October began his lectures in that ſcience. His ſingular talents for arrangement, his diſtinctneſs of enunciation, his vivacity of manner, and his knowledge of the ſcience he taught, rendered his lectures intereſting to the ſtudents to a degree that had been till then unknown at that univerſity. He became, therefore, in ſome meaſure, adored by the ſtudents. The former profeſſors were eclipſed by the brilliancy of his reputation; and he had to experience all thoſe little rubs that envy and diſappointed ambition naturally threw in his way. Regardleſs, however, of theſe ſecret ſhagreens, he preſſed forward with ardour in his literary career; and, ſupported by the favour of the public, he conſoled himſelf for the contumely he met with from a few individuals. His practice as a phyſician increaſed from day to day; and a vacancy having occurred in the year 1751, he was then appointed by the king profeſſor of medicine in that univerſity. This new appointment ſerved only to call forth his powers, and to bring to light talents that it was not formerly known he poſſeſſed; ſo that his fame continued to increaſe.

As, at that period, the patrons of the univerſity of Edinburgh were conſtantly on the watch for the moſt eminent medical men to ſupport the riſing fame of the college, their attention was ſoon directed towards Cullen; who, on the death of Dr Plumber, profeſſor of chemiſtry, was, in 1756, unanimouſly invited to accept the vacant chair. This invitation he accepted: and having reſigned all his employments in Glaſgow, he began his academical career in Edinburgh in the month of October of that year; and there he reſided till his death.

If the admiſſion of Cullen into the univerſity of Glaſgow gave great ſpirit to the exertions of the ſtudents, this was ſtill, if poſſible, more ſtrongly felt in Edinburgh. Chemiſtry, which had been till that time of ſmall account in that univerſity, and was attended to by very few of the ſtudents, inſtantly became a favourite ſtudy; and the lectures upon that ſcience were more frequented than any others in the univerſity, anatomy alone excepted. The ſtudents, in general, ſpoke of Cullen with the rapturous ardour that is natural to youth when they are highly pleaſed. Theſe eulogiums appeared extravagant to moderate men, and could not fail to prove diſguſting to his colleagues. A party was formed among the ſtudents for oppoſing this new favourite of the public; and theſe ſtudents, by miſrepreſenting the doctrines of Cullen to others who could not have an opportunity of hearing theſe doctrines themſelves, made even ſome of the moſt intelligent men in the univerſity think it their duty publicly to oppoſe theſe imaginary tenets. The ferment was thus augmented; and it was ſome time before the profeſſors diſcovered the arts by which they had been impoſed upon, and univerſal harmony reſtored.

During this time of public ferment, Cullen went ſteadily forward, without taking any part himſelf in theſe diſputes. He never gave ear to any tales reſpecting his colleagues, nor took any notice of the doctrines they taught: That ſome of their unguarded ſtrictures might at times come to his knowledge, is not impoſſible; but if they did, they ſeemed to make no impreſſion on his mind.

Theſe attempts of a party of ſtudents to lower the character of Cullen on his firſt outſet in the univerſity of Edinburgh having proved fruitleſs, his fame as a profeſſor, and his reputation as a phyſician, became more and more reſpected every day. Nor could it well be otherwiſe: Cullen's profeſſional knowledge was always great, and his manner of lecturing ſingularly clear and intelligible, lively and entertaining; and to his patients, his conduct in general as a phyſician was ſo pleaſing, his addreſs ſo affable and engaging, and his manner ſo open, ſo kind, and ſo little regulated by pecuniary conſiderations, that it was impoſſible for thoſe who had occaſion to call once for his medical aſſiſtance, ever to be ſatisfied on any future occaſion without it. He became the friend and companion of every family he viſited; and his future acquaintance could not be diſpenſed with.

But if Dr Cullen in his public capacity deſerved to be *admired*, in his private capacity by his ſtudents he deſerved to be *adored*. His conduct to them was ſo attentive, and the intereſt he took in the private concerns of all thoſe ſtudents who applied to him for advice, was ſo cordial and ſo warm, that it was impoſſible for any one who had a heart ſuſceptible of generous emotions, not to be enraptured with a conduct ſo uncommon and ſo kind. Among ingenuous youth, gratitude eaſily degenerates into rapture—into reſpect nearly allied to adoration. Thoſe who advert to this natural conſtruction of the human mind, will be at no loſs to account for that popularity that Cullen enjoyed—a popularity, that thoſe who attempt to weigh every occurrence by the cool ſtandard of *reaſon* alone, will be inclined to think exceſſive. It is fortunate, however, that the bulk of mankind will ever be influenced in their judgment not leſs by feelings and affections than by the cold and phlegmatic dictates of *reaſon*. The adoration which generous conduct excites, is the reward which nature hath appropriated excluſively to diſintereſted beneficence. This was the ſecret charm that Cullen ever carried about with him, which faſcinated ſuch numbers of thoſe who had intimate acceſs to him. This was the power which his envious opponents never could have an opportunity of feeling.

The general conduct of Cullen to his ſtudents was thus. With all ſuch as he obſerved to be attentive and diligent, he formed an early acquaintance, by inviting them by twos, by threes, or by fours at a time, to ſup with him, converſing with them on theſe occaſions with the moſt engaging eaſe, and freely entering with them on the ſubject of their ſtudies, their amuſements, their difficulties, their hopes, and future proſpects. In this way he uſually invited the whole of his numerous claſs, till he made himſelf acquainted with their abilities, their private character, and their objects of purſuit. Thoſe among them whom he found moſt aſſiduous, beſt diſpoſed, or the moſt friendleſs, he invited the moſt frequently, till an intimacy was gradually formed, which proved highly beneficial to them. Their doubts, with regard to their objects of ſtudy, he liſtened to with attention, and ſolved with the moſt obliging condeſcenſion. His library, which conſiſted of an excellent aſſortment of the beſt books, eſpecially on medical ſubjects, was at all times open for their accommodation; and his advice, in every caſe of difficulty to them, they always had it in their power moſt readily to obtain. They ſeemed to be his family; and few perſons of diſtinguiſhed merit have left the univerſity of Edinburgh in his time, with whom he did not keep up a correſpondence till they were fairly eſtabliſhed in buſineſs. By theſe means he came to have a moſt accurate knowledge of the ſtate of every country, with reſpect to practitioners in the medical line; the only uſe he made of which knowledge was, to direct ſtudents in their choice of places, where they might have an opportunity of engaging in buſineſs with a reaſonable proſpect of ſucceſs. Many, very many, able men has he thus put into a good line of buſineſs where they never could have thought of it themſelves; and they are now reaping the fruits of this beneficent foreſight on his part.

Nor was it in this way only that he befriended the ſtudents at the univerſity of Edinburgh. Poſſeſſing a benevolence of mind that made him ever think firſt of the wants of others, and recollecting the difficulties that he himſelf had had to ſtruggle with in his younger days, he was at all times ſingularly attentive to their pecuniary concerns. From his general acquaintance among the ſtudents, and the friendly habits he was on with many of them, he found no difficulty in diſcovering thoſe among them who were rather in hampered circumſtances, without being obliged to hurt their delicacy in any degree. To ſuch perſons, when their habits of ſtudy admitted of it, he was peculiarly attentive. They were more frequently invited to his houſe than others; they were treated with more than uſual kindneſs and familiarity; they were conducted to his library, and encouraged by the moſt delicate addreſs to borrow from it freely whatever books he thought they had occaſion for: and as perſons in theſe circumſtances were uſually more ſhy in this reſpect than others, books were ſometimes preſſed upon them as a ſort of conſtraint, by the Doctor inſiſting to have their opinion of ſuch or ſuch paſſages they had not read, and deſiring them to carry the book home for that purpoſe. He, in ſhort, behaved to them rather as if he courted their company, and ſtood in need of their acquaintance than they of his. He thus raiſed them in the opinion of their acquaintance to a much higher degree of eſtimation than they could otherwiſe have obtained; which, to people whoſe minds were depreſſed by penury, and whoſe ſenſe of honour was ſharpened by the conſciouſneſs of an inferiority of a certain kind, was ſingularly engaging. Thus they were inſpired with a ſecret ſenſe of dignity, which elevated their minds, and excited an uncommon ardour of purſuit, inſtead of that melancholy inactivity which is ſo natural in ſuch circumſtances, and which too often leads to deſpair. Nor was he leſs delicate in the manner of ſupplying their wants, than attentive to diſcover them. He often found out ſome polite excuſe for refuſing to take payment for a firſt courſe, and never was at a loſs for one to an after courſe. Before they could have an opportunity of applying for a ticket, he would ſometimes lead the converſation to ſome ſubject that occurred in the courſe of his lectures; and as his lectures were never put in writing by himſelf, he would ſometimes beg the favour to ſee their notes, if he knew they had been taken with attention, under a pretext of aſſiſting his memory. Sometimes he would expreſs a wiſh to have their opinion of a particular part of his courſe, and preſented them with a ticket for that purpoſe; and ſometimes he refuſed to take payment, under the pretext that they had not received his full courſe the preceding year, ſome part of it having been neceſſarily omitted for want of time, which he meant to include in this courſe. By ſuch delicate addreſs, in which he greatly excelled, he took care to forerun their wants. Thus he not only gave them the benefit of his own lectures, but by refuſing to take their money, he alſo enabled them to attend thoſe of others that were neceſſary to complete their courſe of ſtudies. Theſe were particular devices he adopted to individuals to whom economy was neceſſary; but it was a general rule with him, never to take money from any ſtudent for more than two courſes of the ſame ſet of lectures, permitting him to attend theſe lectures as many years longer as he pleaſed *gratis*.

He introduced another general rule into the univerſity, that was dictated by the ſame principle of diſintereſted beneficence, that ought not to be here paſſed over in ſilence. Before he came to Edinburgh, it was the cuſtom of medical profeſſors to accept of fees for their medical aſſiſtance, when wanted, even from medical ſtudents themſelves, who were perhaps attending the profeſſor's own lectures at the time. But Cullen never would take fees as a phyſician from any ſtudent at the univerſity, though he attended them, when called in as a phyſician, with the ſame aſſiduity and care as if they had been perſons of the firſt rank, who paid him moſt liberally. This gradually induced others to adopt a ſimilar practice; ſo that it is now become a general rule for medical profeſſors to decline taking any fees when their aſſiſtance is neceſſary to a ſtudent. For this uſeful reform, with many others, the ſtudents of the univerſity of Edinburgh are ſolely indebted to the liberality of Dr Cullen.

The firſt lectures which Cullen delivered in Edinburgh were on chemiſtry; and for many years he alſo gave clinical lectures on the caſes which occurred in the Royal Infirmary. In the month of February 1763, Dr Alſton died, after having begun his uſual courſe of lectures on the materia medica; and the magiſtrates of Edinburgh, as patrons of that profeſſorſhip in the univerſity, appointed Dr Cullen to that chair, requeſting that he would finiſh the courſe of lectures that had been begun for that ſeaſon. This he agreed to do; and though he was under a neceſſity of going on with the courſe in a few days after he was nominated, he did not once think of reading the lectures of his predeceſſor, but reſolved to deliver a new courſe entirely his own.

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The popularity of Cullen at this time may be gueſſed at by the increaſe of new ſtudents who came to attend his courſe in addition to the eight or ten who had entered to Dr Alſton. The new ſtudents exceeded 100. An imperfect copy of theſe lectures, thus fabricated in haſte, having been publiſhed, the Doctor thought it neceſſary to give a more correct edition of them in the latter part of his life. But his faculties being then much impaired, his friends looked in vain for thoſe ſtriking beauties that characteriſed his literary exertions in the prime of life.

Some years afterwards, on the death of Dr White, the magiſtrates once more appointed Dr Cullen to give lectures on the theory of phyſic in his ſtead. And it was on that occaſion Dr Cullen thought it expedient to reſign the chemical chair in favour of Dr Black, his former pupil, whoſe talents in that department of ſcience were then well known, and who filled the chair till his death with great ſatisfaction to the public*. Soon after, on the death of Dr Rutherford, who for many years had given lectures with applauſe on the practice of phyſic, Dr John Gregory (whoſe name can never be mentioned by any one who had the pleaſure of his acquaintance without the warmeſt tribute of a grateful reſpect) having become a candidate for this place along with Dr Cullen, a ſort of compromiſe took place between them; by which they agreed each to give lectures alternately on the theory and on the practice of phyſic during their joint lives, the longeſt ſurvivor being allowed to hold either of the claſſes he ſhould incline. In conſequence of this agreement, Dr Cullen delivered the *firſt* courſe of lectures on the practice of phyſic in winter 1766, and Dr Gregory ſucceeded him in that branch the following year. Never perhaps did a literary arrangement take place that could have proved more beneficial to the ſtudents than this. Both theſe men poſſeſſed great talents, though of a kind extremely diſſimilar. Both of them had certain failings or defects, which the other was aware of, and counteracted. Each of them knew and reſpected the talents of the other. They co-operated, therefore, in the happieſt manner, to enlarge the underſtanding, and to forward the purſuits of their pupils. Unfortunately this arrangement was ſoon deſtroyed by the unexpected death of Dr Gregory, who was cut off in the flower of life by a ſudden and unforeſeen event. After this time, Cullen continued to give lectures on the practice of phyſic till a few months before his death, which happened on the 5th of February 1790, in the 77th year of his age.

In drawing the character of Dr Cullen, Dr Anderſon, to whom we are indebted for this ſketch, obſerves, that in ſcientific purſuits men may be arranged into two grand claſſes, which, though greatly different from each other in their extremes, yet approximate at times ſo near as to be blended indiſcriminately together; thoſe who poſſeſs a talent for detail, and thoſe who are endowed with the faculty of arrangement. The firſt may be ſaid to view objects individually as through a microſcope. The field of viſion is confined; but the objects included within that field, which muſt uſually be conſidered ſingly and apart from all others, are ſeen with a wondrous degree of accuracy and diſtinctneſs. The other takes a ſweeping view of the univerſe at large, conſiders every object he perceives not individually, but as a part of one harmonious whole: His mind is therefore not ſo much employed in examining the ſeparate parts of this individual object, as in tracing its relations, connections, and dependencies, on thoſe around it.—Such was the turn of Cullen's mind. The talent for arrangement was that which peculiarly diſtinguiſhed him from the ordinary claſs of mortals; and this talent he poſſeſſed perhaps in a more diſtinguiſhed degree than any other perſon of the age in which he lived. Many perſons exceeded him in the minute knowledge of particular departments, who, knowing this, naturally looked upon him as their inferior; but poſſeſſing not at the ſame time that glorious faculty, which, "with an eye wide roaming, glances from the earth to heaven," or the charms which this talent can infuſe into congenial minds, felt diſguſt at the pre-eminence he obtained, and aſtoniſhment at the means by which he obtained it. An Ariſtotle and a Bacon have had their talents in like manner appretiated; and many are the perſons who can neither be exalted to ſublime ideas with Homer, nor raviſhed with the natural touches of a Shakeſpeare. Such things are wiſely ordered, that every department in the univerſe may be properly filled by thoſe who have talents exactly ſuited to the taſk aſſigned them by heaven.

Had Cullen, however, poſſeſſed the talents for arrangement alone, ſmall would have been his title to that high degree of applauſe he has attained. Without a knowledge of *facts*, a talent for arrangement produces nothing but chimeras; without materials to work upon, the ſtructures which an over-heated imagination may rear up are merely "the baſeleſs fabric of a viſion." No man was more ſenſible of the juſtneſs of this remark than Dr Cullen, and few were at greater pains to avoid it. His whole life, indeed, was employed, almoſt without interruption, in collecting facts. Whether he was reading, or walking, or converſing, theſe were continually falling into his way. With the keen perception of an eagle, he marked them at the firſt glance; and without ſtopping at the time to examine them, they were ſtored up in his memory, to be drawn forth as occaſion required, to be confronted with other facts that had been obtained after the ſame manner, and to have their truth aſcertained, or their falſity proved, by the evidence which ſhould appear when carefully examined at the impartial bar of juſtice. Without a memory retentive in a ſingular degree, this could not have been done; but ſo very extraordinary was Dr Cullen's memory, that till towards the very decline of life, there was ſcarcely a fact that had ever occurred to him which he could not readily recollect, with all its concomitant circumſtances, whenever he had occaſion to refer to it. It was this faculty which ſo much abridged his labour in ſtudy, and enabled him ſo happily to avail himſelf of the labour of others in all his literary ſpeculations. He often reaped more by the converſation of an hour than another man would have done in whole weeks of laborious ſtudy.

In his prelections, Dr Cullen never attempted to read. His lectures were delivered *viva voce*, without having been previouſly put into writing, or thrown into any particular arrangement. The vigour of his mind was ſuch, that nothing more was neceſſary than a few ſhort notes before him, merely to prevent him from varying from the general order he had been accuſtomed to obſerve. This gave to his diſcourſes an eaſe, a vivacity,

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* See *Black*, Suppl.

vacity, a variety, and a force, that are rarely to be met with in academical diſcourſes. His lectures, by conſequence, upon the ſame ſubject were never exactly the ſame. Their general tenor indeed was not much varied; but the particular illuſtrations were always new, well ſuited to the circumſtances that attracted the general attention of the day, and were delivered in the particular way that accorded with the caſt of mind the prelector found himſelf in at the time. To theſe circumſtances muſt be aſcribed that energetic artleſs elocution, which rendered his lectures ſo generally captivating to his hearers. Even thoſe who could not follow him in thoſe extenſive views his penetrating mind glanced at, or who were not able to underſtand thoſe apt alluſions to collateral objects which he could only rapidly point at as he went along, could not help being warmed in ſome meaſure by the vivacity of his manner. But to thoſe who could follow him in his rapid career, the ideas he ſuggeſted were ſo numerous, the views he laid open were ſo extenſive, and the objects to be attained were ſo important—that every active faculty of the mind was rouſed; and ſuch an ardour of enthuſiaſm was excited in the proſecution of ſtudy, as appeared to be perfectly inexplicable to thoſe who were merely unconcerned ſpectators. In conſequence of this unſhackled freedom in the compoſition and delivery of his lectures, every circumſtance was in the niceſt uniſon with the tone of voice and expreſſion of countenance, which the particular caſt of mind he was in at the time inſpired. Was he joyous, all the figures introduced for illuſtration were fitted to excite hilarity and good humour: was he grave, the objects brought under view were of a nature more ſolemn and grand: and was he peeviſh, there was a peculiarity of manner in thought, in word, and in action, which produced a moſt ſtriking and intereſting effect. The languor of a nerveleſs uniformity was never experienced, nor did an abortive attempt to excite emotions that the ſpeaker himſelf could not at the time feel, ever produce thoſe diſcordant ideas which prove diſguſting and unpleaſing.

It would ſeem as if Dr Cullen had conſidered the proper buſineſs of a preceptor to be that of putting his pupils into a proper train of ſtudy, ſo as to enable them to proſecute thoſe ſtudies at a future period, and to carry them on much farther than the ſhort time allowed for academical prelections would admit. He did not, therefore, ſo much ſtrive to make thoſe who attended his lectures deeply verſed in the particular details of objects, as to give them a general view of the whole ſubject; to ſhew what had been already attained reſpecting it; to point out what remained yet to be diſcovered; and to put them into a train of ſtudy that ſhould enable them at a future period, to remove thoſe difficulties that had hitherto obſtructed our progreſs; and thus to advance of themſelves to farther and farther degrees of perfection. If theſe were his views, nothing could be more happily adapted to them than the mode he invariably purſued. He firſt drew, with the ſtriking touches of a maſter, a rapid and general outline of the ſubject, by which the whole figure was ſeen at once to ſtart boldly from the canvas, diſtinct in all its parts, and unmixed with any other object. He then began anew to retrace the picture, to touch up the leſſer parts, and to finiſh the whole in as perfect a manner as the ſtate of our knowledge at the time would permit. Where materials were wanting, the picture there continued to remain imperfect. The wants were thus rendered obvious; and the means of ſupplying theſe were pointed out with the moſt careful diſcrimination. The ſtudent, whenever he looked back to the ſubject, perceived the defects; and his hopes being awakened, he felt an irreſiſtible impulſe to explore that hitherto untrodden path which had been pointed out to him, and fill up the chaſm which ſtill remained. Thus were the active faculties of the mind moſt powerfully excited; and inſtead of labouring himſelf to ſupply deficiencies that far exceeded the power of any one man to accompliſh, he ſet thouſands at work to fulfil the taſk, and put them into a train of going on with it, when he himſelf ſhould be gone to that country "from whoſe dread bourne no traveller returns."

It was to theſe talents, and to this mode of applying them, that Dr Cullen owed his celebrity as a profeſſor; and it was in this manner that he has perhaps done more towards the advancement of ſcience than any other man of his time, though many individuals might perhaps be found who were more deeply verſed in the particular departments he taught than he himſelf was. Chemiſtry, which was before his time a moſt diſguſting purſuit, was by him rendered a ſtudy ſo pleaſing, ſo eaſy, and ſo attractive, that it is now proſecuted by numbers as an agreeable recreation, who but for the lights that were thrown upon it by Cullen and his pupils, would never have thought of engaging in it at all; though perhaps they never heard of Cullen's name, nor have at this time the moſt diſtant idea that they owe any obligations to him; and the ſame may be ſaid of the other branches of ſcience which he taught.

According to a man who knew him well, there are three things which eminently diſtinguiſhed Cullen as a profeſſor. "The energy of his mind, by which he viewed every ſubject with ardour, and combined it immediately with the whole of his knowledge.

"The ſcientific arrangement which he gave to his ſubject, by which there was a *lucidus ordo* to the dulleſt ſcholar. He was the firſt perſon in this country who made chemiſtry ceaſe to be a chaos.

"A wonderful art of intereſting the ſtudents in every thing which he taught, and of raiſing an emulative enthuſiaſm among them."

We are well aware that this character will by many be deemed an extravagant panegyric; but having no opportunity of judging for ourſelves, we would rather adopt from others an extravagant panegyric than an unmerited cenſure. Dr Anderſon himſelf admits that Cullen's character was far from perfect; and, in the opinion of moſt other men with whom we have converſed on the ſubject, and who were at the ſame time qualified to form an eſtimate of his mental powers, his imagination was not balanced by his judgment. Hence the common remark in the univerſity of Edinburgh, that Dr Cullen was more ſucceſsful in demoliſhing the theories of others than in giving ſtability to thoſe which were reared by himſelf.

Dr Cullen's external appearance, though ſtriking and not unpleaſing, was not elegant. His countenance was expreſſive, and his eye in particular remarkably lively, and at times wonderfully penetrating. In his perſon he was tall and thin, ſtooping very much about the ſhoulders. When he walked, he had a contemplative look, and

and did not ſeem much to regard the objects around him.

CURFEU Bell (ſee Curfew, *Encycl*), called in the law Latin of the middle ages *ignitegium* or *pyritegium*, and in French, *cuvre-feu*—was a ſignal for all perſons to extinguiſh their fires at a certain hour. In thoſe ages people made fires in their houſes in a hole or pit in the centre of the floor, under an opening formed in the roof; and when the fire was burnt out, or the family went to bed, the hole was ſhut by a cover of wood or of earth. This practice ſtill prevails among the cottagers in ſome parts of Scotland, and we doubt not of other countries. In the dark ages, when all ranks of people were turbulent, a law was almoſt everywhere eſtabliſhed, that the fire ſhould be extinguiſhed at a certain time in the evening; that the cover ſhould be put over the fire-place; and that all the family ſhould retire to reſt, or at leaſt keep within doors The time when this ought to be done was ſignified by the ringing of a bell, called therefore the *curfeu-bell* or *ignitegium*. The law of William the Conqueror, which introduced this practice into England, as has been mentioned in the Encyclopædia, was aboliſhed by Henry I. in 1100.

The ringing of the curfeu-bell gave riſe to the prayer-bell, as it is called, which is ſtill retained in ſome Proteſtant countries. Pope John XXIII. with a view to avert certain apprehended misfortunes, which rendered his life uncomfortable, gave orders, that every perſon, on hearing the *ignitegium*, ſhould repeat the *Ave Maria* three times. When the appearance of a comet, and a dread of the Turks, afterwards alarmed all Chriſtendom, Pope Calixtus III. increaſed theſe periodical times of prayer, by ordering the prayer-bell to be rung alſo at noon. *Beckmann's Hiſtory of Inventions.*

CURVE of Equable Approach. It was firſt propoſed by Leibnitz, namely, to find a curve, down which a body deſcending by the force of gravity ſhall make equal approaches to the horizon in equal portions of time. It has been found by Bernoulli and others, that the curve is the ſecond cubical parabola, placed with its vertex uppermoſt, and which the deſcending body muſt enter with a certain determinate velocity. Varignon rendered the queſtion general for any law of gravity, by which a body may approach towards a given point by equal ſpaces in equal times. And Maupertuis alſo reſolved the problem in the caſe of a body deſcending in a medium which reſiſts as the ſquare of the velocity.

CUSSO, or Banksia Abyssinica, is a beautiful and uſeful tree, indigenous to the high country of Abyſſinia. At leaſt Mr Bruce, who has given of it the only deſcription which we have ſeen, ſays that he never ſaw it in any other part of Aſia or Africa. It ſeldom grows above 20 feet high, very rarely ſtraight, generally crooked or inclined. Its leaf, which is of a deep unvarniſhed green, having the fore part covered with ſoft hair or down, is about 2¼ inches long, divided by a ſtrong rib into two unequal diviſions, of which the upper is broader and larger than the lower. It is more indented than even the nettle leaf, which it in ſome meaſure reſembles, only the leaf of the *Cuſſo* is narrower and longer.

Thoſe leaves grow two and two upon a branch, having between each two the rudiments of *two pair* of leaves, which probably are *deciduous;* but the branch is terminated with a ſingle leaf or *ſtipula* at the point. The end of this ſtalk is broad and ſtrong, like that of a palm branch. It is not ſolid like the gerid of the date tree, but opens in the part that is without leaves about an inch and a half from the bottom, and out of this aperture proceeds the flower. There is a round ſtalk, bare for about an inch and a quarter, from which proceed crooked branches with ſingle flowers attached to their ends; the ſtalk that carries theſe proceeds out of every crook or geniculation. The whole cluſter of flowers has very much the ſhape of a cluſter of grapes; the ſtalks which ſupport it reſemble the ſtalks of the grape; and a very few ſmall leaves are ſcattered through the cluſter of flowers.

"The calyx or flower cup is of a *greeniſh* colour, tinged with purple; when fully blown it is altogether of a deep *red* or purple; the corolla is *white*, and conſiſts of five petals; in the midſt is a ſhort piſtil with a round head, ſurrounded by eight ſtamina, of the ſame form, loaded with yellow farina. The cup conſiſts of five petals, which much reſemble another flower; they are rounded at the top, and nearly of an equal breadth every way. The ſeed is very ſmall, ſmaller than even the ſemen ſantonicum; and being likewiſe very bitter it is uſed in Abyſſinia as a vermifuge. From its ſmallneſs, however, and its being very eaſily ſhed, no great quantity of it is ever gathered, and therefore the flower is often ſubſtituted in its ſtead. The Abyſſinians, ſays our author, of both ſexes, and at all ages, are troubled with the ſort of worm called aſcarides, of which every individual evacuates a large quantity once a-month. The method of promoting theſe evacuations is by infuſing a handful of dry cuſſo flowers in about two Engliſh quarts of bouza, or the beer they make of teff (ſee Teff, *Encycl.*), and after it has been ſteeped all night, the next morning it is fit for uſe.

"The bark of the tree is ſmooth, of a yellowiſh white, interſperſed with brown ſtreaks, which paſs through the whole body of the tree. It is not firm or hard, but rather ſtringy and reedy. On the upper part, before the firſt branch of leaves ſet out, are rings round the trunk, of ſmall filaments of the conſiſtence of horſe hair: theſe are generally fourteen or ſixteen in number, and are a very remarkable characteriſtic belonging to the tree."

From this deſcription, which, it muſt be confeſſed, is not remarkable for perſpicuity, and from an inſpection of the figure which Mr Bruce has given of the cuſſo, we are inclined to rank it with the palms, as a new genus, neareſt to the *caryota*.

CUVETTE, or Cunette, in fortification, is a kind of ditch within a ditch, being a pretty deep trench, about four fathoms broad, ſunk and running along the middle of the great dry ditch, to hold water; ſerving both to keep off the enemy and prevent him from mining.

CYCLE of Indiction, is a ſeries of 15 years, returning conſtantly around like the other cycles, and commenced from the third year before Chriſt; whence it happens that if 3 be added to any given year of Chriſt, and the ſum be divided by 15, what remains is the year of the indiction.

CYCLOID (ſee *Encycl.*) is a curve, which is thus generated: Suppoſe a wheel or circle to roll along a ſtraight line till it has completed juſt one revolution; a nail or point in that part of the circumference of the circle, which at the beginning of the motion touches the ſtraight line, will, at the end of the revolution, have deſcribed on a vertical plane a cycloid.

DAGELET,

D.

Dagelet, Dairy.

DAGELET, the name given by *La Perouſe*, the celebrated though unfortunate navigator, to an iſland on the coaſt of Corea (ſee Corea, *Encycl.*), which he diſcovered in the year 1787. It is little more than three leagues in circumference; and our author almoſt made its circuit at the diſtance of a mile without finding bottom. This ſmall ſpot is very ſteep, but covered with the fineſt trees from the ſea-ſhore to the ſummit. A rampart of bare rock, like a wall, encircles the whole outline of it, with the exception of ſeven little ſandy creeks, where it is poſſible to land. In theſe creeks the Frenchmen ſaw upon the ſtocks ſome boats of a conſtruction altogether Chineſe; but the ſight of their ſhips frightened the workmen, who fled from their dock-yard into the wood, which was not more than fifty paces diſtant. As a few huts were ſeen, but neither villages nor cultivation, La Perouſe concluded that the iſland is without inhabitants, and that the men whom he ſaw at work were Corean carpenters, who during the ſummer months go with proviſion to Dagelet for the purpoſe of building boats, which they ſell upon the continent. He places the north-eaſt point of this iſland in Lat. 37°. 25′. and E. Long. 129°. 2′. from Paris.

DAIRY is a word which ſignifies ſometimes the art of making various kinds of food from milk; ſometimes the place where milk is manufactured; and ſometimes the management of a milk-farm. On the *dairy*, in the firſt and ſecond of theſe ſenſes, enough has been ſaid in the *Encyclopædia* under the titles Butter, Cheese, and Dairy; on the management of a milk farm that work contains nothing.

When a dairy is eſtabliſhed, the undertaker may ſometimes think it his intereſt to obtain the greateſt poſſible quantity of produce; ſometimes it may be more beneficial for him to have it of the fineſt quality; and at other times it may be neceſſary to have both theſe objects in view, the one or the other in a greater or leſs proportion: it is therefore of importance that he ſhould know how he may accompliſh the one or the other of theſe purpoſes in the eaſieſt and moſt direct manner.

To be able to convert his milk to the higheſt poſſible profit in every caſe, he ought to be fully acquainted with every circumſtance reſpecting the manufacture both of butter and of cheeſe; as it may in ſome caſes happen, that a certain portion of that milk may be more advantageouſly converted into butter than into cheeſe, while another portion of it would return more profit if made into cheeſe.

The firſt thing to be adverted to, in an undertaking of this nature, is to chooſe cows of a proper ſort. Among this claſs of animals, it is found, by experience, that ſome kinds give milk of a much thicker conſiſtence and richer quality than others; nor is this richneſs of quality neceſſarily connected with the ſmallneſs of the quantity yielded by cows of nearly an equal ſize; it therefore behoves the owner of a dairy to be peculiarly attentive to this circumſtance. In judging of the value of a cow, it ought rather to be the quantity and the quality of the cream produced from the milk of the cow, in a given time, than the quantity of the milk itſelf: this is a circumſtance that will be ſhewn hereafter to be of more importance than is generally imagined. The ſmall cows of the Alderney breed afford the richeſt milk hitherto known; but individual cows in every country may be found, by a careful ſelection, that afford much thicker milk than others; theſe therefore ought to be ſearched for with care, and their breed reared with attention, as being peculiarly valuable.

Few perſons who have had any experience at all in the dairy, can be ignorant, however, that in comparing the milk of two cows, to judge of their reſpective qualities, particular attention muſt be paid to the time that has elapſed ſince their calving; for the milk of the ſame cow is always thinner ſoon after calving than it is afterwards; as it gradually becomes thicker, though generally leſs in quantity, in proportion to the time ſince the cow has calved. The colour of the milk, ſoon after calving, is richer than it is afterwards; but this, eſpecially for the firſt two weeks, is a faulty colour that ought not to be coveted.

To make the cows give abundance of milk, and of a good quality, they muſt at all times have plenty of food. Graſs is the beſt food yet known for this purpoſe, and that kind of graſs which ſprings up ſpontaneouſly on rich dry ſoils is the beſt of all. If the temperature of the climate be ſuch as to permit the cows to graze at eaſe throughout the day, they ſhould be ſuffered to range on ſuch paſtures at freedom; but if the cows are ſo much incommoded by the heat as to be prevented from eating through the day, they ought in that caſe to be taken into cool ſhades for protection; where, after allowing them a proper time to ruminate, they ſhould be ſupplied with abundance of green food, freſh-cut for the purpoſe, and given to them by hand frequently, in ſmall quantities, freſh and freſh, ſo as to induce them to eat it with pleaſure. When the heat of the day is over, and they can remain abroad with eaſe, they may be again turned into the paſture, where they ſhould be allowed to range with freedom all night, during the mild weather of ſummer.

Cows, if abundantly fed, ſhould be milked three times a-day, during the whole of the ſummer ſeaſon (a); in

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(a) If cows be milked only twice in the day (24 hours), while they have abundance of ſucculent food, they will yield a much ſmaller quantity of milk, in the ſame time, than if they be milked three times. Some attentive obſervers think a cow, in theſe circumſtances, will give nearly as much milk at each time, if milked three times, as if ſhe were milked only twice. This fact, however, has not, that we know of, been aſcertained by experiment. There can be no doubt but they give more, how much more is not aſcertained; nor, whether it would be advantageous, in any caſe, to milk them four times, or oftener; nor, what effect frequent milking produces on the quality of the milk.

the morning early, at noon, and in the evening, juſt before night-fall. In the choice of perſons for milking the cows, great caution ſhould be employed; for if that operation be not carefully and properly performed, not only the quantity of the produce of the dairy will be greatly diminiſhed, but its quality alſo will be very much debaſed; for if all the milk be not thoroughly drawn from a cow when ſhe is milked, that portion of milk which is left in the udder ſeems to be gradually abſorbed into the ſyſtem, and Nature generates no more than to ſupply the waſte of what has been taken away. If this leſſened quantity be not again thoroughly drawn off, it occaſions a yet farther diminution of the quantity of milk generated; and thus it may be made to proceed, in perpetual progreſſion from little to leſs, till none at all is produced. In ſhort, this is the practice in all caſes followed, when it is meant to allow a cow's milk to dry up entirely, without doing her hurt. In this manner, therefore, the profits of a dairy might be wonderfully diminiſhed; ſo that it much behoves the owner of it to be extremely attentive to this circumſtance, if he wiſhes to avoid ruin. It ought to be a rule without an exception, never to allow this important department to be entruſted, without controul, to the management of hired ſervants (B). Its importance will be ſtill more manifeſt from what follows.

It is to Dr James Anderſon that we are indebted for theſe judicious obſervations, as well as for the following aphoriſms which, though they may be in part known to attentive houſewifes, he has reaſon to believe are not commonly adverted to as their importance deſerves.

Aphoriſm 1.

“ Of the milk that is drawn from any cow at one time, that which comes off at the firſt is always thinner, and of a much worſe quality, than that which comes afterwards; and the richneſs goes on continually increaſing to the very laſt drop that can be drawn from the udder at that time.”

Few perſons are ignorant that the milk which is laſt of all taken from the cow at milking (in this country called *ſtroakings*) is richer than the reſt of the milk; but fewer ſtill are aware of the greatneſs of the diſproportion between the quality of the firſt and the laſt drawn milk, from the ſame cow, at one milking. The following facts (ſays our author) reſpecting this circumſtance were aſcertained by me many years ago, and have been confirmed by many ſubſequent experiments and obſervations.

Having taken ſeveral large tea-cups, exactly of the ſame ſize and ſhape, one of theſe tea-cups was filled at the beginning of the milking, and the others at regular intervals, till the laſt, which was filled with the dregs of the ſtroakings. Theſe cups were then weighed, the weight of each having been ſettled, ſo as to aſcertain that the quantity of milk in each was preciſely the ſame; and from a great number of experiments, frequently repeated with many different cows, the reſult was in all caſes as follows:

The quantity of cream obtained from the firſt-drawn cup was, in every caſe, much ſmaller than from that which was laſt drawn; and thoſe between afforded leſs or more as they were nearer the beginning or the end. It is unneceſſary here to ſpecify theſe intermediate proportions; but it is proper the reader ſhould be informed, that the quantity of cream obtained from the laſt-drawn cup, from ſome cows, exceeded that from the firſt in the proportion of ſixteen to one. In other cows, however, and in particular circumſtances, the diſproportion was not quite ſo great; but in no caſe did it fall ſhort of the rate of eight to one. Probably, upon an average of a great many cows, it might be found to run as ten or twelve to one.

Secondly, The difference in the quality of the cream, however, obtained from theſe two cups, was much greater than the difference in the quantity. In the firſt cup, the cream was a thin tough film, thinner, and perhaps whiter, than writing paper; in the laſt, the cream was of a thick *butyrous* conſiſtence, and of a glowing richneſs of colour that no other kind of cream is ever found to poſſeſs.

Thirdly, The difference in the quality of the milk that remained, after the cream was ſeparated, was perhaps ſtill greater than either in reſpect to the quantity or the quality of the cream. The milk in the firſt cup was a thin bluiſh liquid, as if a very large proportion of water had been mixed with ordinary milk; that in the laſt cup was of a thick conſiſtence, and yellow colour, more reſembling cream than milk both in taſte and appearance.

From this important experiment, it appears that the perſon who, by bad milking of his cows, loſes but half a pint of his milk, loſes in fact about as much cream as would be afforded by ſix or eight pints at the beginning, and loſes, beſides, that part of the cream which alone can give richneſs and high flavour to his butter.

Aphoriſm 2.

“ If milk be put into a diſh, and allowed to ſtand till it throws up cream, that portion of cream which riſes firſt to the ſurface is richer in quality, and greater in quantity, than what riſes in a ſecond equal ſpace of time; and the cream that riſes in the ſecond interval of time is greater in quantity, and richer in quality, than that which riſes in a third equal ſpace of time; that of the third than the fourth, and ſo on: the cream that riſes decreaſing in quantity, and declining in quality, continually, as long as any riſes to the ſurface.”

Our ingenious author confeſſes, that his experiments not having been made with ſo much accuracy in this caſe as in the former, he was not enabled to aſcertain the difference in the proportion that takes place in equal portions of time; but they have been ſo often repeated as not to leave any room to doubt the fact, and it will be allowed to be a fact of no ſmall importance in the management of the dairy. It is not certain, however, but that a greater quantity of cream may, upon the whole, be obtained from the milk by taking it away

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(B) Cows ſhould always be treated with great gentleneſs, and ſoothed by mild uſage, eſpecially when young and ticklish, or when the paps are tender; in which laſt caſe, the udder ought to be fomented with warm water before milking, and touched with the greateſt gentleneſs, otherwiſe the cow will be in danger of contracting bad habits, becoming ſtubborn and unruly, and retaining her milk ever after. A cow never lets down her milk pleaſantly to the perſon ſhe dreads or diſlikes. The udder and paps ſhould always be waſhed with clean water before milking; but care ſhould be taken that none of that water be admitted into the milking-pail.

away at different times; but the proceſs is ſo troubleſome as not to be counterbalanced by the increaſed quantity obtained, if indeed an increaſed quantity be thus obtained, which is not as yet quite certain.

Aphoriſm 3. "Thick milk always throws up a ſmaller proportion of the cream it actually contains to the ſurface, than milk that is thinner; but that cream is of a richer quality. If water be added to that thick milk, it will afford a conſiderably greater quantity of cream than it would have done if allowed to remain pure, but its quality is, at the ſame time, greatly debaſed."

This is a fact that every perſon attentive to a dairy muſt have remarked; but I have never (ſays our author) heard of any experiment that could aſcertain, either the preciſe amount of the increaſed quantity of cream that might thus be obtained, or of the ratio in the decreaſe of its quality. The effects of mixing water with the milk in a dairy are at leaſt aſcertained; and the knowledge of this fact will enable attentive perſons to follow that practice which they think will beſt promote their own intereſt.

Aphoriſm 4. "Milk which is put into a bucket or other proper veſſel, and carried in it to any conſiderable diſtance, ſo as to be much agitated, and in part cooled, before it be put into the milk-pans to ſettle for cream, never throws up ſo much, nor ſo rich cream, as if the ſame milk had been put into the milk-pans directly after it was milked."

In this caſe, it is believed the loſs of cream will be nearly in proportion to the time that has elapſed, and the agitation the milk has ſuſtained, after being drawn from the cow. But Dr Anderſon ſays that he is not yet in poſſeſſion of any experiments which ſufficiently aſcertain how much is to be aſcribed to the time, and the agitation, taken ſeparately. On every branch of agriculture we find experiments wanting, at each ſtep we advance in our inquiries; and it is the duty of every enquirer to point out, as he goes along, where they are wanted, ſince the labours of no one man can poſſibly complete the whole.

From the above facts, the following corollaries ſeem to be clearly deducible:

Firſt. It is of importance that the cows ſhould be always milked as near the dairy as poſſible, to prevent the neceſſity of carrying and cooling the milk before it is put into the diſhes; and as cows are much hurt by far driving, it muſt be a great advantage in a dairy-farm to have the principal graſs fields as near the dairy or homeſtead as poſſible.

Secondly. The practice of putting the milk of all the cows of a large dairy into one veſſel, as it is milked, there to remain till the whole milking is finiſhed, before any part of it is put into the milk-pans—ſeems to be highly injudicious; not only on account of the loſs that is ſuſtained by agitation and cooling, but alſo, more eſpecially, becauſe it prevents the owner of the dairy from diſtinguiſhing the good from the bad cow's milk, ſo as to ſeparate theſe from each other, where it is neceſſary. He may thus have the whole of his dairy product greatly debaſed by the milk of one bad cow, for years together, without being able to diſcover it. A better practice, therefore, would be, to have the milk drawn from each cow put ſeparately into the creaming-pans as ſoon as it is milked, without being ever mixed with any other. Thus would the careful manager of the dairy be able on all occaſions to obſerve the particular quality of each individual cow's milk, as well as its quantity, and to know with preciſion which of his cows it was his intereſt to diſpoſe of, and which of them he ought to keep and breed from.

Thirdly. If it be intended to make butter of a very fine quality, it will be adviſable in all caſes to keep the milk that is firſt drawn ſeparate from that which comes laſt; as it is obvious, that if this be not done, the quality of the butter will be greatly debaſed, without much augmenting its quantity. It is alſo obvious, that if this is done, the quality of the butter will be improved in proportion to the ſmallneſs of the quantity of the laſt-drawn milk that is retained; ſo that thoſe who wiſh to be ſingularly nice in this reſpect, will do well to retain only a very ſmall portion of the laſt-drawn milk.

To thoſe owners of dairies who have profit only in view, it muſt ever be a matter of trial and calculation, how far it is expedient for them to carry the improving of the quality of their butter at the expence of diminiſhing its quantity. In different ſituations prudence will point out different kinds of practice as moſt eligible; and all perſons muſt be left, after making accurate trials, to determine for themſelves. It is likewiſe a conſideration of no ſmall importance, to determine in what way the inferior milk, that is thus to be ſet apart where fine butter is wanted, can be employed with the greateſt profit. In the Highlands of Scotland they have adopted, without thinking of the improvement of their butter, a very ſimple and economical practice in this reſpect. As the rearing of calves is there a principal object with the farmer, every cow is allowed to ſuckle her own calf with a part of her milk, the remainder only being employed in the dairy. To give the calf its portion regularly, it is ſeparated from the cow, and kept in an incloſure, with all the other calves belonging to the ſame farm. At regular times, the cows are driven to the door of the incloſure, where the young calves fail not to meet them. Each calf is then ſeparately let out, and runs directly to its mother, where it ſucks till the dairy-maid judges it has had enough; ſhe then orders it to be driven away, having previouſly ſhackled the hinder legs of the mother, by a very ſimple contrivance, to oblige her to ſtand ſtill. Boys drive away the calf with ſwitches, and return it to the incloſure, while the dairy-maid milks off what was left by the calf: thus they proceed till the whole of the cows are milked. They obtain only a ſmall quantity of milk, it is true, but that milk is of an exceeding rich quality; which in the hands of ſuch of the inhabitants as know how to manage it, is manufactured into the richeſt marrowy butter that can be anywhere met with. This richneſs of the Highland butter is univerſally aſcribed to the old graſs the cows feed upon in their remote glens; but it is in fact chiefly to be attributed to the practice here deſcribed, which has long prevailed in thoſe regions. Whether a ſimilar practice could be economically adopted elſewhere, our author takes not upon him to ſay; but doubtleſs other ſecondary uſes might be found for the milk of inferior quality. On ſome occaſions, it might be converted into butter of an inferior quality; on other occaſions, it might be ſold ſweet, where the ſituation of the farm was within reach of a market-town; and on others, it might be converted into cheeſes, which, by being made of ſweet milk, would be of a very fine quality if carefully made (c). Still other uſes might be deviſed for its application; of which the following is worthy of notice. Take common ſkimmed milk, when it has begun to turn ſour, put it into an upright ſtand churn, or a barrel with one of its ends out, or any other convenient veſſel. Heat ſome water, and pour it into a tub that is large enough to contain with eaſe the veſſel in which the milk was put. Set the veſſel containing the milk into the hot water, and let it remain there for the ſpace of one night. In the morning it will be found that the milk has ſeparated into two parts; a thick cream-like ſubſtance, which occupies the upper part of the veſſel, and a thin watery part that remains at the bottom. Draw off the thin part (called in Scotland *wigg*), by opening a ſtop-cock, placed for that purpoſe cloſe above the bottom, and reſerve the cream for uſe. Not much leſs than half of the milk is thus converted into a ſort of cream, which, when well made, ſeems to be as rich and fat as real cream itſelf, and is only diſtinguiſhable from it by its ſourneſs. It is eaten with ſugar, and eſteemed a great delicacy, and uſually ſells at double the price of freſh unſkimmed milk. It requires practice, however, to be able to make this nicely; the degree of the heat of the water, and many other circumſtances, greatly affecting the operation.

Fourthly. If the quality of the butter be the chief object attended to, it will be neceſſary, not only to ſeparate the firſt from the laſt drawn milk, but alſo to take nothing but the cream that is firſt ſeparated from the beſt milk, as it is this firſt riſing cream alone that is of the prime quality. The remainder of the milk, which will be ſtill ſweet, may be either employed for the purpoſe of making ſweet milk cheeſes, or may be allowed to ſtand, to throw up cream for making butter of an inferior quality, as circumſtances may direct.

Fifthly. From the above facts, we are enabled to perceive, that butter of the very beſt poſſible quality can only be obtained from a dairy of conſiderable extent, judiciouſly managed; for when only a ſmall portion of each cow's milk can be ſet apart for throwing up cream, and when only a ſmall proportion of that cream can be reſerved, of the prime quality, it follows (the quantity of milk being upon the whole very inconſiderable), that the quantity of prime cream produced would be ſo ſmall as to be ſcarcely worth manufacturing ſeparately.

Sixthly. From theſe premiſes we are alſo led to draw another concluſion, extremely different from the opinion that is commonly entertained on this ſubject, viz. That it ſeems probable, that the very beſt butter could be made with economy in thoſe dairies only where the manufacture of cheeſe is the principal object. The reaſons are obvious: If only a ſmall portion of milk ſhould be ſet apart for butter, all the reſt may be made into cheeſe, while it is yet warm from the cow, and perfectly ſweet; and if only that portion of cream which riſes during the firſt three or four hours after milking is to be reſerved for butter, the rich milk which is left after that cream is ſeparated, being ſtill perfectly ſweet, may be converted into cheeſe with as great advantage nearly as the newly-milked milk itſelf.

But as it is not probable that many perſons could be found who would be willing to purchaſe the very fineſt butter, made in the manner above pointed out, at a price that would be ſufficient to indemnify the farmer for his trouble in making it, theſe hints are thrown out merely to ſhew the curious in what way butter poſſeſſing this ſuperior degree of excellence may be obtained, if they chooſe to be at the expence; but for an ordinary market, Dr Anderſon is ſatisfied, from experience and attentive obſervation, that if in general about the firſt drawn half of the milk be ſeparated at each milking, and the remainder only ſet up for producing cream, and if that milk be allowed to ſtand to throw up the whole of its cream (even till it begins ſenſibly to taſte ſouriſh), and that cream be afterwards carefully managed, the butter thus obtained will be of a quality greatly ſuperior to what can uſually be procured at market, and its quantity not conſiderably leſs than if the whole of

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(c) The making of cheeſe has never yet been reduced to ſcientific principles, and conſequently the reaſoning relating to it is very inconcluſive. It is in general ſuppoſed, that the goodneſs of cheeſe depends almoſt entirely upon its richneſs, by which is meant the proportion of oily matter, whether natural or extraneous, it contains; nothing, however, is more certain, than that this opinion is erroneous. Sometimes a very lean cheeſe is much better taſted than one that is much fatter; and, which will appear to moſt perſons ſtill more extraordinary, it frequently happens that a cheeſe that taſtes ſoft and fat is much leaner than one that is hard, dry, and ſticky. The mode of manufacturing it occaſions this, and not the quantity of cream it contains. It is very poſſible by art to make poor ſkim milk cheeſe aſſume the ſoft buttery taſte and appearance even of cream cheeſe. This ſubject, therefore, deſerves to be more particularly elucidated than it has hitherto been.

Connected as they are with the object diſcuſſed in the text, we beg leave with our author to ſuggeſt the following particulars, as proper objects of examination and experiment, viz. Is the quantity of caſeous matter afforded by milk neceſſarily connected with the proportion of cream that milk contains, or does it depend upon ſome other principle not hitherto inveſtigated? Without pretending to decide this queſtion, Dr Anderſon feels himſelf ſtrongly inclined to believe it does not depend upon the quantity of cream. It is well known that cow's milk, which always throws up more cream, and that of a much richer quality, than ewe-milk, does in no caſe afford above one-half the proportion of cheeſe that ewe-milk does. Nor can this ſingular tendency of ewe-milk, to yield a great proportion of curd, be attributed to its ſuperior thickneſs; for cow-milk can be often had that is thicker and richer than ewe-milk, but it always affords a much ſmaller proportion of curd. From theſe conſiderations, it is not impoſſible but it might be found, upon a careful inveſtigation, that the refuſe milk, which ought to be ſeparated from the other in making the beſt butter, might be equally proper, or very nearly ſo, for making cheeſe, as if no ſuch ſeparation had been made. We therefore recommend this as a proper object of experimental enquiry.

of the milk had been treated alike. This, therefore, is the practice that our author thinks moſt likely to ſuit the frugal farmer, as his butter, though of a ſuperior quality, could be afforded at a price that would always enſure it a rapid ſale.

Dr Anderſon throws out many other ingenious and uſeful obſervations on this important branch of rural economy. In particular, he points out, in the plaineſt manner, the requiſites of a good milk-houſe, which, as he truly obſerves, ſhould be cool in ſummer and warm in winter, ſo as to preſerve a temperature nearly the ſame throughout the year. But we have treated of this part of the ſubject elſewhere, and muſt therefore refer ſuch as are deſirous to know the Doctor's ſentiments on it, to *The Letters and Papers of the Bath and Weſt-of-England Society* for the encouragement of agriculture, &c. or to the eighth volume of *The Repertory of Arts and Manufactures*.

DAHALAC, the largeſt iſland in the Red Sea, is thus deſcribed by Mr Bruce. It is low and even, the ſoil fixed gravel and white ſand, mixed with ſhells and other marine productions. It is deſtitute of all ſorts of herbage, at leaſt in ſummer, unleſs a ſmall quantity of bent graſs, juſt ſufficient to feed the few antelopes and goats that are on the iſland. There is a very beautiful ſpecies of this laſt animal found here, ſmall, ſhort-haired, with thin black ſharp horns, having rings upon them, and they are very ſwift of foot.

This iſland is, in many places, covered with large plantations of acacia trees, which grow to no height, ſeldom above eight feet, but ſpread wide, and turn flat at top, probably by the influence of the wind from the ſea. Though in the neighbourhood of Abyſſinia, Dahalac does not partake of its ſeaſons; no rain falls here from the end of March to the beginning of October; but in the intermediate months, eſpecially December, January, and February, there are violent ſhowers for 12 hours at a time, which deluge the iſland, and fill the ciſterns ſo as to ſerve all next ſummer; for there are no hills nor mountains in Dahalac, and conſequently no ſprings. Theſe ciſterns alone preſerve the water, and of them there yet remain 370, all hewn out of the ſolid rock. They ſay theſe were the works of the Perſians; it is more probable they were thoſe of the firſt Ptolemies. But whoever were the conſtructors of theſe magnificent reſervoirs, they were a very different people from thoſe that now poſſeſs them, who have not induſtry enough to keep one of the 370 clear for the uſe of man. All of them are open to every ſort of animal, and half full of the filth they leave there, after drinking and waſhing in them; yet one of theſe ciſterns, cleaned and ſhut up with a door, might afford them wholeſome ſweet water all the year over.

After the rains fall, a prodigious quantity of graſs immediately ſprings up; and the goats give the inhabitants milk, which in winter is the principal part of their ſubſiſtence, for they neither plow nor ſow; all their employment is to work the veſſels which trade to the different parts of the coaſt. One half of the inhabitants is conſtantly on the Arabian ſide, and by their labour is enabled to furniſh with *dora* (millet or Indian corn) and other proviſions the other half who ſtay at home; and when their time is expired, they are relieved by the other half, and ſupplied with neceſſaries in their turn. But the ſuſtenance of the poorer ſort is entirely ſhell and other fiſh. Their wives and daughters are very bold and expert fiſherwomen. Several of them, entirely naked, ſwam off to the veſſel before it came to an anchor, begging handfuls of wheat, rice, or dora. They are very importunate and ſturdy beggars, and not eaſily put off with denials. These miſerable people, who live in the villages not frequented by barks from Arabia, are ſometimes a whole year without taſting bread. Yet ſuch is the attachment to their place of nativity, they prefer living in this bare, barren, parched ſpot, almoſt in want of neceſſaries of every kind, eſpecially of theſe eſſential ones, bread and water, to thoſe pleaſant and plentiful countries on both ſides of them.

There are in Dahalac twelve villages or towns, of which each has a plantation of doomtrees round it, which furniſh the only manufacture in the iſland. The leaves of this tree, when dried, are of a gloſſy white, which might very eaſily be miſtaken for ſattin: of theſe they make baſkets of ſurpriſing beauty and neatneſs, ſtaining part of the leaves with red or black, and working them into figures very artificially. Our author knew ſome of theſe, reſembling ſtraw-baſkets, continue full of water for 24 hours, without one drop coming through. They ſell theſe at Loheia and Jidda, the largeſt of them for four commeſh, or ſixpence. This is the employment, or rather amuſement, of the men who ſtay at home; for they work but very moderately at it, and all of them indeed take ſpecial care not to prejudice their health by any kind of fatigue from induſtry.

People of the better ſort, ſuch as the Shekh and his relations, men privileged to be idle, and never expoſed to the ſun, are of a brown complexion. But the common ſort employed in fiſhing, and thoſe who go conſtantly to ſea, are not indeed black but red, and little darker than the colour of new mahogany.

The inhabitants of Dahalac ſeemed to be a ſimple, fearful, and inoffenſive people. It is the only part of Africa or Arabia (call it which you pleaſe) where you ſee no one carry arms of any kind: neither gun, knife, nor ſword, is to be ſeen in the hands of any one. Whereas at Loheia, and on all the coaſt of Arabia, and more particularly at Yamboo, every perſon goes armed; even the porters, naked and groaning under the weight of their burden and heat of the day, have yet a leather belt, in which they carry a crooked knife, ſo monſtrouſly long, that it needs a particular motion and addreſs in walking not to lame the bearer. This was not always the caſe at Dahalac; ſeveral of the Portugueſe, on their firſt arrival here, were murdered, and the iſland often treated ill, in revenge, by the armaments of that nation. The men ſeemed healthy. They told our author they had no diſeaſes among them, unleſs ſometimes in ſpring, when the boats of Yemen and Jidda bring the ſmall-pox among them, and very few eſcape with life that are infected. He did not obſerve among them a man that ſeemed to be ſixty years old; from which he inferred that they are not long livers, though the air ſhould be healthy, as being near the channel, and as they have the north wind all ſummer, which moderates the heat.

Dahalac, like all the other iſlands in the Red Sea, depends upon Maſuah. The revenue of its governor conſiſts in a goat brought to him monthly by each of the twelve villages. Every veſſel that puts in there for Maſuah pays him alſo a pound of coffee, and every one from

from Arabia a dollar or pataka. No ſort of ſmall money is current at Dahalac, excepting Venetian glaſs-beads, old and new, of all ſizes and colours, broken and whole.

Although this is the miſerable ſtate of Dahalac at preſent, matters were widely different in former times. The pearl fiſhery flouriſhed greatly here under the Ptolemies; and even long after, in the time of the caliphs, it produced a great revenue, and till the ſovereigns of Cairo, of the preſent miſerable race of ſlaves, began to withdraw themſelves from their dependency on the port, Dahalac was the principal iſland that furniſhed the pearl fiſhers or divers. It was, indeed, the chief port for the fiſhery on the ſouthern part of the Red Sea, as Suakem was on the north; and the baſha of Maſuah paſſed part of every ſummer here, to avoid the heat at his place of reſidence on the continent.

The fiſhery extended from Dahalac and its iſlands nearly to lat. 20°. The inhabited iſlands furniſhed each a bark and ſo many divers, and they were paid in wheat, flour, &c. ſuch a portion to each bark for their uſe, and ſo much to leave with their family for their ſubſiſtence; ſo that a few months employment furniſhed them with every thing neceſſary for the reſt of the year. The fiſhery was rented in later times to the baſha of Suakem; but there was a place between Suakem and the ſuppoſed river Frat, in lat. 21° 28′ north, called *Gungunnah*, which was reſerved to the grand ſignior in particular, and a ſpecial officer was appointed to receive the pearls on the ſpot and ſend them to Conſtantinople. The pearls found there were of the largeſt ſize, and inferior to none in water or roundneſs. Tradition ſays, that this was excluſively the property of the Pharaohs; by which is meant, in Arabian manuſcripts, the old kings of Egypt before Mahomet.

In the ſame extent between Dahalac and Suakem was another very valuable fiſhery, that of tortoiſes, from which the fineſt ſhells of that kind were produced, and a great trade was carried on with the Eaſt Indies (China eſpecially) at little expence, and with very conſiderable profits. But the immenſe treaſures in the bottom of the Red Sea have now been abondoned for near 200 years, though they never were richer in all probability than at preſent. No nation can now turn them to any profit but the Engliſh Eaſt India Company, more intent on multiplying the number of their enemies, and weakening themſelves by ſpreading their inconſiderable force over new conqueſts, than creating additional profit by engaging in new articles of commerce. A ſettlement upon the river Frat, which never yet has belonged to any one but wandering Arabs, would open them a market both for coarſe and fine goods from the ſouthern frontiers of Morocco, to Congo and Angola, and ſet the commerce of pearls and tortoiſe ſhell on foot again. All this ſection of the gulf from Suez, as we are told, is in their charter, and twenty ſhips might be employed on the Red Sea without any violation of territorial claims. The myhrrh, the frankincenſe, ſome cinnamon, and variety of drugs, are all in the poſſeſſion of the weak king of Adel; an uſurper, tyrant, and Pagan, without protection, and willing to trade with any ſuperior power that only would ſecure him a miſerable livelihood.

There are neither horſes, dogs, ſheep, cows, nor any ſort of quadruped but goats, aſſes, a few half-ſtarved camels, and antelopes at Dahalac, which laſt are very numerous. The inhabitants have no knowledge of fire-arms, and there are no dogs nor beaſts of prey in the iſland to kill them; they catch indeed ſome few of them in traps.

The language at Dahalac is that of the ſhepherds, though Arabic, too, is ſpoken by moſt of them. Our author ſtates the latitude of Dahalac to lie between 15° 27′ 30″, and 15° 54′ 30′ north.

DALRYMPLE (Sir David), was born in Edinburgh on the 28th of October (N. S.) 1726. His father was Sir James Dalrymple of Hailes, Bart. and his mother Lady Chriſtian Hamilton, a daughter of the Earl of Hadinton. His grandfather Sir David Dalrymple was the youngeſt ſon of the firſt Lord Stair, and is ſaid to have been the ableſt of that family, ſo much diſtinguiſhed for ability. He was Lord Advocate for Scotland in the reign of George I. and his ſon Sir James had the auditorſhip of the exchequer for life.

The ſubject of this memoir was educated at Eton ſchool, where he was diſtinguiſhed as a ſcholar, and long remembered as a virtuous and orderly youth. In that juſtly celebrated ſeminary he acquired a claſſical taſte, which, though it was once prevalent in Scotland, has in that country been long on the decline; and formed, beſides, friendſhips to perſons and attachments to things, which accompanied him through life. Hence probably ſprung his partiality to Engliſh manners and cuſtoms, which marked both his public conduct and private converſation, and was the ſource of much of his dignity, and ſome of his littleneſſes.

From Eton he returned to Edinburgh, whence, after the uſual courſe of a gentleman's ſtudies in that univerſity, he went to Utrecht to ſtudy the civil law; and remained there till after the rebellion in 1746. Upon his return to his native country, ſo promiſing were his parts, and ſuch his induſtry and ſoberneſs of mind, that very ſanguine expectations were entertained of his future eminence; and in ſome reſpects theſe expectations were not fruſtrated. To his intimate friends it was well known, that if left to follow the bent of his own inclinations, he would have devoted his time and his talents to the ſtudy of antiquities and the belles lettres; in both which departments of literature he was eminently qualified to excel. On the death of his father, however, he found his affairs ſo very much encumbered, that in order to retrieve them, and to provide for his brothers and ſiſters, he reſolved to follow the law as a profeſſion, in which ſome of his anceſtors had made a diſtinguiſhed figure.

He was called to the Scotch bar in 1748, where, notwithſtanding the elegant propriety of the caſes which he drew, it muſt be confeſſed that his ſucceſs did not anſwer the expectations which had been formed of him. This was not owing either to want of ſcience or to want of induſtry, but to certain peculiarities, which, if not inherent in his nature, were the reſult of early and deep-rooted habits. He poſſeſſed on all occaſions a ſovereign contempt, not only for verbal antitheſis, but for well rounded periods, and every thing which had the ſemblance of declamation; and indeed he was wholly unfitted by an ill-toned voice and ungraceful elocution, for ſhining as an orator. No wonder, then, that his pleadings, which were never addreſſed to the paſſions, did not rival thoſe of ſome of his opponents, who, poſſeſſed of great rhetorical powers, did not, like him, employ ſtrokes of irony too fine to be perceived by the bulk of any audience, but expreſſed themſelves in full, clear, and harmonious periods. Even his memorials, though claſſically written, and often replete with valuable matter, did not on every occaſion pleaſe the court; for they were always brief, and ſometimes, as it was ſaid, indicated more attention to the minutiæ of forms than to the merits of the cauſe. Yet on points which touched his own feelings, or the intereſts of truth and virtue, his language was animated, his arguments forcible, and his ſcrupulous regard to form thrown aſide.

He was ſometimes employed as a depute advocate, which gave him opportunities at the circuits of diſplaying that candour and tenderneſs of diſpoſition which ſo well becomes the public proſecutor in a criminal court. Of this the following inſtance may be worth relating. On the firſt day of the court at Stirling, he was once accoſted by another advocate in theſe words: “Sir David, why is there not a trial this forenoon? I would be getting on.” “There are (replied he) ſome unhappy culprits to be tried for their *lives;* and therefore it is proper that they have time to confer with their men of law.” “That is of little conſequence (ſaid the other). Laſt year I came to viſit Lord Kames when he was here on the circuit, and he appointed me counſel for a man accuſed of a rape. Though I had very little time to prepare, yet I made a decent ſpeech.” “Pray, Sir, (ſaid Sir David), was your client acquitted or condemned?” “O (replied the other), moſt unjuſtly condemned.” “That, Sir, (ſaid the depute advocate) is no good argument for hurrying on trials.”

To return from this digreſſion, if it be conſidered as ſuch, it is ſurely to the honour of Sir David Dalrymple, that whatever men thought of his ſingularities, his detractors concurred with his admirers in believing him incapable of miſleading the judge by a falſe ſtatement of facts; or his clients, by holding out to them fallacious grounds of hope.

His high ſenſe of honour, and his inflexible integrity, were indeed univerſally admitted; and it was with the warmeſt approbation of the public, that in 1766 he was appointed one of the judges of the court of ſeſſion, the higheſt civil tribunal in Scotland. He took his ſeat on the bench, according to the uſage of that court, by the title of Lord Hailes, the deſignation by which he is generally known among the learned of Europe; and the expectations entertained of him were again ſanguine. His unwearied aſſiduity in ſifting dark and intricate matters to the bottom was well known; his elegant and conciſe manner of expreſſing his ſentiments was admirably ſuited to the character of a judge; and his legal opinions had been generally ſound. Yet it muſt be confeſſed, that as a judge he was neither ſo uſeful nor ſo highly revered as he ought to have been from the extent of his knowledge, and his unqueſtioned integrity. The ſame minute attention to forms, which had in ſome degree obſtructed his riſe at the bar, accompanied him to the bench, and brought upon him the ridicule of the wits about the court (A): and we all know, that the character even of Socrates himſelf was not able to reſiſt the torrent of ridicule. In extenuation of this foible, it may be obſerved, that by ſome of the judges of the court of ſeſſion perhaps too little regard has been paid to form; and that forms, even apparently trifling, cannot in legal proceedings be wholly diſregarded without involving in danger truth and juſtice. Be this as it may, ſuch was the opinion which the other judges entertained of Lord Hailes's accuracy, diligence, and dignified manners, that, in the abſence of the preſident, they generally voted him into the vacant chair.

In May 1776 he was appointed one of the lords commiſſioners of juſticiary; and in that ſtation he commanded the reſpect of all mankind. Fully impreſſed with a deep ſenſe of the importance of his office, he ſeemed, in the criminal court, to lay aſide his ſingularities. So far from throwing his whole weight into the ſcale of the crown, a charge which has been ſometimes brought, we believe unjuſtly, againſt the Scotch judges, Lord Hailes, like the judges of England, was always counſel for the priſoner when the king's counſel appeared too ſtrong for their opponents, or when there was any particular intricacy in the caſe. In adminiſtering the oath to the witneſſes, he had none of that indecorum which we have elſewhere cenſured in ſome of his brethren (ſee Oath, *Encycl.*); but riſing ſolemnly from his ſeat, he repeated the words in ſo ſerious a manner, as left no doubt in the moſt profligate mind but that he was himſelf impreſſed with a ſenſe of the immediate preſence of the Supreme Being, and with the firm belief of a future judgment. When the witneſs appeared to be young or ignorant, we have beheld, with the utmoſt love and veneration, the pious pains which his Lordſhip took to diſcover whether he was duly acquainted with the nature and obligation of an oath, before he admitted him to ſwear; and though it is perhaps impoſſible for human vigilance and ſagacity to prevent perjury altogether in courts of juſtice, he muſt ſurely have been a villain uncommonly hardened and artful who could perjure himſelf in the preſence of Lord Hailes. In doubtful caſes his Lordſhip inclined always to the ſide of mercy; but when it became his duty to paſs ſentence of death upon convicted criminals, he addreſſed them in a ſtrain of ſuch piety and commiſeration, as to draw tears from the eyes of every beholder, and was calculated to make a deep and proper impreſſion on the unhappy perſon himſelf. In the diſcharge of this painful duty, we never ſaw him ſurpaſſed, and have ſeldom ſeen him equalled.

Had Lord Hailes been conſpicuous only as a ſound lawyer and an able and upright judge, we ſhould not have thought his life intitled to a place in this Work; but he was no leſs eminent as a man of general erudition, and as a voluminous author. His ſkill in claſſical learning, the belles lettres, and hiſtorical antiquities, eſpecially thoſe of his own country, is univerſally admitted;

(A) In a ſatirical ballad on the court of ſeſſion, Mr Boſwell, alluding to Lord Hailes's fondneſs for verbal criticiſm, makes him addreſs the preſident in the following words:

To judge of this matter I cannot pretend,
For juſtice, my Lord, wants an *e* at the end.

ted; but it cannot be denied, that the ſame faſtidiouſneſs, and the ſame microſcopic attention to minutiæ, which characteriſed him as a barriſter, prevented him from riſing to that rank in the republic of letters to which his learning and genius would otherwiſe have infallibly carried him. But if he was not one of the moſt celebrated writers of the age, he was unqueſtionably one of the moſt virtuous; if his publications were not always edifying, they were at leaſt innocent and ingenious; and ſome of them are in the higheſt degree valuable. In proof of this aſſertion, we need inſtance only his *Annals of Scotland*, and his *Inquiry into the Secondary Cauſes which Mr Gibbon has aſſigned for the Rapid Progreſs of Chriſtianity.* Of the former of theſe works, though little calculated to pleaſe the common herd of readers, it may with truth be ſaid, that in reſearch and ingenuity it ſtands unrivalled among the writings of Scotch antiquaries; and of the latter, it is ſurely not too much to ſay, that it diſplays uncommon acumen, cloſeneſs of reaſoning, and zeal for the cauſe of truth, without the uſual rancour of theological controverſy.

His taſte for retirement, which the ſtate of his affairs rendered for a while neceſſary, grew upon him as he advanced in years. His conſtitution, of which he was very careful, as well as his principles and habits, rendered him averſe from diſſipation of every kind. After he was made a judge, he conſidered abſtraction from the gay and faſhionable world as connected with the duty of one whoſe time was no longer his own; and when he choſe to unbend his mind, it was in the ſociety of a few eaſy friends, whom he ſelected as much for their worth and good humour as for their genius or their learning. He had indeed occaſionally much converſation with that conſtellation of wits and men of ſcience who flouriſhed in Edinburgh at the ſame period with himſelf; but it was impoſſible for friendſhip or intimacy to ſubſiſt between men who thought ſo differently as he and they thought on the moſt important of all ſubjects. Though an old-faſhioned whig, zealouſly attached to the conſtitution, he ſcorned to take any ſhare in the civil or eccleſiaſtical broils in which ſome of his brother judges were warmly engaged for the firſt 20 years of the preſent reign; for he looked on theſe as either frivolous or miſchievous.

Although his Lordſhip's conſtitution had been long in an enfeebled ſtate, he proſecuted his ſtudies, and attended his duty on the bench, till within three days of his death, which happened on the 29th of November 1792, in the 66th year of his age.

His Lordſhip was twice married; by his firſt wife Anne Brown, only daughter of Lord Coalſton, one of the judges of the court of ſeſſion, he left iſſue one daughter, who inherits the family eſtate. His ſecond marriage (of which alſo their is iſſue one daughter) was to Helen Ferguſſon, youngeſt daughter of Lord Kilkerran, who has the affliction to ſurvive him. Leaving no male iſſue, the title of Baronet deſcends to his nephew.

Though the church of Scotland does not much encourage funeral diſcourſes, a very laudable endeavour was made to render the talents and virtues of Lord Hailes a theme of inſtruction to mankind, in a ſermon preached ſoon after his death in the church of Invereſk, by his learned friend and venerable paſtor Dr Carlyle; from which we ſhall tranſcribe a ſummary view of his character as a judge, a ſcholar, a Chriſtian, and a citizen.

“ His knowledge of the laws was accurate and profound, and he applied it in judgment with the moſt ſcrupulous integrity. In his proceedings in the criminal court, the ſatisfaction he gave to the public could not be ſurpaſſed. His abhorrence of crimes, his tenderneſs for the criminals, his reſpect for the laws, and his reverential awe of the Omniſcient Judge, inſpired him on ſome occaſions with a commanding ſublimity of thought, and a feeling ſolemnity of expreſſion, that made condemnation ſeem juſt as the doom of Providence to the criminals themſelves, and raiſed a ſalutary horror of crimes in the breaſt of the audience.

“ Conſcious of the dignity and importance of the high office he held, he never departed from the decorum that becomes that reverend character; which indeed it coſt him no effort to ſupport, becauſe he acted from principle and ſentiment, both public and private. Affectionate to his family and relations, ſimple and mild in his manners, pure and conſcientious in his morals, enlightened and entertaining in his converſation; he left ſociety only to regret, that, devoted as he was to more important employments, he had ſo little time to ſpare for intercourſe with them.

“ He was well known to be of high rank in the republic of letters, and his loſs will be deeply felt through many of her departments. His labours, in illuſtration of the hiſtory of his country, and many other works of profound erudition, remain as monuments of his accurate and faithful reſearch for materials, and his ſound judgement in the ſelection of them. Of his unfeigned piety and devotion, you have very often been witneſſes where we now are. I muſt add, however, that his attendance on religious ordinances was not merely out of reſpect to the laws and for the ſake of example (motives which ſhould never fail to have influence on perſons of ſuperior rank, for the moſt obvious reaſons), but from principle and conviction, and the moſt conſcientious regard to his duty; for he not only practiſed all the virtues and charities in proof of his faith, but he demonſtrated the ſincerity of his zeal by the uncommon pains he took to illuſtrate primitive Chriſtianity, and by his elaborate and able defences of it againſt its enemies.

“ His profound reſearches into hiſtory, and his thorough knowledge of the laws, made him perfectly acquainted with the progreſs of the conſtitution of Britain, from the firſt dawn of liberty in the common law of the land, and the trial by jury which precede all written records, and afterwards in the origin and eſtabliſhment of parliaments, through all its viciſſitudes and dangers, till at laſt, by the bleſſing of divine Providence, which brought many wonderful events to concur to the ſame end, it was renewed, ſtrengthened, and finally confirmed by the Revolution.

“ It was this goodly and venerable fabric of the Britiſh conſtitution which the deceaſed moſt reſpectable character contemplated with admiration and delight (of late, indeed, with a mixture of anxiety and fear), as the temple of piety, as the genuine ſource of greater happineſs and freedom, to a larger portion of mankind than ever flowed from any government upon earth.

“ Ill indeed can the times bear the loſs of ſuch an

affectionate

affectionate patriot and able guardian of the laws of his country. But we muſt not murmur at the will of Providence, which in its mercy ‘ may have withdrawn the good man from the evil to come.’ In mercy, I ſay, to him, whoſe righteous ſpirit was ſo deeply grieved when ‘ he ſaw the wicked rage, and the people imagine a vain thing.”

Such is the memorial which, in the hour of recent ſorrow, followed this excellent man to the grave; and we believe it will yet be allowed to be juſt by all who had the happineſs of his Lordſhip's acquaintance, and are what he was, friends to the beſt intereſts of mankind.

This ſketch of the life of Lord Hailes would be more imperfect than even it is, if we could not ſubjoin to it a catalogue of his publications, of which the greater part are exceedingly curious. We call them *publications*, becauſe he employed almoſt as much of his time in republiſhing old and uſeful books as in preparing for the preſs his own valuable works.

Beſides his eſſays in the papers called *The World* and *The Mirror*, which are well known and univerſally admired, his Lordſhip publiſhed the following works:

Sacred Poems, or a Collection of Tranſlations and Paraphraſes from the Holy Scriptures; by various authors, Edinburgh, 1751, 12mo. Dedicated to Charles Lord Hope, with a preface of ten pages.

The Wiſdom of Solomon, Wiſdom of Jeſus the Son of Sirach, or Eccleſiaſticus, 12mo, Edin. 1755.

Select Diſcourſes (in number nine), by John Smith, late Fellow of Queen's College, Cambridge, 12mo, 291 pages. Edin. 1756; with a preface of five pages, “ many quotations from the learned languages tranſlated,—and notes added, containing alluſions to ancient mythology, and to the erroneous philoſophy which prevailed in the days of the author,—various inaccuracies of ſtyle have been corrected, and harſh expreſſions ſoftened.”

A diſcourſe of the unnatural and vile Conſpiracy attempted by John Earl of Gowry and his brother, againſt his Majeſty's perſon, at St Johnſtoun, upon the 5th of Aug. 1600. No date of the republication, but the edition and notes ſuppoſed by Lord Hailes, 12mo, 1757.

A Sermon, which might have been preached in Eaſt Lothian upon the 25th day of October 1761, on Acts xxviii. 1, 2. “ The barbarous people ſhewed us no little kindneſs.” Edin. 1761, pp. 25, 12mo. “ Occaſioned by the country people pillaging the wreck of two veſſels, viz. the Betſy, Cunningham, and the Leith Packet, Pitcairn, from London to Leith, caſt away on the ſhore between Dunbar and North Berwick. All the paſſengers on board the former, in number 17, periſhed; five on board the latter, October 16. 1761.”—A moſt affecting diſcourſe, admirably calculated to convince the offenders!

Memorials and Letters relating to the Hiſtory of Britain, in the reign of James I. publiſhed from the originals, Glaſgow, 1762.—Addreſſed to Philip Yorke, Viſcount Royſton, pp. 151. “ From a collection in the advocate's library, by Balfour of Dennyln.” The preface of four pages, ſigned Dav. Dalrymple.

The works of the ever memorable Mr John Hales of Eaton, now firſt collected together in 3 vols, Glaſgow, 1765; preface of three pages. Dedicated to William (Warburton), Biſhop of Glouceſter. “ The edition ſaid to be undertaken with his approbation; obſolete words altered, with corrections in ſpelling and punctuation.”

A ſpecimen of a book entitled “ Ane Compendious Booke of Godly and Spiritual Sangs, collectit out of ſundrie parts of the Scripture, with ſundrie of other Ballates changed out of prophaine Sanges, for avoyding of Sin and Harlotrie, with augmentation of ſundry Gude and Godly Ballates, not contained in the firſt edition. Edinburgh, printed by Andro Hart.” 12mo. Edin. 1765, pp. 42; with a Gloſſary of four pages.

Memorials and Letters relating to the Hiſtory of Britain in the reign of Charles I. publiſhed from the originals, Glaſgow, 1766, pp. 189. Preface of ſix pages, ſigned Dav. Dalrymple, chiefly collected by Mr Wodrow, author of the Hiſtory of the Church of Scotland. Inſcribed to Robert Dundas of Arniſton, Lord Preſident of the Court of Seſſion.

An account of the preſervation of Charles II. after the Battle of Worceſter, drawn up by himſelf; to which are added, his Letters to ſeveral perſons. Glaſgow, 1766, pp. 190, from the MSS. of Mr Pepys, dictated to him by the king himſelf, and communicated by Dr Sandby, maſter of Magdalen College. The letters are collected from various books; ſome of them now firſt publiſhed, communicated by the tutors of the Duke of Hamilton, by the Earl of Dundonald, &c. The preface of four pages, ſigned Dav. Dalrymple, dedicated to Thomas Holles, Duke of Newcaſtle, chancellor of the univerſity of Cambridge.

The Secret Correſpondence between Sir Robert Cecil and James VI. 12mo, 1766.

A catalogue of the Lords of Seſſion, from the Inſtitution of the College of Juſtice in the year 1532, with Hiſtorical Notes. *Suum cuique rependet poſteritas.* Edin. 1767, 4to, pp. 26.

The Private Correſpondence of Dr Francis Atterbury, Biſhop of Rocheſter, and his friends, in 1725, never before publiſhed. Printed in 1768, 4to. Advertiſement, pp. 2. Letters, pp. 10. A fac ſimile of the firſt from Biſhop Atterbury to John Cameron of Lochiel, to prove their authenticity.

An examination of ſome of the Arguments for the High Antiquity of *Regiam Majeſtatem*; and an Inquiry into the authenticity of the *Leges Malcolmi*; by Sir David Dalrymple, 4to, pp. 52. Edin. 1769.

Hiſtorical Memoirs concerning the Provincial Councils of the Scottiſh Clergy, from the earlieſt Accounts to the Æra of the Reformation; by Sir David Dalrymple. Edinburgh, 1769, 4to, pp. 41.—*Nota*, Having no high opinion of the popularity of his writings, he prefixes to this work the following motto: “ Si delectamur quum ſcribimus quis eſt tam invidus qui ab eo nos abducat? ſin laboramus quis eſt qui alienæ modum ſtatuat induſtriæ.”—*Cicero*.

Canons of the church of Scotland, drawn up in the Provincial Councils held at Perth, A. D. 1242, and 1269. Edinburgh, 1769, 4to, pp. 48.

Ancient Scottiſh Poems, publiſhed from the MS. of George Bannatyne, 1568. Edin. 1770, 12mo. Preface ſix pages; Poems pp. 221; very curious notes pp. 92; gloſſary and liſts of paſſages and words not underſtood, pp. 14.

The additional caſe of Elizabeth, claiming the title and dignity of Counteſs of Sutherland; by her Guardians. Wherein the facts and arguments in ſupport of her claim are more fully ſtated, and the errors in the additional caſes for the other claimants are detected, 4to.—This ſingularly learned and able caſe was ſubſcribed by Alexander Wedderburn (preſent Lord Chancellor), and Sir Adam Ferguſſon, but is the well-known work of Lord Hailes. It ought not to be regarded merely as a law-paper of great ability, but as a treatiſe of profound reſearch into the hiſtory and antiquity of many important and general points of ſucceſſion and family hiſtory. Introduction, pp. 21 ; the firſt four chapters pp. 70 ; the fifth and ſixth chapters pp. 177.

Remarks on the Hiſtory of Scotland, by Sir David Dalrymple.—" Utinam tam facile vera invenire poſſem quam falſa convincere." *Cicero.*—Edin. 1773, inſcribed to George Lord Lyttleton, in nine chapters, pp. 284. 12mo.

Huberti Langueti Epiſtolæ ad Philippum Sydneium Equitem Anglum, accurante D. Dalrymple de Hailes, Eq. Edinburgh, 1776, 8vo. Inſcribed to Lord Chief Baron Smythe.—Virorum Eruditorum Teſtimonia de Langueto, pp. 7. Epiſtolæ, pp. 289. Index Nominum, pp. 41.

Annals of Scotland, from the Acceſſion of Malcolm III. ſurnamed Canmore, to the Acceſſion of Robert I. by Sir David Dalrymple. Edin. 1776, pp. 311. Appendix, pp. 51.

Tables of the Succeſſion of the Kings of Scotland, from Malcolm III. to Robert I. their marriages, children, and time of their death ; and alſo of the Kings of England and France, and of the Popes who were their contemporaries.

Chronological Abridgement of the Volume, pp. 30. The Appendix contains eight diſſertations : 1. Of the law of Evenus and Mercheta Mulierum, pp. 17. 2. A commentary on the 22d ſtatute of William the Lion, pp. 8. 3. Of the 18th ſtatute of Alexander III. pp. 5. 4. Bull of Pope Innocent IV. pp. 6. 5. Of Walter Stewart Earl of Menteeth, 1296, pp. 7. 6. Of M'Duff, ſlain at Falkirk in 1298, pp. 3. 7. Of the death of John Comyn, 10th February, 1305, pp. 4. 8. Of the origin of the houſe of Stuart, pp. 6.

Annals of Scotland, from the Acceſſion of Robert I. ſurnamed Bruce, to the Acceſſion of the Houſe of Stuart ; by Sir David Dalrymple, Edin. 1779, 4to, pp. 277. Appendix, pp. 54, containing, 1. Of the manner of the death of Marjory, daughter of Robert I. pp. 7. 2. Journal of the campaign of Edward III. 1327, pp. 9. 3. Of the genealogy of the family of Seton in the 14th century. 4. Liſt of the Scottiſh commanders at the battle of Hallidon, 19th July 1383, pp. 11. 5. Whether Edward III. put to death the ſon of Sir Alexander Seton, pp. 8. 6. Liſt of the Scottiſh commanders killed or made priſoners at the battle of Durham, pp. 8. 7. Table of kings, p. 1. 8. Corrections and additions to volume i. pp. 16. Chronological abridgement of the volume, pp. 39.

Account of the Martyrs of Smyrna and Lyons, in the 2d century, 12mo, with explanatory notes, Edin. 1776. Dedicated to Biſhop Hurd, pp. 68. Notes and illuſtrations, pp. 142. This is a new and correct verſion of two moſt ancient epiſtles, the one from the church at Smyrna to the church at Philadelphia ; the other from the Chriſtians at Vienna and Lyons to thoſe in Aſia and Phrygia—their antiquity and authenticity are undoubted. Great part of both is extracted from Euſebius's Eccleſiaſtical Hiſtory. The former was firſt completely edited by Archbiſhop Uſher. The author of the notes ſays of them, with his uſual and ſingular modeſty, " That they will afford little new or intereſting to men of erudition, though they may prove of ſome benefit to the unlearned reader." But the erudition he poſſeſſed in theſe branches is ſo rare, that this notice is unneceſſary. They diſplay much uſeful learning and ingenious criticiſm, and breathe the moſt ardent zeal, connected with an exemplary knowledge of Chriſtianity. N. B. This is the firſt volume of the remains of Chriſtian Antiquity.

Remains of Chriſtian Antiquity, with explanatory notes, vol. ii. Edin. 1778, 12mo. Dedicated to Dr Newton biſhop of Briſtol. Preface, pp. 7. This volume contains the trial of Juſtin Martyr and his companions, pp. 8. Epiſtle of Dionyſius biſhop of Alexandria, to Fabius biſhop of Antioch, pp. 16. The trial and execution of Cyprian biſhop of Carthage, pp. 8. The trial and execution of Fructuoſus biſhop of Tarracona in Spain, and of his two deacons, Augurius and Eulogius, pp. 8. The maiden of Antioch, pp. 2. Theſe are all newly tranſlated by Lord Hailes from Ruinart, Euſebius, Ambroſe, &c. The notes and illuſtrations of this volume extend from p. 47 to 165, and diſplay a moſt intimate acquaintance with antiquity, great critical acumen, both in elucidating the ſenſe and detecting interpolations ; and above all, a fervent and enlightened zeal, in vindicating ſuch ſentiments and conduct as are conformable to the word of God, againſt the malicious ſarcaſms of Mr Gibbon. To this volume is added an Appendix of pp. 22, correcting and vindicating certain parts of vol. i.

Remains of Chriſtian Antiquity, vol. iii. Edin. 1780. Dedicated to Thomas Balguy, D. D. Preface, pp. 2. It contains the Hiſtory of the martyrs of Paleſtine in the third century, tranſlated from Euſebius, pp. 94. Notes and illuſtrations, pp. 135 ; in which Mr Gibbon again comes, and more frequently, under review.—The partiality and miſrepreſentations of this popular writer are here expoſed in the calmeſt and moſt ſatisfactory manner.

Pity it is that Lord Hailes ſhould have printed and publiſhed theſe valuable volumes, and indeed moſt of his other works, at his own expence ; and diſperſed them ſo liberally to his friends, that they have been little circulated among any other.

Octavius, a Dialogue, by Marcus Minucius Felix. Edin. 1781, pp. 16. Preface.—The ſpeakers are, Cæcilius a Heathen, Octavius a Chriſtian ; whoſe arguments prevail with his friend to renounce Paganiſm and become a Chriſtian proſelyte. Notes and illuſtrations, pp. 120.

Of the Manner in which the Perſecutors died ; a Treatiſe, by L. C. F. Lactantius, Edin. 1782. Inſcribed to Dr Porteous biſhop of Cheſter (preſent biſhop of London). Preface, pp. 37, in which it is proved that Lactantius is the author. Text, pp. 125. Notes and illuſtrations, pp. 109.

L. C. F. Lactantii Divinarum Inſtitutionum Liber Quintus ſeu de Juſtitia, 1777.

Diſquiſitions concerning the Antiquity of the Chriſtian Church. Glaſgow, 1783. Inſcribed to Dr Halifax biſhop of Glouceſter, pp. 194.—This ſmall original and moſt excellent work conſiſts of ſix chapters. Chap 1. A commentary on the conduct and character of Gallio. Acts xviii. 5, 12, 17.—Chap. 2. Of the time at which the Chriſtian religion became publicly known at Rome.—Chap. 3. Cauſe of the perſecution of the Chriſtians under Nero. In this the hypotheſis of Mr Gibbon, vol. i. 4to, p. 641, is examined.—Chap. 4. Of the eminent Heathen writers who are ſaid (by Gibbon) to have diſregarded or contemned Chriſtianity, viz. Seneca, Pliny ſen. Tacitus, Pliny jun. Galen, Epictetus, Plutarch, Marcus Antoninus. To the admirers of Heathen philoſophers, and to thoſe eſpecially who ſtate between them and the Chriſtian doctrine any conſanguinity, this chapter is earneſtly recommended.—Chap. 5. Illuſtration of a conjecture by Gibbon, reſpecting the ſilence of Dio Caſſius concerning the Chriſtians. In this chapter, with extreme impartiality, he amplifies and ſupports an idea of Mr Gibbon on this head. Chap. 6. Of the circumſtances reſpecting Chriſtianity that are to be found in the Auguſtan hiſtory.

It ſeems very probable that the cloſe attention which Lord Hailes appears to have given to ſuch ſubjects, was in ſome meaſure the effect of the miſtakes and partiality of Gibbon. In no one work from 1776, the date of Mr Gibbon's firſt publication, has he omitted to trace this unfair and inſinuating author; but in 1786 he came forth of ſet purpoſe with the moſt able and formidable reply which he has received, intitled, "An Inquiry into the Secondary Cauſes which Mr Gibbon has aſſigned for the rapid growth of Chriſtianity; by Sir David Dalrymple." Edin. 1786; gratefully and affectionately inſcribed to Richard (Hurd) Biſhop of Worceſter, 4to, pp. 213. In five chapters.

Sketch of the Life of John Barclay, 4to, 1786.

Sketch of the Life of John Hamilton, a Secular Prieſt, 4to (one of the moſt ſavage and bigotted adherents of Popery, who lived about A. D. 1600.)

Sketch of the Life of Sir James Ramſay, a general officer in the armies of Guſtavus Adolphus king of Sweden, with a head.

Life of George Leſlie (an eminent capuchin friar in the early part of the 17th century, 4to, pp. 24.

Sketch of the Life of Mark Alex. Boyd, 4to.

Theſe lives were written and publiſhed as a ſpecimen of the manner in which a *Biographia Scotica* might be executed; and it is likely that Lord Hailes ſelected purpoſely the leaſt intereſting.

The Opinions of Sarah Dutcheſs Dowager of Marlborough, publiſhed from her original MSS. 1788, 12mo, pp. 120. (with a few foot notes by Lord Hailes, in which he corrects the ſplenetic partiality of her Grace).

The Addreſs of Q. Sept. Tertullian to Scapula Tertullus, Proconſul of Africa, tranſlated by Sir David Dalrymple, 12mo. Edin. 1790, inſcribed to Dr John Butler, biſhop of Hereford; preface, pp. 4; tranſlation, pp. 18; original, pp. 13; notes and illuſtrations, pp. 135.

This addreſs contains many particulars relating to the church after the third century. The tranſlator has rejected all words and phraſes of French origin, and written entirely in the Anglo Saxon dialect. In the courſe of the notes many obſcurities of the original, not adverted to by other commentators, are explained. Some ſtrange inaccuracies of Mr Gibbon are alſo detected, not included in the miſrepreſentations of his two famous chapters.

This was the laſt work of this truly learned, reſpectable, and uſeful man. Whether he left behind him any thing elſe finiſhed for the preſs, is known only to his friends. We have repeatedly heard that he was engaged in examining the authenticity of the books of the New Teſtament, and that, with the exception of two or three, he found every verſe contained in it in the writings of the firſt three centuries. This ſeems indeed to have been an object in all his works; for, at the end of each of his tranſlations and editions of the primitive Chriſtian writers, a table is given of paſſages quoted or mentioned by them. If his Lordſhip completed any work of this kind, it ſhould not be withheld from the public. We may indeed be told that its utility is in a great meaſure ſuperſeded by the laborious collections of Lardner (B), and the more elegant work of Paley (C); but not to mention the prejudices generally entertained againſt Lardner on account of his evident bias to Unitarianiſm, it would ſurely be proper, in the preſent age of wild opinions, to ſhew the multitude, who are guided by authority, how important a ſubject the Chriſtian religion was deemed by this learned and accompliſhed layman.

DARCY (Count), an ingenious philoſopher and mathematician, was born in Ireland in the year 1725; but his friends being, like many other great and good families at that period, attached to the houſe of Stuart, he was at 14 years of age ſent to France, where he ſpent the reſt of his life. Giving early indications of a genius for ſcience, he was put under the care of the celebrated Clairaut (ſee CLAIRAUT, *Encycl*), under whoſe tuition he improved ſo rapidly in the mathematics, that at 17 years of age he gave a new ſolution of the problem concerning the curve of equal preſſure in a reſiſting medium. This was followed the year after by a determination of the curve deſcribed by a heavy body, ſliding by its own weight along a moveable plane, at the ſame time that the preſſure of the body cauſes a horizontal motion in the plane.

Though Darcy ſerved in the war of 1744, he found leiſure, during the buſtle of a military life, to ſend two memoirs to the academy: the firſt of theſe contained a general principle in mechanics, that of the preſervation of the rotatory motion; a principle which he again brought forward in 1750, by the name of the principle of the preſervation of action. He was taken priſoner in this war by the Engliſh; and ſuch was either the reſpect paid to ſcience, or the mercy of the cabinet of St James's, that he was treated, not as an Iriſh rebel, but as a French ſubject fighting for his king and his country.

In 1760, Darcy publiſhed An Eſſay on Artillery, containing ſome curious experiments on the charges of gunpowder, &c. &c. and improvements on thoſe of the

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(B) See his *Credibility of the Goſpel Hiſtory*, and other works, in 11 vols 8vo.

(C) See his *Evidences of the Chriſtian Religion*, in 2 vols 8vo.

ingenious Robins; a kind of experiments which our author carried on occaſionally to the end of his life. In 1765, he gave to the public the moſt ingenious of all his works, his Memoir on the Duration of the Senſation of Sight; in which he endeavours to prove, and indeed completely proves, that a body may ſometimes paſs by our eyes without producing a ſenſation attended with conſciouſneſs or marking its preſence, otherwiſe than by weakening the brightneſs of the object which it may chance to cover in its paſſage. If in this work he ſhall be thought to have taken hints from Dr Hartley, it is not perhaps too much to ſay, that ſome of our moſt celebrated writers on viſion have ſince been beholden to Darcy. No man indeed has cauſe to be aſhamed of being indebted to him; for all his works diſplay in an eminent degree the union of genius and philoſophy; but as he meaſured every thing upon the largeſt ſcale, and required extreme accuracy in experiment, neither his time, fortune, nor avocations, allowed him to execute more than a very ſmall part of what he projected.

In his diſpoſition, Darcy was amiable, ſpirited, lively, and a lover of independence; a paſſion to which he nobly ſacrificed, even in the midſt of literary ſociety.—He died of a cholera morbus in 1779, at 54 years of age. He was admitted of the French academy in 1749, and was made penſioner-geometrician in 1770. His eſſays, printed in the Memoirs of the Academy of Sciences, are various and very ingenious, and are contained in the volumes for the years 1742, 1747, 1749, 1750, 1751, 1752, 1753, 1754, 1758, 1759, 1760, 1765, and in tom. 1. of the Savans Etrangers.

DATA OF EUCLID, the firſt in order of the books that have been written by the ancient geometricians, to facilitate and promote the method of reſolution or analyſis. In general, a thing is ſaid to be given which is either actually exhibited or can be found out, that is, which is either known by hypotheſis, or that can be demonſtrated to be known: and the propoſitions in the book of Euclid's data ſhew what things can be found out or known, from thoſe that by hypotheſis are already known: ſo that in the analyſis or inveſtigation of a problem, from the things that are laid down as given or known, by the help of theſe propoſitions, it is demonſtrated that other things are given, and from theſe laſt that others again are given, and ſo on, till it is demonſtrated that that which was propoſed to be found out in the problem is given; and when this is done, the problem is ſolved, and its compoſition is made and derived from the compoſitions of the data which were employed in the analyſis. And thus the data of Euclid are of the moſt general and neceſſary uſe in the ſolution of problems of every kind.

Marinus, at the end of his preface to the data, is miſtaken in aſſerting that Euclid has not uſed the ſynthetical, but the analytical method in delivering them: for though in the analyſis of a theorem, the thing to be demonſtrated is aſſumed in the analyſis; yet in the demonſtrations of the data, the thing to be demonſtrated, which is, that ſomething is given, is never once aſſumed in the demonſtration; from which it is manifeſt, that every one of them is demonſtrated ſynthetically: though indeed if a propoſition of the data be turned into a problem, the demonſtration of the propoſition becomes the analyſis of the problem. *Simpſon's Preface to his Edition of the Data.*

CIRCULATING DECIMALS, called alſo *recurring* or *repeating decimals*, are thoſe in which a figure or ſeveral figures are continually repeated. They are diſtinguiſhed into *ſingle* and *multiple*, and theſe again into *pure* and *mixed*.

A *pure ſingle* circulate is that in which one figure only is repeated; as $\cdot 222$, &c. and is marked thus $\cdot\dot{2}$.

A *pure multiple* circulate is that in which ſeveral figures are continually repeated; as $\cdot 232323$, &c. marked $\cdot\dot{2}\dot{3}$; and $\cdot 524524$, &c. marked $\cdot\dot{5}2\dot{4}$.

A *mixed ſingle* circulate is that which conſiſts of a terminate part, and a ſingle repeating figure; as $4\cdot 222$, &c. or $4\cdot\dot{2}$. And

A *mixed multiple* circulate is that which contains a terminate part with ſeveral repeating figures; as $45\cdot\dot{5}2\dot{4}$.

That part of the circulate which repeats is called the *repetend;* and the whole repetend, ſuppoſed infinitely continued, is equal to a vulgar fraction, whoſe numerator is the repeating number or figures, and its denominator the ſame number of nines: ſo $.\dot{2}$ is $= \frac{2}{9}$; and $\cdot\dot{2}\dot{3}$ is $= \frac{23}{99}$; and $\cdot\dot{5}2\dot{4}$ is $= \frac{524}{999}$.

It ſeems it was Dr Wallis who firſt diſtinctly conſidered or treated of infinite circulating decimals, as he himſelf informs us in his Treatiſe of infinites. Since his time many other authors have treated on this part of arithmetic; the principal of theſe, however, to whom the art is moſtly indebted, are Meſſrs Brown, Cunn, Martin, Emerſon, Malcolm, Donn, and Henry Clarke; in whoſe writings the nature and practice of this art may be fully ſeen, eſpecially in the laſt mentioned ingenious author.

DEFERENS, or DEFERENT, in the ancient aſtronomy, an imaginary circle, which, as it were, carries about the body of a planet, and is the ſame with the eccentric; being invented to account for the eccentricity, perigee, and apogee of the planets.

DEFLECTION, the turning any thing aſide from its former courſe by ſome adventitious or external cauſe. The word is often applied to the tendency of a ſhip from her true courſe by reaſon of currents, &c. which turn her out of her right way. It is likewiſe applied by aſtronomers to the tendency of the planets from the line of their projection, or the tangent of their orbit. See ASTRONOMY in this Supplement.

DEJECTION, in aſtrology, is applied to the planets when in their detriment, as aſtrologers ſpeak, i. e. when they have loſt their force or influence, as is pretended, by reaſon of their being in oppoſition to ſome others which check and counteract them. Or it is uſed when a planet is in a ſign oppoſite to that in which it has its greateſt effect or influence, which is called its *exaltation*. Thus, the ſign Aries being the exaltation of the ſun, the oppoſite ſign Libra is its dejection.

DELIACAL PROBLEM, a celebrated problem among the ancients, concerning the duplication of the cube.

DEMI-BASTION, in fortification, a baſtion that has only one face and one flank.

DENDROMETER, in its uſual acceptation, is the name of an inſtrument for meaſuring trees, of which the reader will find a deſcription in the Encyclopædia Britannica. The ſame name has been lately given, by

William Pitt, Eſq; of Pendeford near Wolverhampton, to an inſtrument propoſed by him for meaſuring diſtances by one obſervation.

The idea of ſuch an inſtrument is not new. It has been frequently diſcuſſed, both in converſation and upon paper; but has been generally treated by ſound mathematicians with contempt, on the ſuppoſition of its being founded on falſe principles. Of all this our author is fully aware; but he, notwithſtanding, ſtrongly recommends it to the attention of the ingenious mathematical inſtrument maker.

To determine diſtances by one obſervation, two methods may be propoſed, founded on different principles; the one on the ſuppoſition of the obſerver being in the centre, and the object in the circumference, of a circle; the other, on the contrary ſuppoſition, of the obſerver being in the circumference, and the object in the centre.

To determine the diſtance of any object on the firſt ſuppoſition, the bulk or dimenſions of ſuch object muſt be known, either by meaſure or eſtimation, and the angle formed by lines drawn to its extremities being taken by an accurate inſtrument, the diſtance is eaſily calculated; and ſuch calculations may be facilitated by tables or theorems adapted to that purpoſe. For this method our preſent inſtruments, with a nonius, and the whole very accurately divided, are ſufficient; the only improvement wanting ſeems to be the application of a micrometer to ſuch inſtruments, to enable the obſerver to read his angle with more minute accuracy, by aſcertaining, not only the degrees and parts of a degree, but alſo the minutes and parts of a minute.

As in this method the bulk of inacceſſible objects can only be eſtimated, the error in diſtance will be exactly in the proportion of the error in ſuch eſtimation; little dependence can therefore be placed on diſtances thus aſcertained. For the purpoſes of ſurveying, indeed, a ſtaff of known length may be held by an aſſiſtant; and the angle from the eye of the obſerver to its two ends being meaſured by an accurate inſtrument, with a micrometer fitted to aſcertain minutes and parts of a minute, diſtances may be thus determined with great accuracy; the application of a micrometer to the theodelite, if it could be depended upon, for thus determining the minute parts of a degree, in ſmall angles, is very much a deſideratum with the practical ſurveyor.

This method of meaſuring diſtances, though plain and ſimple enough, our author illuſtrates by an example: Suppoſe A, fig. 1. (ſee Plate XXI.) the place of the inſtrument; BC the aſſiſtant's ſtaff, with a perpendicular pin at D, to enable the aſſiſtant to hold it in its right poſition; now, if the angle BAC could, by the help of a micrometer, be aſcertained to parts of a minute, the diſtance from A to B, or to C, might be eaſily calculated by the rules of plane TRIGONOMETRY; for which ſee that article in the Encyclopædia.

But this method of aſcertaining diſtances cannot be applied to inacceſſible objects, and it is moreover ſubject to the inconvenience of an aſſiſtant being obliged to go to the object whoſe diſtance is required (an inconvenience almoſt equal to the trouble of actual admeaſurement); therefore the perfection of the ſecond method propoſed, if attainable, is principally to be deſired; namely, that of conceiving the obſervation made on the circumference of a circle, whoſe centre is in the object whoſe diſtance is to be aſcertained; and, none of our inſtruments now in uſe being adapted to this mode of obſervation, a new conſtruction of a mathematical inſtrument is therefore propoſed, the name intended for which is the *dendrometer*.

Our author admits, that this name is not now uſed for the firſt time, though he thinks that the principle has never been applied in practice, for the familiar purpoſe of aſcertaining terreſtrial diſtances, in ſurveying, or otherwiſe, though the ſame principle has been ſo generally and ſucceſsfully applied in determining the diſtance of the heavenly bodies by means of their parallax.

The following principles of conſtruction are propoſed, which may perhaps be otherwiſe varied and improved. O, fig. 2. the object of whoſe diſtance is required; ABCDE the inſtrument *in plano*; BC a teleſcope, placed exactly parallel to the ſide AE; CE an arch of a circle, whoſe centre is at A, accurately divided from E in degrees, &c.; AD an index, moveable on the centre A, with a nonius ſcale at the end D, graduated to apply to the diviſions of the arch; alſo with a teleſcope, to enable the obſerver to diſcriminate the object, or any particular part or ſide thereof, the more accurately. The whole ſhould be mounted on three legs, in the manner of a plain table or theodolite, and furniſhed with ſpirit-tubes to adjuſt it to an horizontal poſition. The inſtrument being placed in ſuch poſition, the teleſcope BC muſt be brought upon the object O, or rather upon ſome particular point or ſide thereof; when, being there faſtened, the index AD muſt be moved till its teleſcope exactly ſtrikes the ſame point of the object; then the diviſions on the arch ED mark out the angle DAE, which will be exactly equal to the angle BOA, as is demonſtrated in the XV. and XXIX. propoſitions of Euclid, Book I.; and the ſide BA, as well as the angles ABO, and BAO, being already known, the diſtance BO or AO may be eaſily determined.

As the perfection of this inſtrument depends altogether upon its accuracy in taking ſmall angles, ſo that accuracy muſt depend, not only upon the inſtrument's being properly fitted with a micrometer, but alſo in ſome meaſure upon the length of the line BA in the figure. That line, therefore, might be extended, by the inſtrument being conſtructed to fold or ſlide out to a greater length when in uſe; upon which principle, connected with the application of a micrometer, an accurate and uſeful inſtrument might certainly be conſtructed. To adjuſt ſuch inſtrument for uſe, let a ſtaff be held up at a diſtance, in the manner of fig. 1. exactly equal in length to the diſtance of the two teleſcopes, and the index AD being brought exactly upon the ſide AE, if the two teleſcopes accurately ſtrike either end of the ſtaff, the inſtrument is properly adjuſted.

The conſtruction of a ſimilar inſtrument, on the principles of Hadley's quadrant, for naval obſervations, would alſo doubtleſs be an acceptable object in navigation, by enabling the mariner to aſcertain the diſtances of ſhips, capes, and other objects, at a ſingle obſervation; and that, perhaps, with greater accuracy than can be done by any method now in uſe.

For this purpoſe, the following conſtruction is propoſed: ABCDE, fig. 3. the inſtrument *in plano*; O the object whoſe diſtance is required; at A, at C, at E, and at 3, are to be fixed ſpeculums, properly framed.

med and fitted, that at 3 having only its lower part quickſilvered, the upper part being left tranſparent to view the object; the ſpeculum at A being fixed obliquely, ſo that a line A 1, drawn perpendicular to its ſurface, may biſect the angle BAC in equal parts; that at C being perpendicular to the line C 2; thoſe at E and 3 being perpendicular to the index E 3, and that at E being furniſhed with a ſight; the arch DC to be divided from D in the manner of Hadley's quadrant; the movement of the index to be meaſured as before by a micrometer; and as the length of the line AE would tend to the perfection of the inſtrument, it may be conſtructed to fold up in the middle, on the line C 2, into leſs compaſs when not in uſe. The inſtrument may be adjuſted for uſe by holding up a ſtaff at a diſtance, as before propoſed, whoſe length is exactly equal to the line AE.

To make an obſervation by this inſtrument, it being previouſly properly adjuſted, the eye is to be applied at the ſight in the ſpeculum E, and the face turned towards the object; when the object being received on the ſpeculum A, is reflected into that at C, and again into that at E, and that at 3 on the index; the index being then moved till the reflected object in the ſpeculum at 3 exactly coincides with the real object in the tranſparent part of the glaſs, the diviſions on the arch D 3, ſubdivided by the micrometer, will determine the angle DE 3 = the angle AOE; from which the diſtance O may be determined as before.

DENOMINATOR of a Ratio is the quotient ariſing from the diviſion of the antecedent by the conſequent. Thus, 6 is the denominator of the ratio 30 to 5, becauſe 30 divided by 5 gives 6. It is otherwiſe called the *exponent* of the ratio.

DEPRESSION of a Star, or *of the Sun*, is its diſtance below the horizon; and is meaſured by an arc of a vertical circle, intercepted between the horizon and the place of the ſtar.

Depression of the Viſible Horizon, or *Dip of the Horizon*, denotes its ſinking or dipping below the true horizontal plane, by the obſerver's eye being raiſed above the ſurface of the ſea; in conſequence of which, the obſerved altitude of an object is by ſo much too great.

DEROOBUST, in Bengal, Entire; as an entire diſtrict, oppoſed to Kismut, which ſee.

DESAULT (Peter Joſeph), ſurgeon in chief to the Hoſpital of Humanity, formerly the *Hotel-Dieu* at Paris, was born on the 6th of February 1744 at Magny Vernois, a village in the neighbourhood of Lure, in the department of Haute Saone (formerly the province of *Franche Comté)*. His father and mother were in that ſituation of life which is removed from want, and yet does not diſpenſe with labour; he himſelf was the youngeſt child of a numerous family.

At Lure, under the direction of a private inſtructor, he was taught the firſt rudiments of the Latin tongue; his parents afterwards confided him to the care of the Jeſuits, then almoſt excluſively entruſted with the education of youth in the public ſchools. This celebrated ſociety, prompt in diſcovering, as expert at developing, and adroit in appropriating talents, ſoon diſtinguiſhed the young ſtudent from the crowd; and he, in his turn, was not diſpleaſed with the life he led in one of their ſeminaries.

On the completion of his ſtudies, his father, who had deſtined him for the church, intimated a wiſh that he ſhould apply himſelf to theology; but his genius had taken a different direction, and he was averſe to the profeſſion of an eccleſiaſtic: in ſhort, young Deſault declared that he was determined to betake himſelf to the ſtudy of the healing art; and, after a long and ineffectual reſiſtance on the part of his family, he was ſent to Béfort, in order to ſerve an *apprenticeſhip*, as it was then termed, in the military hoſpital of that place. He accordingly ſpent three years there; during which he acquired ſome knowledge of anatomy, attended to the dreſſing of the patients, and endeavoured to ſupply, by his own obſervations, what was wanting in his inſtruction.

In the midſt of theſe profeſſional labours, his mind frequently rambled towards another ſcience but little connected with ſurgery: this was mathematics, the elements of which he had acquired among the Jeſuits. His progreſs in this favourite ſtudy was rapid; but he fell into one of the many errors ſo common among the phyſicians of that day; this conſiſted in a falſe application of the rules of geometry to the laws of the animal economy.

He not only peruſed with avidity the treatiſe of Borelli *De Motu Animalium*, but actually tranſlated the whole of it, and even added a commentary, ſtill more abundant in calculation than that of the celebrated profeſſor of Naples.

His ſucceſs in a branch of phyſiology ſo much cultivated at that time, attracted the attention of one of his ſuperiors, a zealous partizan of the doctrine of the mechanicians, who wiſhed to attach him to his perſon; but his deſire of fame required a more extenſive theatre, and his love of ſtudy made him ſolicitous of better means of inſtruction. Paris preſented both theſe advantages; and he accordingly repaired thither in 1764, at the age of nineteen, in ſearch of them.

Surgery at that period flouriſhed in the capital under the auſpices of a Lafaye, a Morand, an Andouillet, and a Louis. The ſight of ſuch great maſters excited the genius of thoſe who aſpired to emulate them: young Deſault deemed himſelf worthy of equalling men whom other ſtudents were content with only admiring. Animated by this ſentiment, he entirely reſigned himſelf to his ardour; anatomy became the ſpecial object of his labours, and his diſſections were not confined to the human body, for he inveſtigated, by means of his knife, a prodigious number of animals of all kinds: at firſt, from a difficulty of procuring human ſubjects, and afterwards on account of the advantages which he experienced from this general method. In order to become intimately acquainted with our own organization, it is neceſſary to compare it with whatever has a reſemblance to it in other bodies.

He accordingly ſpent the greater part of the day in the amphitheatres. The hours ſtolen from his favourite labours were employed in attending the hoſpitals; he was the firſt at the bed of the patient where an operation was to be performed, and was ſure to be preſent at the dreſſings, on purpoſe to examine the reſult. The infirmities of mankind, ſterile in reſpect to the vulgar, ſerved him as the beſt treatiſe for curing them; and the great ſurgeons of all nations have formed their mode of practice by contemplating the ſame book.

But he reckoned too much on a robuſt and vigorous temperament; for, after two years cloſe and aſſiduous application, he fell into a cachectical habit of body, which had nearly proved mortal, and which confined him for almoſt twelve months to his bed; but at length, owing partly to the vigour of his youth, and partly to the attention of his young friend Chopart, his inſeparable companion in his operations, who attended him alſo during his laſt illneſs, and only ſurvived him a few days, he was ſo fortunate as to recover.

Reſtored to life, he forgot that an exceſs of attention had conducted him to the very gates of death; a new career opened to his view, and required new efforts on his part. In the winter of 1766 he commenced a courſe of anatomy, and ſoon reckoned 300 pupils, moſt of them older than himſelf, who were attracted by the clearneſs of his demonſtrations, the methodical arrangement of his deſcriptions, and, above all, by his indefatigable zeal in the ſcience of inſtruction.

His ſucceſs inſpired the privileged profeſſors, whoſe ſchools became deſerted, with jealouſy and revenge; they employed the authority of the corporation againſt him, and would have nipped his efforts in the bud, had it not been for the protection of Louis and Lamartiniere, who were zealous of protecting a youth of talents, whoſe ſole reproach was, that he had not wealth enough to purchaſe certain franchiſes. After all, had it not been for the permiſſion he obtained of borrowing the name of a celebrated phyſician, he muſt have actually deſiſted from his lectures.

Default's reputation now began to be buzzed about, and a multitude of patients claimed his aſſiſtance; but he conſtantly refuſed to practiſe until he ſhould be placed at the head of ſome great eſtabliſhment.

At length, at the repeated ſolicitations of his friends, he preſented himſelf as a candidate to the corporation of ſurgeons; and they, much to their honour, admitted him in 1776, on condition of paying the uſual fees when convenient. The following is the title of his theſis: "*De calculo veſicæ urinariæ, eoque extrahendo, præviâ ſectione, ope inſtrumenti Haukenſiani emendati.*"

His public lectures were accompanied with as much celebrity as his private ones. Brilliant diſcoveries were not the object of his anatomical labours, which were always connected with the art of healing: he was, however, the firſt man in France who taught ſurgical anatomy.

After becoming firſt a ſimple member, and then a counſellor, of the perpetual committee of the academy of ſurgery, he was appointed chief ſurgeon to the hoſpital of the college, and conſulting ſurgeon to that of St Sulpice: neither of theſe added any thing to his fortune, but they gave him a clear inſight into practice, and enabled him to judge of caſes by the inductions ariſing from his own experience.

In 1779 he invented the bandage now in uſe for fractures; by means of which, the fragments being kept in a ſtate of perpetual contact, become conſolidated, without the leaſt appearance of deformity, an almoſt inevitable conſequence of the former mode.

On his appointment to the place of ſurgeon major to the hoſpital *de la Charité*, in 1782, he introduced a new method of treatment in oblique fractures of the thigh-bone; and he alſo healed, by means of a methodical compreſſion, thoſe various ulcers whoſe cure had hitherto been attended with great difficulty. In addition to this, he ſubſtituted new bandages in fractures of the humerus and clavicle, and adopted a new mode of treating the hare-lip, ſuperior to that uſed by Louis. He never recurred to amputation but in extreme caſes, when there was a certainty that diſſolution would have followed a neglect of the operation.

When a premature death carried off Ferrand, chief ſurgeon of the *Hotel Dieu* in Paris, Default was conſidered as the moſt proper perſon to ſucceed him; and, on the demiſe of Moreau, the whole charge of the hoſpital devolved on him. After three years of ſolicitations and diſputes, he at length in 1788 proceeded in his long projected ſcheme of eſtabliſhing a clinical ſchool; and a ſpacious amphitheatre was accordingly erected for that purpoſe. Scarcely had his firſt (A) courſe commenced, when the number of pupils who flocked around him was really aſtoniſhing. Foreigners repaired from all parts, and ſeveral of the neighbouring ſtates ſent ſtudents to Paris, expreſsly for the purpoſe of aſſiſting at his demonſtrations. More than 600 auditors conſtantly attended, in order to learn a new ſyſtem, conſiſting of a ſimple mode of treatment, diſengaged from ancient prejudices, and a complex incoherent practice.

A few of his improvements are here ſpecified.

1. The method of ligature employed by the ancients in the cure of umbilical hernias of children, having been generally omitted in the practice of the moderns, he again introduced and perfected this mode, and demonſtrated, by his ſucceſs, its ſuperiority over compreſſive bandages.

2. He was one of the firſt men in France to extract the looſe cartilages *(cartilâges flottans)* in joints.

3. He employed a new treatment, that of a methodical compreſſion, in reſpect to ſchirroſities of the rectum; in order to which he introduced a candle or bougie, the ſize of whice he gradually augmented.

4. He ſimplified, and rendered more commodious, the reduction of luxations of the humerus.

5. Fatal experience having pointed out the danger of employing the trepan in wounds of the head, he ſubſtituted another method of treatment *(l'uſage de l'émétique)* now adopted by many practitioners.

6. He made ſeveral very uſeful improvements on chirurgical inſtruments; ſuch as thoſe employed in the

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(A) The buſineſs of the day was conducted in the following routine: 1. A public conſultation concerning the indigent out-patients. 2. The young practitioners belonging to the hoſpital read a detailed account of all the intereſting caſes of ſuch patients as were to be diſcharged that day. 3. The operations: each of theſe was preceded by a diſſertation on the ſtate of the patient, who was then carried to the amphitheatre, where Default, attended by his aſſiſtants, performed the operation in preſence of all the pupils. 4. Argumentative details, by the profeſſor, either on the dangerous maladies exiſting in the hoſpital, or on the ſituation of the patients on whom operations had been performed during the preceding day. 5. The diſſection of ſubjects. And, 6. A lecture on ſome particular branch of pathology.

caſes of polypus in the womb and noſtrils (*la pince à gaîne et des porte-nœuds pour la ligature des polypes*, &c.;) for cutting through obſtructions in the different cavities (*le kiotome*); and for the *fiſtula in ano*. In caſes of inciſion he introduced the uſe of the inſtrument (*le gorgeret*) invented by Marchetti, well known among foreigners, but almoſt totally neglected in France before this period.

He at the ſame time retrenched the uſe of a great number of ſuperfluous ones, and baniſhed all practices attended with greater pain than utility. Avoiding every thing that was complex, he proved that the art of healing, in imitation of nature, ought to be ſimple in its means, and fruitful in its reſources.

In 1791 he publiſhed his *Journal de Chirurgerie*, which was edited by his pupils, and deſtined to deſcribe the moſt intereſting occurrences in his ſchool, and alſo extracts from his lectures, which were then dedicated to the inveſtigation of the maladies incident to the urinary paſſages. The treatment of theſe diſeaſes, hitherto the reproach of practitioners, had been much improved by the aſſiſtance of the artiſt Bernard. The elaſtic probes (*les ſandes élaſtiques*), on their firſt appearance, fixed the attention of all profeſſional men; but none knew better than Default how to appretiate their advantages. By means of them, he introduced a novel mode of cure in contractions of the urethra, which ſaved a great number of lives every year in the *Hotel-Dieu*. But he did not confine their uſe to the diſeaſes of the urethra alone, for he employed them to remove the divers obſtacles that impede deglutition or reſpiration.

In the midſt of ſuch a multiplicity of labours, and although he was obliged to attend 400 ſick twice a-day, Default nevertheleſs employed more than four hours of his time in viſiting private patients.

Few ſurgeons ever enjoyed ſuch an excluſive ſhare of public confidence; few ever poſſeſſed ſimilar means of enriching themſelves; and yet he neglected for a long time to take advantage of this. Had he been leſs ardent for glory, he would have been more favoured by fortune; but he ſacrificed all intereſted views to the noble ambition of advancing his art. His clinical and anatomical courſes were gratuitouſly opened by him to the world after the year 1790; and while the public ſchools languiſhed in the midſt of troubles, inſeparable perhaps from a mighty revolution, he was forming the greater part of thoſe ſurgeons employed at this preſent moment in the numerous armies of the republic. Conſidered under this point of view alone, the ſervices which he rendered to humanity are incalculable: too happy if perſecution had not been his ſole reward!

While out of mere attachment to the public weal, he added to his various functions that of a member of the council of health, conferred on him in 1792 by the miniſter Servan, he was denounced in the popular ſocieties as an *egotiſt*, an *indifferent*, &c. and became one of the firſt victims of that proſcription which, under Robeſpierre, extended to nearly every man of talents.

Chaumette accuſed him to the ſections as having neglected the brave men wounded on the 10th of Auguſt, while they themſelves were laviſhing their bleſſings at the *Hotel-Dieu* on their ſaviour. Twice was he brought to the bar of a commune; deſirous of diſcovering a pretext for perſecution, the clamours of the people were unremittingly excited againſt him. He was at length carried away from his amphitheatre, while in the very act of haranguing his pupils; and, in conſequence of a *mandat d'arr't* from the revolutionary committee, conducted by a body of armed men to the Luxembourg. From this horrid priſon few ever departed but to meet their fate; luckily, however, his name was not yet entered on that bloody liſt, in which thoſe of Maleſherbes and Lavoiſier were inſerted. On the contrary, at the end of three days he was liberated, and inſtantly reſumed all his functions.

On the eſtabliſhment of *L'Ecolede Santé*, Default was appointed clinical profeſſor; and for external maladies he ſoon after obtained from the government the converſion of the *Eveché* into an hoſpital for ſurgical operations.

In the midſt of theſe plans, the troubles that occurred in the month of May unfortunately affected his mind, and made him dread leſt the days of proſcription ſhould return. It was in vain that his friends attempted to ſoothe his ſufferings; for on the night of the 29th of May, a malignant fever made its appearance, and a nearly continual delirium enſued until his death, which occurred on the 1ſt of June 1795. on which day he breathed his laſt, in the arms of his pupils, at the age of 51.

The populace were perſuaded that he was poiſoned. This ridiculous opinion originated in conſequence of the epoch of his death, which preceded but a ſhort time that of the ſon of Louis XVI. whom he had viſited during his illneſs in the priſon of the Temple. It is pretended that he fell a victim to his conſtant refuſal to yield to the criminal views entertained againſt the life of that child.

Default was of a middling ſtature. He was well proportioned, and poſſeſſed an open countenance. His temperament, naturally robuſt, had been fortified by his early education, and was never ſapped by an exceſs of pleaſures, for to them his heart was always indifferent. His ruling paſſion was the love of glory; his favourite purſuit, the practice and advancement of his art. He was warm, nay ſometimes violent; and his ſcholars were not always inclined to praiſe the ſweetneſs of his temper. On the other hand, his mind was noble, elevated, and great, even to exceſs.

The French republic, eager to pay homage to his memory, has preſented his widow with a penſion of 2000 livres *per annum*. A ſon, Alexis Mathias Default, was the ſole fruit of his marriage; and he has left but one work behind him, in which the name of his friend Chopart is joined with his own. It is entitled *Traité des Maladies Chirurgicales et des Operations qui leur conviennent*, 2 vols 8vo.

DETERMINATE PROBLEM, is that which has but one ſolution, or a certain limited number of ſolutions; in contradiſtinction to an indeterminate problem, which admits of infinite ſolutions.

DETERMINATE Section, the name of a tract or general problem, written by the ancient geometrician Apollonius. None of this work has come down to us, excepting ſome extracts and an account of it by Pappus, in the Preface to the 7th book of his Mathematical Collections. He there ſays that the general problem was. "To cut an infinite right line in one point ſo, that, of the ſegments contained between the point of ſection ſought, and given points in the ſaid line, either the ſquare on one of them, or the rectangle contained by two of them, may have a given ratio, either to the rectangle contained by one of them and a given line, or to the rectangle contained by two of them."

DETONATION (ſee that word *Encycl.*). The aſtoniſhing violence with which the oxy-muriat of potaſs, when mixed with various ſubſtances, detonates, has been already noticed in this Supplement under the article CHEMISTRY, n° 722, where the theory of theſe exploſions is likewiſe given. But as ſeveral chemiſts ſeem to think that this ſalt, which decrepitates by friction, and ſpontaneouſly takes fire when mixed with ſulphur, contains in itſelf the elements and phenomena of thunder, it will not probably be unacceptable to our readers to find, in this place, a diſtinct account of the various mixtures which produce its detonations. The following are the principal which have been diſcovered by Fourcroy and Vauquelin.

1. Three parts of the oxy-muriat of potaſs, and one part of powdered ſulphur, rubbed together in a metal mortar, produce numerous ſucceſſive exploſions, reſembling the ſmacking of a whip, or even as loud as the report of a piſtol or a muſket, according to the rapidity of the motion, and the force of the preſſure made uſe of. A few grains of the ſame mixture, by being ſtruck ſmartly upon an anvil with a hammer, occaſion a report equal to that of a muſket; and torrents of purpliſh light are ſeen about the anvil. If this mixture be thrown into concentrated ſulphuric acid, it inſtantly takes fire, and burns, without noiſe, with a flame of a dazzling whiteneſs.

2. A mixture of three parts of this ſalt, half a part of ſulphur, and half a part of charcoal, cauſes ſtronger exploſions than the preceding when rubbed in a mortar, and a louder noiſe when ſtruck upon an anvil. Its flame alſo, when the mixture is made to explode, or when it is thrown into ſulphuric acid, is more rapid, more lively, and of a redder colour, than that of the preceding.

3. A mixture of equal parts of oxy-muriat of potaſs and antimony in powder explodes with noiſe by percuſſion; but produces only reddiſh ſparks when thrown into ſulphuric acid. If zinc be ſubſtituted in the place of antimony, a ſimilar exploſion takes place, accompanied with a white flame. Sulphuric acid has no effect upon this laſt mixture.

4. With regulus of arſenic, this ſalt explodes very violently by the ſtroke of a hammer; it inflames, with ſingular rapidity and brilliancy, by the contact of ſulphuric acid. In this laſt experiment there ariſes a ſmoke, which in the air takes the form of a crown, in the ſame manner as phoſphorated hydrogenous gas does when it inflames ſpontaneouſly in a ſtill atmoſphere.

5. Sulphuret of iron or martial pyrites inflames rapidly, but without noiſe, when rubbed in a metal mortar with oxy-muriat of potaſs. This mixture, when ſtruck upon an anvil, explodes violently, and with a red flame.

6. The red ſulphuret of mercury or cinnabar, and the ſulphurated calces of antimony, explode with the oxy-muriat of potaſs by percuſſion, but they do not inflame by ſulphuric acid. The ſame thing happens when charcoal alone is mixed with this ſalt.

Any of the following ſubſtances, namely, ſugar, gums, oils (both fixed and volatile), alcohol, ether, when mixed with oxy-muriat of potaſs, have the property of exploding very violently by the ſtroke of a hammer, and all of them ſend forth a briſk flame at the time of their exploſion. The liquid combuſtible ſubſtances above mentioned are to be mixed with the ſalt in ſuch a manner as to form a kind of paſte. None of theſe mixtures explode or inflame by being rubbed in a mortar; but ſome of them inflame by being mixed with concentrated ſulphuric acid, their combuſtion being ſlow and progreſſive.

8. All the ſubſtances above mentioned, which, being mixed with the oxy-muriat of potaſs, take fire and burn inſtantly, and with conſiderable noiſe, by the quick preſſure of the ſtrokes of a hammer, produce a much ſtronger exploſion when they are ſo cloſely wrapped up in paper, two or three times doubled, as to be thereby compreſſed before they are ſtruck.

9. An electric ſhock from a battery of large ſurface, charged by a ſtrong electric machine, cauſes all the forementioned mixtures to explode in the ſame manner as percuſſion, and their exploſion is alſo accompanied by a bright light.

To the above mentioned facts, the authors add, that it was already well known that gunpowder would explode by a violent blow, or very ſtrong preſſure; but they obſerve, that the ſtroke which is neceſſary for that purpoſe muſt be much ſtronger than that which ſuffices to produce an exploſion in the above-mentioned mixtures of combuſtible ſubſtances with the oxy-muriat of potaſs; and that its exploſion is by no means ſo remarkable as that which is produced by the help of this new ſalt.

DEWAN, under the Mogul government, the receiver general and civic governor of a province: in private life a ſteward.

DEWANNY, the revenue department of a province.

DIABETES MELLITUS (ſee MEDICINE, n° 318, &c. *Encycl.*), is ſo formidable a diſeaſe, though not very frequent, that it would be unpardonable in us not to mention every method of treating it ſucceſsfully which has come to our knowledge. Since our article MEDICINE was publiſhed, Dr Rollo, ſurgeon general to the royal artillery, has ſuggeſted a method of treating this diſeaſe, which in various inſtances has been crowned with ſucceſs.

The Doctor ſuppoſes, that in this complaint the vegetable matter taken into the ſtomach has not, from ſome defect in this organ, undergone a ſufficient change to form proper chyle; that in conſequence of this, much ſaccharine matter is evolved, which, when carried into the circulation, proves a general ſtimulus, producing head-aches and quickneſs of pulſe, but that it acts more remarkably on the kidneys, occaſioning a conſtant and copious ſecretion of ſweet urine. From this hypotheſis, he was naturally led to adopt a plan of cure, which has proved completely ſucceſsful. The indications he lays down are: 1. To prevent the formation of ſaccharine matter in the ſtomach; and, 2. To remove the morbidly increaſed action of this organ, and reſtore it to a healthful condition. Theſe indications are to be anſwered by a complete diet of animal food, and by the uſe of ſuch medicines as ſhall diminiſh the action of the ſtomach, and at the ſame time counteract the formation of ſaccharine matter. The remedies employed for this purpoſe have been emetics, kali ſulphuratum, lime-water, hepatized ammonia, and vegetable narcotics. But the principal dependence is to be placed on a total abſtinence from all vegetable matter, which alone can ſupply the ſaccharine principle. By a regular perſeverance in this plan, the firſt of two patients was completely cured in four weeks, although the diſeaſe had been of ſeven months continuance. The urine, which at the commencement of the treatment was ſweet, and amounted to 24 pints daily, was at laſt reduced to 1½ pint, being at the ſame time free from any ſaccharine impregnation. The ſecond patient, from his age and other circumſtances, although relieved from the diabetic affection, did not regain his wonted ſtate of health; but even in this caſe, the effects produced by the treatment, when properly attended to, were moſt decidedly in confirmation of this plan of cure.

The Doctor has received ſeveral communications in conſequence of the diſperſion of the printed notes on the firſt caſe. The moſt important are the reſult of two caſes treated in this way by Dr Cleghorn of Glaſgow, and one by Drs Currie and Gerard at Liverpool; all of which afford the ſtrongeſt corroboration of the efficacy of this mode of treatment.

DIAMOND, the moſt precious of all the gems; for the nature of which ſee CHEMISTRY, nº 33, &c. in this *Supplement*.

DIDEROT (Dionyſius) of the academy of Berlin, the ſon of a cutler, was born at Langres in 1713. The Jeſuits, with whom he went through a courſe of ſtudy, were deſirous of having him in their order; and one of his uncles, deſigning him for a canonry which he had in his gift, prevailed upon him to take the tonſure.

His father ſeems to have known him better; for perceiving that he was not inclined to be a Jeſuit, nor fit to be a canon, he ſent him to Paris to proſecute the ſtudy of the law. To the law, however, he paid very little attention, but devoted his time to ſcience and general literature; which ſo offended his father, that he ſtopped the remittance of his pecuniary allowance, and ſeemed for ſome time to have abandoned him.

The talents of young Diderot ſupplied him with a maintenance, and drew him from obſcurity. According to his friends, his capacious mind embraced phyſics, geometry, metaphyſics, ethics, and the belles lettres, from the time that he began to read with reflection; and it is certain that he aſpired at being a maſter in all theſe departments of literature. His bold and elevated imagination ſeemed to give him likewiſe a turn for poetry; but he neglected it for the ſciences. He ſettled at an early period at Paris, where the natural eloquence which animated his converſation procured him friends and patrons. What firſt drew the attention of the public to him as an author, and gave him a high reputation among a certain claſs of readers, was a ſmall volume written againſt the Chriſtian religion, and intitled *Penſées Philoſophiques*; which was reprinted afterwards under the title of *Etrennes aux Eſprits-forts*.

This book appeared in 1746, 12mo. The adepts of the new philoſophy compared it, for perſpicuity, elegance, and force of diction, to the *Penſées de Paſcal.* But the aim of the two authors was widely different; Paſcal employed his talents and his erudition, which was profound and various, to ſupport and illuſtrate the great truths of our holy religion, which Diderot attacked by all the diſingenuous arts of an unprincipled ſophiſt. The *Penſées Philoſophiques*, however, became popular. It contributed to promote the object of that conſpiracy which had been for ſome time formed againſt every thing which ennobles human nature (See JACOBINS in this *Supplement*). It was therefore applauded by Voltaire and D'Alembert, and read, of courſe, by every man and woman of taſte in Paris.

Our author was more uſefully employed in 1746, when, together with Meſſrs *Eidous* and *Touiſſant*, he publiſhed a general Dictionary of Medicine, in ſix volumes folio. This work, it muſt be confeſſed, has conſiderable merit; for though there are in it ſeveral articles ſuperficial and erroneous, there are many others of ſuch deep and accurate diſquiſition, as deſervedly recommended it to men of ſcience.

It was about this time that an intimacy was formed between Diderot and D'Alembert, and that, under the direction of Voltaire, they formed the idea of a *Dictionaire Encyclopedique*. The great objects which they had in view when they entered upon this work are now univerſally known. D'Alembert was a profound mathematician, Diderot had conſiderable knowledge in the phyſical ſciences, more eſpecially mechanical philoſophy, and Voltaire was a maſter of the belles lettres.

It is not to be ſuppoſed that ſuch men would publiſh any thing very defective in theſe departments of ſcience; but an *Encyclopædia* muſt treat of *religion*; and to every kind of religion they were all ſworn enemies. They engaged, however, a very worthy, though not very acute, clergyman, to furniſh the theological articles; and for other branches of knowledge, they were promiſed the aſſiſtance of ſeveral men of letters, and of a variety of artiſts.

Diderot took upon himſelf the deſcription of arts and trades; one of the moſt important departments of the work, and the moſt acceptable to the public. To the particulars of the ſeveral proceſſes of the workmen he ſometimes added reflections, ſpeculations, and principles, adapted to the elucidation. But beſides his own department, he furniſhed articles on almoſt every other ſubject.

By thoſe who knew not the great aim of the undertakers of this work, it has been regretted that Diderot was not leſs verboſe, leſs of the diſſertator, and leſs inclined to digreſſions. He has alſo been cenſured for employing needleſsly a ſcientific language, and for having recourſe to metaphyſical doctrines, frequently unintelligible, which occaſioned him to be called *the Lycophron of philoſophy*; for having introduced a number of definitions incapable of enlightening the ignorant, and which the philoſopher ſeems to have invented for no other purpoſe than to have it thought that he had great conceptions; while, in fact, he had not the art of expreſſing perſpicuouſly and ſimply the ideas of others. But theſe complaints ariſe from miſtaking entirely the purpoſe for which he wrote.

It has been completely proved, that one great object for which the philoſophers, as they called themſelves, undertook the compilation of the *Encyclopedie* was to ſap the foundation of all religion. This was to be attempted, not directly and avowedly; for bare-faced atheiſm would not then have been ſuffered in France.

A cloak, therefore, was to be worn, and the poiſoned dagger to be concealed under it. Whilſt the well-meaning divine was ſupporting, by the beſt arguments which he could deviſe, the religion of his country, Diderot and D'Alembert were overturning thoſe arguments under titles which properly allowed of no ſuch diſquiſitions. This neceſſarily produced digreſſions; for the greateſt genius on earth could not, when writing on the laws of motion, attack the myſteries of Chriſtianity without wandering from his ſubject; but that the object of theſe digreſſions might not paſs unnoticed by *any* claſs of readers, care was taken to refer to them from the articles where the queſtion was diſcuſſed by the divine. That when employed in this way, Diderot ſeems to write obſcurely, is indeed true; but the obſcurity is not his. His atheiſm was ſo plain, that for the moſt part D'Alembert, or ſome other leader of the gang, had to retouch his articles, and throw a miſt over them, to render their intention the leſs obvious.

Even with all this care and ſtudied obſcurity, the deſign of the *Encyclopedie* was too palpable not to be ſeen, and too wicked not to give offence. Certain wild poſitions on government and on religion occaſioned the impreſſion to be ſuſpended in 1752. At that time there were no more than two volumes of the dictionary publiſhed; and the prohibition of the ſucceeding ones was only taken off at the end of 1753. Five new volumes then ſucceſſively appeared. But in 1757 a new ſtorm aroſe, and the book was ſuppreſſed. The remainder did not appear till about ten years after; and was then for a while only privately diſtributed; ſome copies having been ſeized by government, and the printers ſhut up in the Baſtile. The merit, however, of ſome of the articles is confeſſedly great; and the firſt edition was quickly ſold off.

Thus was this great work in the preſs from 1751 to 1767; during which period, Diderot and D'Alembert were accuſtomed to frequent the coffee-houſes of Paris, and to enter with keenneſs into religious diſputes: the former attacking Chriſtianity; and the latter, under the maſk of piety, defending it; but always yielding to the arguments of his opponent. This practice was put a ſtop to by the police; and Diderot, when reproached by the lieutenant with preaching atheiſm, replied, "Cela eſt vrai, je ſuis athée, & m'en fais gloire."

Finding his impious converſations interrupted, and the publication of the *Encyclopedie* rendered tedious by the vigilance of government, he thought of propagating his notions by other vehicles. Alternately ſerious and ſportive, ſolid and frivolous, he publiſhed, at the very time he was working on the Dictionary of Sciences, ſeveral productions, which could ſcarcely have been expected from a man ſo completely employed. His *Bijoux Indiſcrets*, 2 vols 12mo, are of this number—a diſguſting work, even to thoſe young people who are unhappily too eager for following after licentious romances. Even here a certain philoſophical pedantry appears in the very paſſages where it is moſt miſplaced, and never is the author more aukward than where he intends to diſplay a graceful eaſe.

The *Fils Naturel*, and the *Pere de Famille*, two comedies in proſe, which appeared in 1757 and 1758, are not of the ſame kind with the *Bijoux Indiſcrets*. They are moral and affecting dramas, where we ſee at once a nervous ſtyle and pathetic ſentiments. The former piece is a picture of the trials of virtue, a conflict between intereſts and paſſions, wherein love and friendſhip play important parts. It has been ſaid that Diderot borrowed it from Goldoni: but if that be the caſe, the copy does honour to the original; and, with the exception of a ſmall number of ſcenes, where the author mixes his philoſophical jargon with the ſentiments of the heart, and ſome ſentences out of place, the ſtyle is affecting and natural enough. In the ſecond comedy, a tender, virtuous, and humane father appears, whoſe tranquillity is diſturbed by the parental ſolicitudes, inſpired by the lively and impetuous paſſions of his children. This philoſophical, moral, and almoſt tragical comedy, has produced conſiderable effects on ſeveral theatres of Europe. The dedication, to the princeſs of Naſſau Saarbuck, is a little moral tract of a ſingular turn, without deviating from nature. This piece, written with a true dignity of ſtyle, proves that the author poſſeſſed a great fund of moral ſentiments and philoſophical ideas. At the end of theſe two pieces, publiſhed together under the title of *Theatre de M. Diderot*, are dialogues, containing profound reflections and novel views of the dramatic art. In his plays he has endeavoured to unite the characters of Ariſtophanes and Plato; and in his reflections he ſometimes diſplays the genius of Ariſtotle.

This ſpirit of criticiſm is exhibited, but with too much licence, in two other works, which made a great noiſe. The former appeared in 1749, 12mo, intitled *Letters on the Blind for the Uſe of thoſe who See.* The free notions of the author in this work coſt him his liberty. He underwent a ſix months impriſonment at Viorcennes. Having naturally ſtrong paſſions and a haughty ſpirit, and finding himſelf on a ſudden deprived of liberty and of all intercourſe with human beings, he was threatened with the loſs of his reaſon. The danger was great; and to prevent it, they were obliged to allow him to leave his room, to take frequent walks, and to receive the viſits of a few literary men; among whom J. J. Rouſſeau, at that time his friend, went and adminiſtered conſolation to him, which he ought not to have forgotten.

The letter on the Blind was followed by another *On the Deaf and Dumb, for the Uſe of thoſe who can Hear and Speak*; 1751; 2 vols, 12mo. Under this title the author delivered reflections on metaphyſics, on poetry, on eloquence, on muſic, &c. In this eſſay there are ſome good things, among others abſurd and imperfect. Though he ſtrives to be perſpicuous, yet he is not always underſtood; and this is more his fault than that of his readers. Of what he has compoſed on abſtract ſubjects, it has been ſaid that it is a chaos on which the light ſhines only at intervals The other productions of Diderot betray the ſame defect of clearneſs and preciſion, and the ſame uncouth emphaſis, for which he has always been blamed.

The principal of them are, 1. Principles of Moral Philoſophy, 1745, 12mo; of which the Abbé de Fontaine ſpeaks well, though it met with no great ſucceſs. It was our philoſopher's fate to write a great deal, and not to leave a good book, or at leaſt a book well compoſed. 2. Hiſtory of Greece, tranſlated from the Engliſh of Stanyan. 3 vols, 12mo; an indifferent tranſlation of an indifferent book 3. Pieces on ſeveral Mathematical Subjects, 1748. 8vo. 4. Reflections on the Inter-

Interpretation of Nature, 1754, 12mo. This interpreter is very obſcure. 5. The Code of Nature, 1755, 12mo; which is certainly not the code of Chriſtianity. 6. The Sixth Senſe, 1752, 12mo. 7. Of Public Education; one of that ſwarm of publications produced by the appearance of Emelius, and the abolition of the Jeſuits. Though all the ideas of this author could not be adopted, yet ſome of them are very judicious, and would be highly uſeful in the execution. 8. Panegyric on Richardſon. Full of nerve and animation. 9. Life of Seneca. This is the laſt work which he acknowledged; and it is one of thoſe by Diderot that is peruſed with moſt pleaſure, even in rectifying the judgments he paſſes on Seneca and other celebrated men. The Abbé Barruel ſays, that he was the author of *Syſteme de la Nature*, which is uſually given to Robinet; and it is certain, that if he was not the author, he furniſhed hints, and reviſed the whole. Yet the junto of atheiſts were themſelves aſhamed of the firſt edition of that work; and after all Diderot's care to improve it, the ſubſequent editions are, notwithſtanding his boaſted knowledge of the laws of nature, contemptible in the eyes of a real mechanical philoſopher.

When a new edition of the *Encyclopedie* was reſolved on, Diderot, the editor of the former edition, thus addreſſes the bookſellers who had undertaken to republiſh it. "The imperfections (ſays he) of this work originated in a great variety of cauſes. We had not time to be very ſcrupulous in the choice of our coadjutors. Among ſome excellent perſons, there were others weak, indifferent, and altogether bad. Hence that motley appearance of the work, where we ſee the rude attempt of the ſchool-boy by the ſide of a piece from the hand of a maſter; a piece of nonſenſe next neighbour to a ſublime performance. Some working for no pay, ſoon loſt their firſt fervour; others, badly recompenſed, ſerved us accordingly. The *Encyclopedie* was a gulf into which all kinds of ſcribblers promiſcuouſly threw their contributions; their pieces ill conceived, and worſe digeſted, good, bad, contemptible, true, falſe, uncertain, and always incoherent and unequal; the reference that belonged to the very parts aſſigned to a perſon, never filled up by him. A refutation is often found where we ſhould naturally expect a proof. There was no exact correſpondence between the text and the plates. To remedy this defect, recourſe was had to long explications. But how many unintelligible machines, for want of letters to denote the plates!" To this confeſſion Diderot added particular details on various parts; ſuch as proved that there were in the *Encyclopedie* ſubjects to be not only retouched, but to be compoſed afreſh: and this was what a new company of literati and artiſts ſet themſelves to work upon in the *Encyclopedie Methodique*.

This immenſe work is not yet completed; and therefore we cannot ſpeak of it as a whole; but it is ſurely not leſs verboſe than the former edition, nor do the aims of its editors appear to be purer. That it contains much valuable information in chemiſtry, and indeed in every department of phyſical ſcience, no candid man will controvert: but its articles on abſtract philoſophy are prolix and obſcure; and it betrays the ſame impiety, the ſame eager deſire to corrupt the principles of the riſing generation, and the ſame contempt for every thing which can make mankind happy here or hereafter, with the former edition.

Notwithſtanding his numerous publications, Diderot was never rich. Soon after the publication of the laſt volumes of the *Encyclopedie*, upon which he had been employed for upwards of twenty years, his circumſtances were ſo ſtraitened, that an expedient was to be deviſed for their improvement. He had long correſponded with the late Empreſs of Ruſſia, whom he perſuaded to conſider him as the greateſt, or *one* of the greateſt economiſts of France. In the courſe of the correſpondence he had mentioned his own library as one of the moſt valuable in Europe; and when Catharine wanted to purchaſe it and make him librarian, he ſaid that his conſtitution could not ſupport the cold climate of St Peterſburgh. She offered to let him keep it during his lifetime in Paris; and the library was ſold for an immenſe price. When her ambaſſador wanted to ſee it, after a year or two's payments, and the viſitation could be no longer put off, Diderot was obliged to run in a hurry through all the bookſellers ſhops in Germany to fill his empty ſhelves with old volumes. He had the good fortune to ſave appearances; but the trick took air, becauſe he had been niggardly in his attention to the ambaſſador's ſecretary. This, however, did not hinder him from viſiting his imperial pupil, to whom he told a poor ſtory, in hopes of getting his daughter married with parade, and patroniſed by her majeſty; but it was ſeen through, and he was diſappointed.

In the year 1784 Diderot's health began viſibly to decline; and one of his domeſtics, perceiving that his death was at no great diſtance, acquainted him with his apprehenſions, and addreſſed him on the importance of preparing for another world. He heard the man with attention, thanked him kindly, acknowledged that his ſituation required ſeriouſneſs, and promiſed to weigh well what he had ſaid. Some time after this converſation he deſired that a prieſt might be brought; and the ſame domeſtic introduced to him M. de Farſac, Curé de St Sulpice. Diderot ſaw this eccleſiaſtic ſeveral times, and was preparing to make a public recantation of his errors. Condorcet and the other adepts now crowded about him, perſuaded him that he was cheated, that his caſe was not ſo dangerous as it was ſaid to be, and that he only wanted the country air to reſtore him to health. For ſome time he reſiſted their attempts to bring him back to atheiſm, but was at laſt prevailed upon to try the effect of the country air. His departure was kept ſecret, and he was concealed in the country till the 2d of July, when he died. His dead body was ſecretly brought back to Paris, and a report was ſpread and believed that he died ſuddenly on riſing from the table, without remorſe, and with his atheiſm unſhaken.

To draw a formal character of this wretch is ſurely ſuperfluous. His friends extol his frankneſs, his diſintereſtedneſs, and his integrity; but except his groſs avowal of atheiſm, which may in France be called frankneſs, this character is belied by every tranſaction of his life. He married, and had a daughter, as has been already mentioned. M. Bauzé, referred to by Abbé Barruel, coming one day into Diderot's houſe, found him explaining to this daughter a chapter of the goſpel. When he expreſſed ſome ſurpriſe at this conduct, Diderot ſaid: "J'entends ce que vous voulez dire;

mais

mais au fond, quelles meilleures leçons pourrois-je lui donner, ou trouverái-je mieux?" It was a common aſſertion of Diderot's, that between him and his dog "il n'y avoit de difference que habit." In uttering this ſentiment, he reſembled not Pope's Indian with untutored mind,

> "Who thinks, admitted to that equal ſky,
> "His faithful dog ſhall bear him company."

The Indian hopes to carry his dog with him to heaven; but Diderot hoped to die like a dog, and to be as if he had never been.

DIFFERENTIAL METHOD, is the art of working with the differences of quantities. By this method any term of a ſeries may be found from the ſeveral orders of differences being given; or *vice verſa*, any difference may be found from having the terms of the ſeries given: it likewiſe ſhews how to find the ſum of ſuch a ſeries. And it gives rules to find by interpolation any intermediate term, which is not expreſſed in the ſeries, by having its place or poſition given.

When any ſeries of quantities is propoſed, take the firſt term from the ſecond, the ſecond from the third, the third from the fourth, &c. then all theſe remainders make a new ſeries, called the *firſt order of differences*. In this new ſeries take the firſt term from the ſecond, the ſecond from the third, the third from the fourth, &c. as before; and theſe remainders make another ſeries, called the *ſecond order of differences*. In like manner, in this ſeries, take the firſt term from the ſecond, the ſecond from the third, &c.; and theſe will make a ſeries called the *third order of differences;* and after this manner you may proceed as far as you will. Thus in the following propoſition A, b, c, d, e, &c. is the ſeries; B, B^2, B^3, B^4, &c. the firſt order of differences; C, C^2, C^3, &c. the ſecond order of differences; D, D^2, &c. the third order; E, &c. the fourth order, and ſo on. But the firſt terms of theſe ſeveral orders of differences, as B, C, D, E, &c. are thoſe that are principally made uſe of in calculations by this method.

PROP. I. If there be any ſeries, A, b, c, d, e, &c. and if there be taken the firſt differences B, B^2, B^3, &c. the ſecond differences C, C^2, C^3, &c. the third differences D, D^2, D^3, &c. and ſo on.

Then if T ſtand for the firſt term of the nth differences,

$$\pm T = A - nb + n \times \frac{n-1}{2} c - n \times \frac{n-1}{2} \times \frac{n-2}{3} d + n \times \frac{n-1}{2} \times \frac{n-2}{3} \times \frac{n-3}{4} e - \text{\&c.}$$

that is, + T, when n is even, and — T when n is odd.

The ſeveral orders of differences being taken as before directed, will ſtand thus. Then,

$$\begin{array}{ccccc} A & & & & \\ & B & & & \\ b & & C & & \\ & B^2 & & D & \\ & & C^2 & & E \\ c & & & D^2 & \\ & B^3 & C^3 & & \\ d & & & & \\ & B^4 & \text{\&c.} & & \\ e & & & & \end{array}$$

ſeries	A , b , c , d , e, &c.
1ſt diff.	$b-A$, $c-b$, $d-c$, $e-d$, &c.
2d diff.	$c-2b+A$, $d-2c+b$, $e-2d+c$, &c.
3d diff.	$d-3c+3b-A$, $e-3d+3c-b$, &c.
4th diff.	$e-4d+6c-4b+A$, &c.

That is, $B = b - A$, $C = c - 2b + A$, $D = d - 3c + 3b - A$, $E = e - 4d + 6c - 4b + A$, &c. or $-B = A - b$, $+C = A - 2b + c$, $-D = A - 3b + 3c - d$, $+E = A - 4b + 6c - 4d + e$, &c. where, putting T ſucceſſively equal to B, C, D, E, &c. and $n = 1, 2, 3, 4$, &c. the prop. will be evident.

Cor. Hence

$A = A$, the firſt term.
$B = -A + b$, the firſt difference.
$C = A - 2b + c$, the 2d difference.
$D = -A + 3b - 3c + d$, the 3d difference.
$E = A - 4b + 6c - 4d + e$, the 4th difference.
$F = -A + 5b - 10c + 10d - 5e + f$, the 5th difference,
&c.

PROP. II. If A, b, c, d, e, &c. be any ſeries, and there be taken B, C, D, E, &c. the firſt of the ſeveral orders of differences;

Then, the nth term of the ſeries will be

$$= A + \frac{n-1}{1} B + \frac{n-1}{1} \times \frac{n-2}{2} C + \frac{n-1}{1} \times \frac{n-2}{2} \times \frac{n--3}{3} D + \frac{n-1}{1} \times \frac{n-2}{2} \times \frac{n-3}{3} \times \frac{n-4}{4} E +, \text{\&c.}$$

For from the equations in the laſt Prop. viz $B = b - A$, $C = c - 2b + A$, &c. we have, by tranſpoſing, $b = A + B$, $= -A + 2b + C = -A + 2A + 2B + C$ (expunging b); that is, $c = A + 2B + C$, $d = A - 3b + 3c + D = A - 3A - 3B + 3A + 6B + 3C + D$ (expunging b and c); that is, $d = A + 3B + 3C + D$. Alſo $e = -A + 4b -- 6c + 4d + E =$ (expunging b, c, d) $-A + 4A + 4B - 6A - 12B - 6C + 4A + 12B + 12C + 4D + E$; that is, $e = A + 4B + 6C + 4D + E$, &c.

Then putting A, b, c, d, &c. for the nth term, and n ſucceſſively $= 1, 2, 3, 4$, &c. the ſeries will be evident.

Cor. 1. If d', d'', d''', &c. be the firſt of the firſt, ſecond, third order, &c. of differences; then

The nth term of the ſeries A, b, c, d, &c. will be

$$= A + \frac{n-1}{1} d' + \frac{n-1}{1} \times \frac{n-2}{2} d'' + \frac{n-1}{1} \times \frac{n-2}{2} \times \frac{n-3}{3} d''' + \frac{n-1}{1} \times \frac{n-2}{2} \times \frac{n-3}{3} \times \frac{n-4}{4} d'''' + \text{\&c.}$$

For $B = d'$, $C = d''$, $D = \underline{d'''}$, &c. And the coefficients are the unciæ of the $n - 1$th power.

Cor. 2. Hence alſo it follows, that any term of a given ſeries may be accurately determined, if the differences of any order happen at laſt to be equal.

Cor. 3. Hence

$A = A$, the firſt term.
$b = A + B$, the 2d term.
$c = A + 2B + C$, the 3d term.
$d = A + 3B + 3C + D$, the 4th term.
$e = A + 4B + 6C + 4D + E$, the 5th term.
$f = A + 5B + 10C + 10D + 5E + F$, the 6th term.
$g = A + 6B + 15C + 20D + 15E + 6F + G$, the 7th term,
&c.

PROP. III. If a, b, c, d, e, &c. be any ſeries, and d' d'', d''', &c. the firſt of the ſeveral orders of differences; then

The ſum of n terms of the ſeries is

$$= na + n \times \frac{n-1}{2} d' + n \times \frac{n-1}{2} \times \frac{n-2}{3} d'' + n \times \frac{n-1}{2} \times \frac{n-2}{3} \times$$

$\times \frac{n-3}{4} d'' + n \times \frac{n-1}{2} \times \frac{n-2}{3} \times \frac{n-3}{4} \times \frac{n-4}{5} d''' +$, &c.

For in the ſeries of quantities,

$o, a, a+b, a+b+c, a+b+c+d$, &c.
1ſt diff. are a, b, c, d, &c.
2d diff. $d', d'2, d3$, &c.
3d diff. $d'', d''2$, &c.
4th diff. d''', &c.

Therefore (by Cor. 1. Prop. II.) the $\overline{n+1}$th term of the ſeries, $o, a, a+b, a+b+c, a+b+c+d$, &c. or the $\overline{n}$th term of the ſeries, $a, a+b, a+b+c, a+b+c+d$, &c. is $= o + na + n \times \frac{n-1}{2} d' + n \times \frac{n-1}{2} \times \frac{n--2}{3} d'' +$ &c. But the nth term of the ſeries $a, a+b, a+b+c$, &c. is the ſum of n terms of the ſeries, a, b, c, d, &c. and therefore equal to $na + n \times \frac{n-1}{2} d + n \times \frac{n-1}{2} \times \frac{n-2}{3} d' +$ &c.

For a fuller account of this method, and its application to curves, we refer the reader to Emerſon's works, from which theſe three propoſitions are taken.

DIFFRACTION, a term firſt uſed by Grimaldi, to denote that property of the rays of light which others have called inflection; the diſcovery of which is attributed by ſome to Grimaldi, and by others to Dr Hook.

DIMINUTION, in muſic, is the abating ſomething of the full value or quantity of any note.

DIOPHANTUS, a celebrated mathematician of Alexandria, has been reputed to be the inventor of algebra; at leaſt his is the earlieſt work extant on that ſcience. It is not certain when Diophantus lived. Some have placed him before Chriſt, and ſome after, in the reigns of Nero and the Antonines; but all with equal uncertainty. It ſeems he is the ſame Diophantus who wrote the Canon Aſtronomicus, which Suidas ſays was commented on by the celebrated Hypatia, daughter of Theon of Alexandria. His reputation muſt have been very high among the ancients, ſince they ranked him with Pythagoras and Euclid in mathematical learning. Bachet, in his notes upon the 5th book De Arithmeticis, has collected, from Diophantus's epitaph in the Anthologia, the following circumſtances of his life; namely, that he was married when he was 33 years old, and had a ſon born five years after; that this ſon died when he was 42 years of age, and that his father did not ſurvive him above four years; from which it appears that Diophantus was 84 years old when he died.

DIOPTER, or DIOPTRA, the ſame with the index or alhidade of an aſtrolabe, or other ſuch inſtrument.

DIOPTRA was an inſtrument invented by Hipparchus, which ſerved for ſeveral uſes; as, to level water courſes; to take the height of towers, or places at a diſtance; to determine the places, magnitudes, and diſtances of the planets, &c.

DIRECT, in arithmetic, is when the proportion of any terms. or quantities, is in the natural or direct order in which they ſtand; being the oppoſite to inverſe, which conſiders the proportion in the inverted order of the terms. So, 3 : 4 : : 6 : 8 directly; or 3 : 4 : : 8 : 6 inverſely.

DIRECTION, in aſtronomy, the motion and other phenomena of a planet when direct.

DIRECTION, in aſtrology, is a kind of calculus, by which they pretend to find the time in which any notable accident ſhall befal the perſon whoſe horoſcope is drawn.

DISCRETE QUANTITY, is ſuch as is not continued and joined together. Such, for inſtance, is any number.

DITTON (Humphry), an eminent mathematician, was born at Saliſbury, May 29. 1675. Being an only ſon, and his father obſerving in him an extraordinary good capacity, determined to cultivate it with a good education. For this purpoſe he placed him in a reputable private academy; upon quitting of which he, at the deſire of his father, though againſt his own inclination, engaged in the profeſſion of divinity, and began to exerciſe his function at Tunbridge in the county of Kent, where he continued to preach ſome years; during which time he married a lady of that place.

But a weak conſtitution, and the death of his father, induced Mr Ditton to quit that profeſſion. And at the perſuaſion of Dr Harris and Mr Whiſton, both eminent mathematicians, he engaged in the ſtudy of mathematics; a ſcience to which he had always a ſtrong inclination. In the proſecution of this ſcience he was much encouraged by the ſucceſs and applauſe he received: being greatly eſteemed by the chief profeſſors of it, and particularly by Sir Iſaac Newton, by whoſe intereſt and recommendation he was elected maſter of the new mathematical ſchool in Chriſt's Hoſpital; where he continued till his death, which happened in 1715, in the 40th year of his age, much regretted by the philoſophical world, who expected many uſeful and ingenious diſcoveries from his aſſiduity, learning, and penetrating genius.

Mr Ditton publiſhed ſeveral mathematical and other tracts, as below. — 1. Of the Tangents of Curves, &c. Philoſ. Tranſ. vol. 23.

2. A Treatiſe on Spherical Catoptrics, publiſhed in the Philoſ. Tranſ. for 1705; from whence it was copied and reprinted in the Acta Eruditorem 1707, and alſo in the Memoirs of the Academy of Sciences at Paris.

3. General Laws of Nature and Motion, 8vo, 1705. Wolfius mentions this work, and ſays that it illuſtrates and renders eaſy the writings of Galileo, Huygens, and the Principia of Newton. It is alſo noticed by La Roche, in the Memoires de Literature, vol. viii. p. 46.

4. An Inſtitution of Fluxions, containing the firſt Principles, Operations, and Applications, of that admirable Method, as invented by Sir Iſaac Newton, 8vo, 1706. This work, with additions and alterations, was again publiſhed by Mr John Clarke, in the year 1728.

5. In 1709 he publiſhed the Synopſi Algebraica of John Alexander, with many additions and corrections.

6. His Treatiſe on Perſpective was publiſhed in 1712. In this work he explained the principles of that art mathematically; and beſides teaching the methods then generally practiſed, gave the firſt hints of the new method afterwards enlarged upon and improved by Dr Brook Taylor; and which was publiſhed in the year 1715.

7. In 1714, Mr Ditton publiſhed ſeveral pieces both theological and mathematical; particularly his Diſcourſe on the Reſurrection of Jeſus Chriſt; and The New Law of Fluids, or a Diſcourſe concerning the Aſcent of Liquids, in exact Geometrical Figures, between two nearly contiguous Surfaces. To this was annexed a tract, to demonſtrate the impoſſibility of thinking or perception being the reſult of any combination of the parts of matter and motion: a ſubject much agitated about that time. To this work alſo was added an advertiſement from him and Mr Whiſton, concerning a method for diſcovering the longitude, which it ſeems they had publiſhed about half a year before. This attempt probably coſt our author his life; for although it was approved and countenanced by Sir Iſaac Newton, before it was preſented to the Board of Longitude, and the method has been ſucceſsfully put in practice, in finding the longitude between Paris and Vienna; yet that board then determined againſt it: ſo that the diſappointment, together with ſome public ridicule (particularly in a poem written by Dean Swift), affected his health ſo that he died the enſuing year, 1715.

In an account of Mr Ditton, prefixed to the German tranſlation of his Diſcourſe on the Reſurrection, it is ſaid that he had publiſhed, in his own name only, another method for finding the longitude; but which Mr Whiſton denied. However, Raphael Levi, a learned Jew, who had ſtudied under Leibnitz, informed the German editor, that he well knew that Ditton and Leibnitz had correſponded upon the ſubject; and that Ditton had ſent to Leibnitz a delineation of a machine he had invented for that purpoſe; which was a piece of mechaniſm conſtructed with many wheels like a clock, and which Leibnitz highly approved of for land uſe; but doubted whether it would anſwer on ſhip-board, on account of the motion of the ſhip.

DIVING-BELL has been already deſcribed in the *Encyclopædia*; but in that work was given no account of its antiquity or its invention. In the works of Ariſtotle we read of a kind of kettle uſed by divers to enable them to remain for ſome time under water; but the manner in which thoſe kettles were employed is not clearly deſcribed. "The oldeſt information (ſays Profeſſor Beckmann) which we have of the uſe of the diving bell in Europe, is that of John Taiſnier, who was born at Hainault in 1509, had a place at court under Charles V. whom he attended on his voyage to Africa. He relates in what manner he ſaw at Toledo, in the preſence of the emperor and ſeveral thouſand ſpectators, two Greeks let themſelves down under water, in a large inverted kettle, with a burning light, and riſe up again without being wet. It appears that this art was then new to the emperor and the Spaniards, and that the Greeks were cauſed to make the experiment in order to prove the poſſibility of it."

When the Engliſh, in 1588, diſperſed the Spaniſh fleet, called the Invincible Armada, part of the ſhips went to the bottom, near the Iſle of Mull, on the weſtern coaſt of Scotland; and ſome of theſe, according to the account of the Spaniſh priſoners, contained great riches. This information excited, from time to time, the avarice of ſpeculators, and gave riſe to ſeveral attempts to procure part of the loſt treaſure. In the year 1665, a perſon was ſo fortunate as to bring up ſome cannon, which, however, were not ſufficient to defray the expences. Of theſe attempts, and the kind of diving bell uſed in them, the reader will find an account in a work printed at Rotterdam in 1669, and entitled *G. Sinclari Ars nova et magna gravitatis et levitatis*. In the year 1680, William Phipps, a native of America, formed a project for ſearching and unloading a rich Spaniſh ſhip ſunk on the coaſt of Hiſpaniola; and repreſented his plan in ſuch a plauſible manner, that King Charles II. gave him a ſhip, and furniſhed him with every thing neceſſary for the undertaking. He ſet ſail in the year 1683; but being unſucceſsful, returned again in great poverty, though with a firm conviction of the poſſibility of his ſcheme. By a ſubſcription promoted chiefly by the Duke of Albemarle, the ſon of the celebrated Monk, Phipps was enabled, in 1687, to try his fortune once more, having previouſly engaged to divide the profit according to the twenty ſhares of which the ſubſcription conſiſted. At firſt all his labour proved fruitleſs; but at laſt, when his patience was almoſt entirely exhauſted, he was ſo lucky as to bring up, from the depth of ſix or ſeven fathoms, ſo much treaſure that he returned to England with the value of two hundred thouſand pounds ſterling. Of this ſum he himſelf got about ſixteen, others ſay twenty thouſand, and the duke ninety thouſand pounds. After he came back, ſome perſons endeavoured to perſuade the king to ſeize both the ſhip and the cargo, under a pretence that Phipps, when he ſolicited for his majeſty's permiſſion, had not given accurate information reſpecting the buſineſs. But the king anſwered, with much greatneſs of mind, that he knew Phipps to be an honeſt man, and that he and his friends ſhould ſhare the whole among them had he returned with double the value. His majeſty even conferred upon him the honour of knighthood, to ſhew how much he was ſatisfied with his conduct. We know not the conſtruction of Phipps's apparatus: but of the old figures of a diving-machine, that which approaches neareſt to the diving-bell is in a book on fortification by Lorini; who deſcribes a ſquare box bound round with iron, which is funiſhed with windows, and has a ſtool affixed to it for the diver. This ingenious contrivance appears, however, to be older than that Italian; at leaſt he does not pretend to be the inventor of it.

In the year 1617, Francis Keſsler gave a deſcription of his water-armour, intended alſo for diving, but which cannot really be uſed for that purpoſe. In the year 1671, Witſen taught, in a better manner than any of his predeceſſors, the conſtruction and uſe of the diving-bell; but he is much miſtaken when he ſays that it was invented at Amſterdam. In 1679 appeared, for the firſt time, Borelli's well known work *de motu animalium*; in which he not only deſcribed the diving-bell, but alſo propoſed another, the impracticability of which was ſhewn by James Bernoulli. When Sturm publiſhed his *Collegium curioſum* in 1678, he propoſed ſome hints for the improvement of this machine, on which remarks were made in the *Journal des ſçavans*. To him ſucceeded Dr Halley, whoſe bell is well known.

DODECATEMORY, the 12 houſes or parts of the zodiac of the primum mobile. Alſo the 12 ſigns of the zodiac are ſometimes ſo called, becauſe they contain each the 12th part of the zodiac.

DOME. See ARCH in this Supplement.

DOMINGO, or St Domingo. See Hispaniola, both in *Encycl.* and in this Supplement.

DON Martin de Mayorga, the name given by the Spaniards to a cluſter of iſlands in the South Sea, diſcovered on the 27th of February 1781 by Don F. A. Maurelle, a celebrated pilot of that nation.

Thoſe iſlands are deſcribed by him as abounding with tropical fruits and roots, as highly cultivated, and as inhabited by a people conſiderably poliſhed. The fertility of the land, ſays he, is ſuch, that its cultivation cannot fail to promiſe a favourable harveſt. Every where are ſeen an endleſs number of cocoa-nut trees, beautiful banana trees ranged in lines with the greateſt order, and numerous plantations of potatoes, of which he deſcribes ſome as fifteen feet in length, and of the thickneſs of a man's thigh. He admired the order with which every thing was diſpoſed. No weeds were ſuffered to grow between the plants; and their roads were kept in repair with a diligence deſerving imitation by the moſt civilized nations.

Their government appears from his account to be deſpotic. The ſovereign, who is called the *Tubou*, is held in the higheſt veneration by his ſubjects, whoſe lives and properties are at his diſpoſal. Under him there is an order of nobles called *Equis*, who, though they ſhrink into inſignificance in the preſence of the *Tubou*, have great authority over the people. Theſe people are ſaid by Maurelle to be of great muſcular ſtrength and large ſtature, the ordinary height of the men being ſix feet or ſix feet four inches, while many of them are much taller. It would appear, too, that they delight in gymnaſtic exerciſes; for when the *Tubou*, by whom he had been treated with great hoſpitality, wiſhed to amuſe him and his ſhip's company, he exhibited to them ſeats of wreſtling and boxing, and that as well by the women as by the men.

Though theſe people put the greateſt confidence in the Spaniards, and frequently ſtaid whole nights on board the frigate, they had yet the common inclination of ſavages to ſteal. "Every time they came on board (ſays our author), clothes, iron-work, whatever fell in their way, they conſidered as lawful prize. They drew out through the port-holes, or the windows, whatever was within their reach. They thieved even to the very chain of the rudder. I made my complaints to the king; he gave me permiſſion to kill whomſoever I ſhould detect in the act; and I was aſſured he had himſelf diſcovered and puniſhed with death the authors of the complained of theft. Our vigilance was neceſſarily called into action; we ſurpriſed the iſlanders ſtriving to tear away the new rudder chains; we fired a piſtol at them, one of them fell dead on the occaſion, and this was an awful leſſon for thoſe who were either on board or alongſide of the frigate; they ſaid to themſelves, or to one another, *chito* (robber) *fama* (death)."

They make of the bark of trees a kind of cloth not unlike that which has been brought from other iſlands in the South Sea; and our author deſcribes the women as being peculiarly neat both in their dreſs and in their perſons. They had their mantles or looſe garments adjuſted in neat plaits and folds, and becomingly attached by a knot over the left ſhoulder. They wore garlands or wreaths on the head, and chaplets of large glaſs beads round their necks; the hair was pleaſingly diſpoſed in treſſes, and the whole perſon perfumed with an oil of an agreeable odour; above all, the ſkin was ſo exquiſitely clean, that they would not have ſuffered the ſmalleſt particle of duſt to remain upon it a moment.

In this archipelago Don Maurelle found a ſafe harbour, to which he gave the name of El Refugio; and which he places in South Lat. 18°. 36′. and W. Lon. 177°. 47′. 45″. of Greenwich.

DRACŒNA Draco (ſee Dracoena, *Encycl.*), is a native of Madeira, though it is there becoming ſcarce. The following account of it is by La Martiniere, naturaliſt in the laſt voyage of diſcovery by La Perouſe. "The idea of the dracœna draco (ſays he) given by the ſhabby ſpecimens cultivated in our hot-houſes, is far inferior to that we entertain of it when we have an opportunity of ſeeing it in its native ſoil. I met with three in particular, of which the trunk was ſix or ſeven feet high, and four and a half, or five in diameter. The principal branches, 12 or 15 in number, and as thick as a man's body, ſhoot out a little obliquely, dividing themſelves generally into two, and now and then into three, to the height of 40 or 50 feet, including the ſeven feet of the trunk. The leaves are all at the extremity of the branches, where they are placed in alternate order, and form a cluſter. This tree preſents the moſt perfect regularity to the eye, and tempts the ſpectator to think that the moſt ſkilful gardener makes it the object of his daily care."

DRAINS. Under this word in the Encyclopædia we publiſhed Mr Bayley of Hope's method of draining land; and by a letter from the author, we have ſince learned, that experience, the beſt guide, has fully proved the uſefulneſs and durability of his *drains*. With a candour, however, worthy of a man who writes not for fame, but for the good of the public, he informs us of a miſtake into which he had led us; and requeſts us to correct it in this Supplement.

"I wiſh (ſays he) that, in the Supplement to the Encyclopædia, due notice may be taken of a very great error into which I was led in my ſcheme of making the *main drains*. I conjectured, that where the bottom of the trench was of a hard or ſolid body, as *clay* or *marl*, it might not be neceſſary to lay it with bricks or ſtones; but in this I was quite wrong. By the runs of water, the alternate changes from wet to dry, and the acceſs of air, theſe hard bottoms have been rendered friable; they have crumbled away, and let in all my drains which were not ſupported by a bottom laid with brick or ſtone." For this information we requeſt the author to accept of our thanks, and we are perſuaded we may add the thanks of the public.

As the draining of land is a matter of great importance in agriculture, and as the ſubject has been again brought before us, we imagine that our agricultural readers will be glad to find here the ſubſtance of a paper on this ſubject, for which the author received the ſilver medal of the *Society* inſtituted for the encouragement of Arts, Manufactures, and Commerce. That author is Mr John Wedge of Bickenhill, near Coventry, who is not only a great farmer himſelf, but had likewiſe been employed by the Earl of Alesford in the management of ſeveral eſtates. Encouraged by his lordſhip's liberality, Mr Wedge informs the ſociety, that he had been employed for ſome years in draining large portions of land, of which part was in the Earl's occupation, and part in his own, as tenant to his lordſhip.

The

The principles upon which he proceeded, as well as his mode of procedure, he ſtates in the following terms:

In every country there are large portions of land that, in wet ſeaſons, have always what may be called a *dry ſurface*, and other portions of land that have always a *moiſt* or *wet ſurface*; the former of theſe admitting all the water which falls upon them to ſink freely through their pores to various depths, till falling on clay, or ſome other unctuous earth, whoſe pores will not permit it to paſs through, it is there held up to a height proportioned to the quantity of water which comes upon it, and the facility with which that water is diſcharged. Thus, held up to various heights, it ſerves as a fountain to diſtribute its water (either by veins of ſand, pebbles, or rock), according to the formation of the different under ſtrata on the neighbouring lands, and there forms bogs and other varieties of wet ſurface, on a baſis that will be always found to conſiſt of marl, or clay, or ſome mixture thereof. The effect of water thus diſtributed may be divided into two claſſes. The firſt claſs, where the water is thrown out by a body of marl or clay, &c. upon the ſurface of deſcending ground, and in the valley (there held up by clay alſo) forms bogs or ſwamps. The ſecond claſs, where the water is held up by marl or clay, as before, having above that marl or clay a ſtratum of ſand, or pebbles, through which the water paſſes; and above thoſe ſands or pebbles another ſtratum of marl or clay, through the weakeſt parts of which the water, by a continual preſſure from its fountain, forces a paſſage upwards; and thus, through the weakeſt parts of the marl or clay, furniſhes a continual ſupply of water on the ſurface, for the formation or growth of bogs, &c. in proportion as this water is more or leſs abundantly ſupplied by its fountain or head, namely, the higher lands, into which rain-water freely paſſes, as before deſcribed. There are alſo different ſoils, under different circumſtances, which may form a third claſs of land for draining; ſuch as, ſtrong deep ſoils, or open light ſoils, having near the ſurface a body of marl or clay. In either of theſe caſes, the water which falls on the ſurface muſt, for reaſons which are ſelf-evident, keep ſuch lands, in rainy ſeaſons, conſtantly wet and cold; and it ſhould be obſerved, that a mixture of all the three before-deſcribed claſſes of wet land ſometimes occur in one field, by ſudden alterations of the under ſtrata, and thereby perplex the operator, by requiring all the different modes of draining in the ſame field.

If it be admitted that bogs are thus formed and fed, their cure may be effected with certainty. The firſt claſs, by cutting through the ſtratum (be it ſand, pebbles, or rock,) that conveys the water to the bog, and carrying off that water by a cloſe drain to ſome proper place, where the level admits of its diſcharge. The ſecond claſs, by ſinking a drain to any convenient depth in the upper clay; and then digging or boring with a large auger, at a ſmall diſtance on one ſide of this drain, through the remaining part, be it (the upper clay) ever ſo deep, into the under ſtratum of ſand, pebbles, or rock, through which the water paſſes; which will then ruſh up into the drain ſo made, with a velocity proportioned to the height of the land or fountain whence it is ſupplied. As this drain advances through the land, holes muſt be dug or bored, as before, every ſeven yards, or at ſuch diſtance as the ſtrength of the ſprings may require; and the whole of the water thus brought up by tapping the ſprings, is carried off by the drain made in the upper clay, which muſt be a cloſe one, to its proper level, and there diſcharged.

By both theſe methods of draining, large tracts of land, under favourable circumſtances, may be cured with one drain. The beſt place for fixing theſe drains is where the ſtratum that conveys the water comes neareſt to the ſurface; and the beſt method of aſcertaining that, is to bore or dig in different parts through the different under ſtrata.

The third claſs may be eaſily cured by cloſe drains, at ſuch diſtances and depths as will beſt carry off the ſurface-water. It may not be improper to obſerve, that where the different ſtrata or meaſures crop out, that is, become gradually more and more ſhallow in ſome certain direction (as is often the caſe, till, one after the other, they all preſent themſelves in ſucceſſion on the ſurface of the earth), draining may often be much more eaſily and better effected by croſſing with the drain the different ſtrata or meaſures where the levels and other circumſtances will admit.

Some of the land drained was part of a common, in the pariſh of Church Bickenhill, in the county of Warwick; part of it was covered with moſs and ling, had a peaty ſurface about ſix inches deep, and produced little or no graſs: in all wet ſeaſons it was filled quite to the ſurface, and often overflowed, with water. Some of the land was much more unſound, deeper of peat, and covered with moſs, in moſt parts nine inches long; another part was an abſolute bog in all ſeaſons.

Having dug or bored with a large auger into ſeveral parts of the land, Mr Wedge found peat, gravel, and ſand mixed, and a quick-ſand almoſt uniformly. The quick-ſand in every part, after getting an inch or two into it, ſeemed almoſt as fluid as water. Judging from this, that no materials for a drain could be laid in the quick-ſand, but what it would immediately bury, he dug a trench almoſt to the quick-ſand, leaving gravel, &c. of ſufficient ſtrength to bear up the materials for a hollow drain; theſe materials were two ſides and a coverer of ſtone, with a peat-turf on the top to keep out the ſoil. At every ſeven yards forward, by the ſide of this drain, he dug a hole in the quick-ſand as deep as it would permit. From theſe holes the water roſe freely into the hollow drain, and was by it diſcharged at a proper level. It may be proper to remark, that the ſtone made uſe of for this drain, and all others here mentioned, was a red ſand and rag-ſtone, which eaſily ſplit into proper ſizes for the purpoſe, and is very durable; it coſt about ſixpence per ton getting, excluſive of carriage. The drain thus formed ran on the whole rather freely, and made the land dry for a few yards on each ſide thereof, but was far from having the effect he improperly expected; for it evidently appears that the drain could only take a very ſmall portion of the water from ſo large a quick-ſand, which it did not penetrate more than two inches; and that it could drain only to its own depth, or, at moſt, to that depth in the fountain which ſupplied the quick-ſand. His purpoſe was then defeated; and his motive for mentioning this error cannot, he hopes, be miſtaken.

He now did what he ſays he ought to have done before, that is, examined the different ſtrata to a greater depth, particularly on the bog, and at the upper edges thereof, and found the bog to be what has been deſcribed under the firſt claſs. He therefore determined to attempt the cure in the manner before preſcribed for that claſs, namely, to cut through the whole of the ſtratum (in this inſtance, of quick-ſand), through which he found the water paſs. This he effected as follows: The ſummer being dry, and favourable for the purpoſe, and having previouſly made his main open drain, he began his main cloſe drain the firſt week in June 1791, three feet wide, on the declivity near the edge of the great bog. In the firſt operation he dug through the peat, the hard ſand, and gravel, and one ſpade's graft (about nine inches deep, and ſeven inches wide) into the quick-ſand the whole length of this drain, which was 73 perches, of eight yards to the perch, in length. The drain thus dug ran copiouſly, not leſs than 60 gallons per minute. In this ſtate he left it about nine days: the effect of it was rapid, both above the drain and on the bog below. Upon examination, he now found about three inches on the top of the ſpade's graft, which had been made into the quick-ſand perfectly dry. He then dug out theſe three inches of dry ſand, to nearly the whole width of the drain, three feet; and at the ſame time dug out, as before, another ſpade's graft from the top of the quick-ſand, as near the middle of the drain as poſſible. This was left to run a few days, as before, and had the ſame effect, namely, three or four inches more of the top of the quick-ſand became dry and hard. The ſame operation was repeated again and again with the ſame effect, till the purpoſe of getting through this quick-ſand was completed, ſo far at leaſt as the level of the main open drain would permit. The ſtream of water continued increaſing during the whole operation; the bog below the drain was quite dry, and the land above perfectly ſo. The drain which was firſt made, and continued running for ſome time during the progreſs of the main cloſe drain, became gradually dry; and has not, ſince that drain was finiſhed, diſcharged one ſingle drop of water. Great care was neceſſary, in making the main cloſe drain, to keep the ſtream of water in the middle of it, otherwiſe the current would have undermined the ſides, as it ſometimes had done, and cauſed them to fall in. For this reaſon it was neceſſary, when the dry ſand was taken from the top of the quick-ſand, immediately to take out a ſpade's graft from the middle thereof, in order to divert the current from the ſides.

The main cloſe drain thus made was three feet wide at top, about nine feet deep on the average, and, bevelling a little from the top, it was about one foot ten inches wide at the bottom. The ſtone and other materials were put into this drain in the following manner:

Where the drain went through the quick-ſand into the ſtratum of clay below it, as in moſt places it did, the bottom, and in ſome inſtances the ſides, wanted no particular ſecurity (A); but where it did not go quite through the quick-ſand, which the level of his main open drain in ſome places would not admit, the bottom of the drain was covered half an inch thick with ling; then peat-turfs, one foot wide and three or four inches thick, were cut in convenient lengths, and placed on their edges on each ſide of the bottom of the drain, forming two ſides of a trough of peat; then ſide ſtones about eight inches high, and a ſtone coverer, were put in upon the ling between the peat-turfs; a large peat-turf, near two feet wide and four inches thick, was then cut and firmly placed over the whole: this left in the bottom of the drain an open ſpace, of more than ſix inches ſquare, for the water to paſs. The whole was then completed by filling in the upper part of the drain.

In this way the author drained, for about L. 80, thirty acres of land, which, from being of no value whatever, became worth at leaſt 14 ſhillings per acre of yearly rent. He likewiſe hollow-drained nine acres by the method preſcribed for the third claſs of wet land. Theſe drains were made a few yards below that part of each field where the dry and wet land ſeparate, about 22 inches deep, with ſides and a coverer of ſtone, and ling on the top of it, to keep the earth from running in. The length of theſe drains was 880 yards, and the expence of labour and materials three halfpence per yard. The drains, in wet weather, diſcharge a large quantity of water; and will, he has no doubt, anſwer the intended purpoſe. Thus far relates to land in his own occupation.

Nine acres of the land in the earl of Ayleſford's occupation was almoſt an entire pulp. This bog was of the ſecond claſs, namely, water paſſing through a quick-ſand, and confined by a ſtratum of clay below, and another ſtratum of clay above it. The water thus confined, being preſſed by its fountain, and forced up thro' the weakeſt parts of the clay, had formed a bog of irregular thickneſs on the ſurface, in ſome places ſix feet deep, in others not more than two. As there is a conſiderable fall in this land from eaſt to weſt, he thought it expedient to put two drains into it; and this appears to him to have been neceſſary, from a conſideration that both theſe drains continue to run in the ſame proportions as when firſt opened. The manner in which theſe drains were executed was, by digging through the different upper ſtrata, and as deep into the clay as the main open drain would admit; then digging or boring through the remaining part of that clay into the quick-ſand, at the diſtance of about ſix yards in a progreſſive manner.

The water riſing rapidly through theſe holes into the cloſe drains, has effected a complete cure of this land, every part of which will now bear a horſe to gallop upon it. Theſe drains diſcharge 3660 gallons an hour; which is much leſs than they did at firſt, as muſt be the caſe in all bogs. This land will be worth twenty ſhillings per acre. The draining coſt twenty-five pounds; and the length of the under-ground drains is eight hundred and fourteen yards.

Mr Wedge had juſt finiſhed (January 1792) draining another piece of land, about forty-three acres. As this was intended to anſwer two purpoſes, one, to drain the land, the other, to give an additional ſupply of water to a mill-pool, and as a circumſtance aroſe in the execution of the work which frequently happens in draining land, namely, a ſudden alteration in the poſition

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(A) He will probably find in time that he was under the ſame miſtake with Mr Bayley, and we hope that with Mr Bayley's candour he will acknowledge it.

ſition of the under ſtrata—a deſcription thereof will not, we hope, be thought tedious. This draining was begun at the level of a mill-pool, and continued, without any great difficulty, to the diſtance of about thirty-two chains, in the manner before deſcribed as a cure for the ſecond claſs of boggy land: but at or near that place the under ſtrata altered their poſition; the quick-ſand which conveyed the water now became of twice its former thickneſs; and the clay, which had hitherto been above that quick ſand, for ſome diſtance diſappeared. From the quick-ſand thus becoming ſo much deeper, he could not, with the level of the mill-pool, cut through it; nor indeed, from the wetneſs of the ſeaſon, would ſuch an operation have been proper. He therefore continued a ſhallow drain to ſome diſtance, making ſide-holes into the quick-ſand, which ran freely; but as this could not cure the whole of the bog below, he branched out another drain (which was made by the method deſcribed for curing the ſecond claſs of wet or boggy land), by ſinking a cloſe drain through the upper ſtrata into the upper clay, and then, at a ſmall diſtance on one ſide of this cloſe drain, boring a hole with an auger through the remaining part of that clay into the quick-ſand; and at every eight yards, as this cloſe drain advanced, ſtill boring other holes, in the manner before deſcribed: through many of theſe holes the water ruſhed with great rapidity. The water diſcharged by theſe drains into the mill-pool is 168 gallons per minute, or 3780 hogſheads in a day; which is after the rate of 1,379,700 hogſheads in a year.

About ſix acres of this land were always ſound; about twelve acres on the north ſide were an abſolute pulp, and the remaining twenty ſix acres very unſound. The whole is now ſound, and will, when cultivated, be worth ſixteen ſhillings per acre. This land would have been drained at a much leſs expence into the main open drain; but then the water, which was much wanted for the mill, would have been loſt. Theſe cloſe drains are in length 1452 yards, and coſt L. 100, of which about L. 30 ought to be charged to the mill.

Important as this ſubject is, we muſt not enlarge this article, or we ſhould make large extracts from Dr Anderſon's *Practical Treatiſe on Draining Bogs and Swampy Grounds*, lately publiſhed. It is proper, however, to inform the public, that the author puts in his claim for being the firſt diſcoverer of that mode of draining for which Mr Elkington has obtained from Parliament a premium of L. 1000; and the reader who ſhall turn to the article DRAINS in the Encyclopædia, will perceive that his claim is well-founded.

DROSSERA ANGLICANA, or the SUNDEW (ſee DROSSERA, *Encycl.*), is a very minute villous plant, uſually growing entangled with moſs on peat bogs; the leaves are curiouſly fringed with numerous ſtrong reddiſh hairs, terminated by ſmall pellucid globules of viſcous liquor, which occaſion, by the reflection of the ſun, that peculiar luſtre from which its name is derived. It is in theſe hairs that theſe eſſential properties of the plant reſide; for if a ſmall inſect ſhould fix itſelf on one of the leaves, theſe hairs immediately begin to cloſe, one by one, till the inſect is wholly environed by them, and then the leaf in which it is impriſoned gradually bends inwards, ſo as to reach the baſe: in this ſtate the inſect is killed by the operation of the acrimonious juice exuding from the ends of the hairs. Rothius (as quoted by Withering, in his Arrangement of Britiſh Plants,) mentions the effects of this ſingular plant, occaſioned by the irritation of an ant, which he placed on the centre of one of the leaves with a pair of pincers. The ant, in endeavouring to eſcape, was held faſt by the viſcous juice of the ſmaller hairs till the large ones, together with the edges of the leaf, cloſed in and impriſoned it. The ant died in fifteen minutes; but he obſerves, that the effects followed ſooner or later, in different experiments, according to the ſtate of the weather. Dr Whithering has publiſhed a ſimilar account of the ſenſitive properties of the ſundew, which was communicated to him by two of his botanical friends, and which he has made very entertaining and intereſting. The ſame thing is confirmed by a writer in the Monthly Magazine for Auguſt 1797; who ſays, that whenever he made experiments on the droſſera with ants and other diminutive inſects, he commonly found them periſh in a ſhorter time than fifteen minutes. His experiments were made on the droſſera rotundifolia. Rothius, however, obſerves, that the longifolia produces the ſame effects, but with greater rapidity. In concluding his account, Dr Withering ſuggeſts this enquiry, "Whether this deſtruction of inſects be not neceſſary to the welfare of the plant?" And it is ſurely worth ſome botaniſt's while to take ſome pains to anſwer the queſtion.

DRUGS (ſee *Encycl.*) are ſo commonly counterfeited, or at leaſt adulterated, that, in London, the royal college of phyſicians, it is well known, has long ago appointed a court of examiners to inveſtigate the goodneſs of drugs and medicines in the different chemiſts and apothecaries ſhops. The counterfeit, however, is made up with ſuch dexterity, that not only the merchant and drug-broker, but even the man of ſkill, is ſometimes deceived; and indeed nothing can detect this impoſition but a practical knowledge of chemiſtry. We therefore recommend it to every father of a family to ſtudy our Supplementary article CHEMISTRY with this view, if with no other; for whatever be the faults of that atricle, we have loſt much labour if it be not ſufficiently perſpicuous to enable every man, not an abſolute ſtranger to phyſical ſcience in all its branches, to detect the common impoſtures of drug-ſellers.

DUFTER, in Bengal, an office or department.

DUFTER Cana, the place where the office is kept.

DWARFING OF VEGETABLES, an art invented by the Chineſe, to which the attention of Sir George Staunton was attracted on the following occaſion:

When the embaſſy was at Chuſan (See CHUSAN in this Supplement), the gentlemen who went on ſhore were introduced to the governor in his hall of audience, where on ſeveral tables were placed, in frames filled with earth, dwarf pines, oaks, and orange trees, bearing fruit. None of them exceeded in height two feet. Some of thoſe dwarfs bore all the marks of decay from age: and upon the ſurface of the ſoil were interſperſed ſmall heaps of ſtones, which, in proportion to the adjoining dwarfs, might be termed rocks. Theſe were honey-combed and moſs-grown, as if untouched for ages, which ſerved to maintain the illuſion, and to give an antique appearance to the whole. This kind of ſtunted vegetation ſeemed to be much reliſhed by the curious in China; and ſpecimens of it were to be found in every conſiderable dwelling. To produce them formed a part of the gardener's ſkill, and was an art invented in that country. Beſide the mere merit of overcoming a difficulty, it had that of introducing vegetables into common apartments, from which their natural ſize muſt otherwiſe have excluded them.

The general method of obtaining vegetable dwarfs is ſaid to be the following: A quantity of clay or mould is applied to the upper part of the trunk of a tree, from which a dwarf is intended to be taken, and cloſe to its diviſion into branches. The mould is to be confined to the ſpot by coarſe hempen or cotton cloth, and to be carefully kept moiſt by water. In conſequence of this application, continued ſometimes above a twelvemonth, ſmall tender fibres ſhoot down like roots from the wood into the mould. The part of the trunk emitting thoſe new fibres, together with the branch riſing immediately above it, is then to be carefully ſeparated from the reſt of the tree, and planted in new earth, in which the fibres become new roots, while the former branch is now the ſtem of the vegetable thus transformed in ſome meaſure. This operation does not deſtroy or alter the productive faculty which thoſe parts enjoyed before their ſeparation from their parent root. That which, while a branch of the original tree, bore flowers and fruit, continues to produce the ſame, though no longer ſupported upon any ſtock. The terminal buds of ſuch branches of trees as are meant to become dwarfs are torn off; which circumſtance prevents the further elongation of thoſe branches, and forces other buds and branchlets from the ſides. Theſe branchlets are bent by wires to whatever form the operator wiſhes: and when the appearance of age and decay is meant to be given to a dwarf tree, it is repeatedly ſmeared with treacle or molaſſes, which attracts multitudes of ants, who, in purſuit of thoſe ſweet juices, attack the bark, and, by a gradual corroſion of it, produce the deſired effect. Theſe different proceſſes are ſometimes attempted to be kept ſecret by the gardeners, and they vary deſignedly in the mode of carrying them on; but the principle on which they are founded is ſufficiently apparent from what is related here; and the contrivance argues ingenuity and perſeverance, rather than the practice does true taſte, which conſiſts in aſſiſting Nature in its moſt favourite works—not in counteracting its operations or diſtorting its productions.

DYEING is an art into which, ſince the article in the Encyclopædia was publiſhed, improvements have been introduced of ſuch importance, that it would be unpardonable not to notice them in this Supplement. They ought to be noticed under the preſent title; but, for reaſons aſſigned at the time, we were under the neceſſity of poſtponing them, in the firſt edition, to the title *Vegetable*, *Animal*, and *Dyeing* SUBSTANCES. We might now reſtore the article DYEING to its proper place; but though we confidently announce this as an improved edition, we doubt whether we can, in juſtice to the purchaſers of the firſt edition, alter its arrangement. We therefore ſtill refer the reader to the article *Dyeing* SUBSTANCES.

DYNAMICS.

1 Definition.

THIS name marks that department of phyſico-mathematical ſcience which contains the abſtract doctrine of MOVING FORCES; that is, whatever neceſſarily reſults from the relations of our ideas of motion, and of the immediate cauſes of its production and changes.

2 Object of dynamics is change of that condition of a thing which we call its *motion*.

All *changes* of motion are conſidered by us as the indications, the characteriſtics, and the meaſures of changing cauſes. This is a phyſical law of human thought, and therefore a principle to which we may refer, and from which we muſt derive all our knowledge of thoſe cauſes. When we appeal to our own thoughts or feelings, we do not find in ourſelves any diſpoſition to refer mere exiſtence to any cauſe, although the beginning of exiſtence certainly produces this reference in an inſtant. Had we always obſerved the univerſe in motion, it does not appear that we ſhould have aſcribed it to a cauſe, till the obſervation of relative reſt, or ſomething leading to it, had enabled us to ſeparate, by abſtraction, the notion of matter from that of motion. We might then perceive, that reſt is not incompatible with matter; and we might even obſerve, by means of relative motions, that abſolute reſt might be produced by the concourſe of equal and oppoſite motions. But all this requires reflection and reaſoning; whereas we are now ſpeaking of the firſt ſuggeſtions of our minds.

3. We cannot have any notion of motion *in abſtracto*, without conſidering it as a ſtate or condition of exiſtence, which would remain, if not changed by ſome cauſe. It is from changes alone, therefore, that we infer any agency in nature; and it is in theſe that we are to find all that we know of their cauſes.

4 Mechanica relation, what.

When we look around us, we cannot but obſerve that the motions of bodies have, in moſt caſes, if not always, ſome relation to the ſituation, the diſtance, and the diſcriminating qualities of other bodies. The motions of the moon have a palpable relation to the earth; the motions of the tides have as evident a relation to the moon; the motions of a piece of iron have a palpable dependence on a magnet. The vicinity of the one ſeems to be the occaſion, at leaſt, of the motions of the other. The cauſes of theſe motions have an evident connection with or dependence on the other body. We are even diſpoſed to imagine, that they are inherent in that body, and that it poſſeſſes certain qualities which are the cauſes of thoſe modifications of motion in other bodies. Theſe ſerve to diſtinguiſh ſome bodies from others, and may therefore be called PROPERTIES; and, ſince the condition of other bodies ſo evidently depends on them, theſe properties expreſs very intereſting relations of bodies, and are chiefly attended to in the enumeration of the circumſtances which aſcertain what we call the *nature* of any thing. We do not mean to ſay that theſe inferences are always juſt; nay, we know that many of them are ill-founded: but they are real, and they ſerve abundantly for informing us what we may expect from any propoſed ſituation of things. It is enough for us to know, that when a piece of iron is ſo and ſo ſituated in relation to a magnet, it will move in a certain manner.

This mutual relation of bodies is differently conſidered, according to the intereſt that we chance to take in the phenomenon. The cauſe of the approach of the iron to a magnet is generally aſcribed to the magnet, which

which is ſaid to attract the iron, becauſe we commonly employ the magnet in order that theſe motions may take place. The ſimilar approach of a ſtone to the earth is aſcribed to the ſtone, and we ſay that it tends to the earth. In all probability, the procedure of nature is the ſame in both; for they are obſerved, in every inſtance, to be mutual between the related bodies. As iron approaches a magnet, ſo the magnet approaches the iron. The ſame thing is obſerved in the motions of electrified bodies ; alſo in the caſe of the ſtone and the earth. Therefore the cauſe of the motions may be conceived as inherent in either, or in both.

Force and *Action* are figurative terms when uſed in mechaniſm;

The qualities thus inherent in bodies, conſtituting their mechanical relations, have been called the MECHANICAL AFFECTIONS OF MATTER. But they are more commonly named POWERS or FORCES ; and the event which indicates their preſence, is conſidered as the effect and mark of their agency. The magnet is ſaid to ACT on the iron, the earth is ſaid to ACT on the ſtone, and the iron and the ſtone are ſaid to ACT on the magnet and on the earth.

All this is figurative or metaphorical language. All languages have begun with ſocial union, and have improved along with it. The firſt collections of words expreſſed the moſt familiar and the moſt intereſting notions. In the proceſs of ſocial improvement, the number of words did not increaſe in the ſame proportion with the notions that became intereſting and familiar in their turn: for it often happened that relations of certain ideas ſo much reſembled the relations of certain other ideas, that the word expreſſing one of them ſerved very well for expreſſing the other; becauſe the diſſimilar circumſtances of the two caſes prevented all chance of miſtake. Thus we are ſaid to *ſurmount* a difficulty without attaching to the word the notion of *getting over* a ſteep hill. Languages are thus filled with figurative expreſſions.

5
But the analogy is not in the force, but in the effect.

Power, Force, and Action, are words which muſt have appeared in the language of the moſt ſimple people ; becauſe the notions of perſonal ability, ſtrength, and exertion, are at once the moſt familiar and the moſt intereſting that can have a place in the human mind. Theſe terms, when uſed in their pure, primitive ſenſe, expreſs the notions of the power, force, and action of a ſentient, active, being. Such a being only is an agent. The exertion of his power or force is (excluſively) action : But the relation of cauſe and effect ſo much reſembles in its reſults the relation between this force and the work performed, that the ſame term may be very intelligibly employed for both. Perhaps the only caſe of pure unfigurative action is that of the mind on the body. But as this is always with the deſign of producing ſome change on external bodies, we think only of them; the inſtrument or tool is overlooked, and we ſay that we act on the external body. Our *real* action therefore is but the firſt movement in a long train of ſucceſſive events, and is but the remote cauſe of the intereſting event. The reſemblance to ſuch actions is very ſtrong indeed in many caſes of mechanical phenomena. A man throws a ball by the motion of his arm. A ſpring impels a ball in the ſame manner by unbending. Theſe two events reſemble each other in every circumſtance but the action of the mind on the corporeal organ—the reſt of it is a train of pure mechaniſm. In general, becauſe the ultimate reſults of the mutual influence of bodies on each other greatly reſemble the ultimate reſults of our actions on bodies, we have not invented appropriated terms, but have contented ourſelves with thoſe already employed for expreſſing our own actions, the exertions of our own powers or forces. The relation of phyſical cauſe and effect is expreſſed metaphorically in the words which belong properly to the relation of agent and action. This has been attended by the uſual conſequences of poverty of language, namely, ambiguity, and ſometimes miſtake, both in our reflections (which are generally carried on by mental diſcourſe), our reaſonings, and our concluſions. It is neceſſary to be on our guard againſt ſuch miſtakes ; for they frequently amount to the confounding of things totally different. Many philoſophers of great reputation, on no better foundation than this metaphorical language, have confounded the relations of activity and of cauſation, and even denied that there is any difference ; and they have affirmed, that there is the ſame invariable relation between the determinations of the will and the inducements that prompt them, as there is between any phyſical power and its effect. Others have maintained, that the firſt mover in the mechanical operations, and indeed through the whole train of any complicated event, is a percipient and intending principle in the ſame manner as in our actions. According to theſe philoſophers, a particle of gravitating matter perceives its relation to every other particle in the univerſe, and determines its own motion according to fixed laws, in exact conformity to its ſituation. But the language, and even the actions of all men, ſhew that they have a notion of the relation of an agent to the action, eaſily diſtinguiſhable (becauſe all diſtinguiſh it) from the relation between the phyſical cauſe and its effect. The proofs of this fact have been adduced in other parts of the Encyclopædia Britannica, as, for example, in the article PHILOSOPHY, n° 42. and in this Supplement in the article ACTION.

Theſe remarks are not made in this place for any philological purpoſe, ſuch as the mere improvement of language ; but becauſe this metaphorical language has affected the doctrines of mechanical philoſophy, and has produced a diſpute about ſome of its firſt principles; and becauſe we find that the only way to decide this diſpute is to avoid, moſt ſcrupulouſly, all metaphorical language, though at the expence of much circumlocution.

6
Directions for the ſafe employment of this analogy.

When we ſpeak of powers or forces as reſiding in a body, and the effect as produced by their exertion, the body, conſidered as poſſeſſing the power, is ſaid to ACT on the other. A magnet is ſaid to act on a piece of iron ; a billiard ball in motion is ſaid to act on one that is hit by it : but if we attempt to fix our attention on this action, as diſtinct both from the agent and the thing acted on, we find no object of contemplation—the exertion or procedure of nature in producing the effect does not come under our view. When we *ſpeak* of the action as diſtinct from the agent, we find that it is not the action, properly ſpeaking, but the act, that we ſpeak of. In like manner, the action of a mechanical power can be conceived only in the effect produced.

7
Action implies change; and mere motion is not action.

A man is not ſaid to act unleſs he produces ſome effect. Thought is the act of the thinking principle ; motion of the limb is the act of the mind on it. In mechanics, alſo, there is action only in ſo far as there is mechanical effect produced. I muſt act violently in order

order to begin motion on a ſlide: I muſt exert force, and this force exerted produces motion. I conceive the production of motion, in all caſes, as the exertion of force; but it requires no exertion to continue the motion along the ſlide; I am conſcious of none, therefore I ought to infer that no force is neceſſary for the continuation of any motion. The continuation of motion is not the production of any new effect, but the permanency of an effect already produced. We indeed conſider motion as the effect of an action; but there would be no effect if the body were not moving. Motion is not the action, but the effect of the action.

8 *Preſſion, impulſion.*

Mechanical actions have been uſually claſſed under two heads: they are either PRESSURES or IMPULSIONS. They are generally conſidered as of different kinds; the exertions of different powers. PRESSURE is ſuppoſed to differ eſſentially from IMPULSE.

Inſtead of attempting to define, or deſcribe, theſe two kinds of forces and actions, we ſhall juſt mention ſome inſtances. This will give us all the knowledge of their diſtinctions that we can acquire.

Examples of preſſion.

When a ball lies on a table, and I preſs it gently on one ſide, it moves toward the other ſide of the table. If I follow it with my finger, continuing my preſſure, it accelerates continually in its motion. In like manner, when I preſs on the handle of a common kitchen jack, the fly *begins* to move. If I continue to urge or preſs round the handle, the fly accelerates continually, and may be brought into a ſtate of very rapid motion. Theſe motions are the effects of genuine preſſure. The ball would be urged along the table in the ſame manner, and with a motion continually accelerated, by the unbending of a ſpring. Alſo, a ſpring coiled up round the axis of the handle of the jack would, by uncoiling itſelf, urge round the fly with a motion accelerating in the ſame way. The more I reflect on the preſſure of my finger on the ball, and compare it with the effect of the ſpring on it, the more clearly do I ſee the perfect ſimilarity; and I call theſe influences, exertions, or actions, by one name, PRESSURE, taken from the moſt familiar inſtance of them.

Again, the very ſame motion may be produced in the ball or fly, by pulling the ball or the machine by means of a thread, to which a weight is ſuſpended. As both are motions accelerated in the ſame manner, I call the influence or action of the thread on the ball or machine by the ſame name PRESSURE, and WEIGHT is conſidered as a preſſing power. Indeed I feel the ſame compreſſion from the real preſſure of a man on my ſhoulders that I would feel from a load laid on them. But the weight in our example is acting by the intervention of the thread. By its preſſure, it is pulling at that part of the thread to which it is faſtened; this part is pulling at the next by means of the force of coheſion; and this pulls at a third, and ſo on, till the moſt remote pulls at the ball or the machine. Thus may elaſticity, weight, coheſion, and other forces, perform the office of a genuine power; and ſince their reſult is always a motion beginning from nothing, and accelerating by perceptible degrees to any velocity, this reſemblance makes us call them by one familiar name.

But farther, I ſee that if the thread be cut, the weight will fall with an accelerated motion, which I will increaſe to any degree, if the fall be great enough. I aſcribe this alſo to a preſſing power acting on the weight. Nay, after a very little refinement, I conſider this power as the cauſe of the body's weight; which word is but a diſtinguiſhing name for this particular inſtance of preſſing power. Gravitation is therefore added to the liſt of preſſures; and, for ſimilar reaſons, the attractions and repulſions of magnets or electric bodies may be added to the liſt; for they produce actual compreſſions of bodies placed between them, and they produce motions gradually accelerated, preciſely as gravitation does. Therefore all theſe powers may be diſtinguiſhed by this deſcriptive name *preſſures*, which, in ſtrict language, belongs to one of them only.

Gravity, attractions, and repulſions, are conſidered as preſſions

Several writers, however, ſubdivide this great claſs into preſſions and ſolicitations. Gravity is a ſolicitation *ab extra*, by which a body is urged downward. In like manner, the forces of magnetiſm and electricity, and a vaſt variety of other attractions and repulſions, are called *ſolicitations*. We ſee little uſe for this diſtinction, and the term is too like an affection of mind.

9 Examples of impulſion.

IMPULSION is exhibited when a ball in motion puts another ball into motion by hitting, or (to ſpeak metaphorically) by ſtriking it. The appearances here are very different. The body that is ſtruck acquires, in the inſtant of impulſe, a ſenſible quantity of motion, and ſometimes a very rapid motion. This motion is neither accelerated nor retarded after the ſtroke, unleſs it be affected by ſome other force. It is alſo remarked, that the rapidity of the motion depends, *inter alia*, on the previous velocity of the ſtriking body. For inſtance, if a clay ball, moving with any velocity, ſtrike another equal ball which is at reſt, the ſtruck ball moves with half the velocity of the other. And it is farther remarkable, that the ſtriking body always loſes as much motion as the ſtruck body gains. This univerſal and remarkable fact ſeems to have given riſe to a confuſed or indiſtinct notion of a ſort of transference of motion from one body to another. The phraſeology in general uſe on this ſubject expreſſes this in the moſt preciſe terms. The one ball is not ſaid to cauſe or produce motion in the other, but to *communicate* motion to it; and the whole phenomenon is called the *communication of motion*. We call this an *indiſtinct* notion; for ſurely no one will ſay that he has any clear conception of it. We can form the moſt diſtinct notion of the communication of heat, or of the cauſe of heat; of the communication of ſaltneſs, ſweetneſs, and a thouſand other *things*; but we cannot conceive how part of that identical motion which was formerly in A, is now infuſed into B, being given up by A. It is in our attempt to form this notion that we find that motion is not a *thing*, not a ſubſtance which can exiſt independently, and is ſuſceptible of actual transference. It appears in this caſe to be a ſtate, or condition, or mode of exiſtence, of which bodies are ſuſceptible, which is producible, or (to ſpeak without metaphor) cauſable, in bodies, and which is the effect and *characteriſtic* of *certain* natural qualities, properties, or powers. We are anxious to have our readers impreſſed with clear and preciſe notions on this ſubject, being confident that ſuch, and only ſuch, will carry them through ſome intricate paths of mechanical and philoſophical reſearch.

Communication of motion, not a good expreſſion.

10 *Inherent force* is the diſtinctive character of impulſion,

The remarkable circumſtance in this phenomenon is, that a rapid motion, which requires for the effecting it the action of a preſſing power, continued for a ſenſible, and frequently a long time, ſeems to be effected in an inſtant by impulſion. This has tended much to ſupport the notion of the actual transference of ſomething formerly

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formerly poſſeſſed excluſively by the ſtriking body, inhering in it, but ſeparable, and now transfuſed, into the body ſtriken. And now room is found for the employment of metaphor, both in thought and language. The *ſtriking* body affects the body which it thus impels: It therefore poſſeſſes the *power* of impulſion, that is, of *communicating* motion. It poſſeſſes it only while it is in motion. This *power*, therefore, is the efficient diſtinguiſhing cauſe of its motion, and its only office muſt be the continuation of this motion. It is therefore called the INHERENT FORCE, the force inherent in a moving body, VIS INSITA *corpori moto*. This force is transfuſed into the body impelled; and *therefore* the transference is inſtantaneous, and the impelled body continues its motion till it is changed by ſome other action. All this is at firſt ſight very plauſible; but a ſcrupulous attention to thoſe feelings which have given riſe to this metaphorical conception, ſhould have produced very different notions. I am conſcious of exertion in order to begin motion on a ſlide; but if the ice be very ſmooth, I am conſcious of no exertion in order to ſlide along. My power is felt only while I am conſcious of exerting it: Therefore I have no primitive feeling or notion of power while I am ſliding along. I am certain that no exertion of power is neceſſary here. Nay, I find that I cannot think of my moving forward without effort otherwiſe than as a certain mode of my exiſtence. Yet we imagine that the partiſans of this opinion did really deduce it in ſome ſhape from their feelings. We muſt continue the *exertion* of walking in order to walk on; our power of walking muſt be continually exerted, otherwiſe we ſhall ſtop. But this is a very imperfect, incomplete, and careleſs obſervation. Walking is much more than mere continuance in progreſſive motion. It is a continually repeated lifting our body up a ſmall height, and allowing it to come down again. This renewed aſcent requires repeated exertion.

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We have other obſervations of importance yet to make on this force of moving bodies, but this is not the moſt proper occaſion. Mean while we muſt remark, that the inſtantaneous production of rapid motion by impulſe has induced the firſt mechanicians of Europe to maintain, that the power or force of impulſe is unſuſceptible of any compariſon with a preſſing power. They have aſſerted, that impulſe is infinitely great when compared with preſſure; not recollecting that they held them to be things totally diſparate, that have no proportion more than weight and ſweetneſs. But theſe gentlemen are perpetually enticed away from their creed by the ſimilarity of the ultimate reſults of preſſure and impulſe. No perſon can find any difference between the motion of two balls moving equally ſwift, in the ſame direction, one of which is deſcending by gravity and the other has derived its motion from a blow. This ſtruggle of the mind to maintain its faith, and yet accommodate its doctrines to what we ſee, has occaſioned ſome other curious forms of expreſſion. Preſſure is conſidered as an *effort* to produce motion. When a ball lies on a table, its weight, which they call a *power*, continually and repeated *endeavours* (mark the metaphorical word and thought) to move the ball downward. But theſe efforts are ineffectual. They ſay that this ineffectual power is *dead*, and call it a VIS MORTUA; but the force of impulſion is called a VIS VIVA, a living force. But this is very whimſical and very inaccurate. If the impelling ball falls perpendicularly on the other lying on the table, it will produce no motion any more than gravity will; and if the table be annihilated, gravity becomes a *vis viva*.

Arguments indiſtinct and inconcluſive.

We muſt now add, that in order to prove that impulſe is infinitely greater than preſſure, theſe mechanicians turn our attention to many familiar facts which plead ſtrongly in their favour. A carpenter will drive a nail into a board with a very moderate blow of his hammer. This will require a preſſure which ſeems many hundred times greater than the impelling effort of the carpenter. A very moderate blow will ſhiver into pieces a diamond which would carry the weight of a mountain. Seeing this prodigious ſuperiority in the impulſe, how ſhall they account for the production of motion by means of preſſure? for this motion of the hammer might have been acquired by its falling from a height; nay, it is actually acquired by means of the continued preſſure of the carpenter's arm. They conſider it as the aggregate of an infinity of ſucceeding preſſures in *every* inſtant of its continuance; ſo that the inſignificant ſmallneſs of each effort is compenſated by their inconceivable number.

No difference between preſſion and impulſion.

On the whole, we do not think that there is clear evidence that there are two kinds of mechanical force eſſentially different in their nature. It is virtually given up by thoſe who ſay that impulſe is infinitely greater than preſſure. Nor is there any conſiderable advantage to be obtained by arranging the phenomenon under thoſe two heads. We may perhaps find ſome method of explaining ſatisfactorily the remarkable difference that is really obſerved in the two modes of producing motion; namely, the gradual production of motion by acknowledged preſſure, and the inſtantaneous production of it by impulſe. Indeed, we ſhould not have taken up ſo much of our reader's attention with this ſubject, had it not been for ſome inferences that have been made from theſe premiſes, which meet us in our very entry on the conſideration of firſt principles, and that are of extenſive influence on the whole ſcience of mechanical philoſophy, and, indeed, on the whole ſtudy of nature.

12
Is impulſion the ſole cauſe of motion?

Mechanicians are greatly divided in their opinion about the nature of the ſole moving force in Nature. Thoſe whom we are now ſpeaking of, ſeem to think that all motion is produced by preſſure: For when they conſider impulſe as equivalent to the aggregate of an infinity of repeated preſſures, they undoubtedly ſuppoſe any preſſure, however inſignificant, as a moving force. But there is a party, both numerous and reſpectable, who maintain that impulſion is the ſole cauſe of motion. We ſee bodies in motion, ſay they, and we ſee them impel others; and we ſee that this production of motion is regulated by ſuch laws, that there is but one abſolute quantity of motion in the univerſe which remains unalterably the ſame. It muſt therefore be transfuſed in the acts of colliſion. We alſo ſee, with clear evidence, in ſome caſes, that motion can produce preſſure. Euler adduces ſome very whimſical and complicated caſes, in which an action, preciſely ſimilar to preſſure, may be produced by motion. Thus, two balls connected by a thread, may be ſo ſtruck that they ſhall move forward, and at the ſame time wheel round. In this caſe the connecting thread will be ſtretched between them. Now, ſay the philoſophers, ſince we ſee motion, and ſee that preſſure may be produced by motion, it is prepoſterous to imagine that it is any thing elſe than

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a reſult of certain motions; and it is the buſineſs of a philoſopher to inquire and diſcover what motions produce the preſſures that we obſerve.

They then proceed to account for thoſe preſſing powers, or ſolicitations to motion, which we obſerve in the acceleration of falling bodies, the attractions of magnetiſm and electricity, and many other phenomena of this kind, where bodies are put in motion by the vicinity of other bodies, or (in the popular language) by the action of other bodies at a diſtance. To ſay that a magnet cannot act on a piece of remote iron, is to ſay that it can act *where* it is not; which is as abſurd as to ſay, that it can act *when* it is not. *Nihil movetur*, ſays Euler, *niſi a contiguo et moto*.

How does it produce preſſure?

The bulk of theſe philoſophers are not very anxious about the way in which theſe motions are produced, nor do they fall upon ſuch ingenious methods of producing preſſure as the one already mentioned, which was adduced by Euler. The piece of iron, ſay they, is put in motion when brought into the neighbourhood of a magnet, becauſe there is a ſtream of fluid iſſuing from one pole of the magnet, which circles round the magnet, and enters at the other pole: This ſtream impels the iron, and arranges it in certain determined poſitions, juſt as a ſtream of water would arrange the flote graſs. In the ſame manner, there is a ſtream of fluid continually moving towards the centre of the earth, which impels all bodies in lines perpendicular to the ſurface; and ſo on with regard to other like phenomena. Theſe motions are thus reduced to very ſimple caſes by impulſion.

Incompatible with the rules of philoſophiſing.

It is unneceſſary to refute this doctrine at preſent; it is enough that it is contrary to all the dictates of common ſenſe. To *ſuppoſe* an agent that we do not ſee, and for whoſe exiſtence we have not the ſmalleſt argument; with equal propriety we might ſuppoſe miniſtering ſpirits, or any thing that we pleaſe.

13
Others maintain that preſſure is the ſole moving force.

Other philoſophers are ſo diſſatisfied with this notion of the production of preſſure, that they, on the other hand, affirm that preſſure is the only moving force in nature; not according to the popular notion of preſſure, by the mutual contact of ſolid bodies, but that kind of preſſure which has been called *ſolicitation*; ſuch as the power of gravity. They affirm, that there is no ſuch thing as contact on inſtantaneous communication of motion by real colliſion. They ſay (and they prove it by very convincing facts (ſee Optics, n° 63—68. *Encycl.*), that the particles of ſolid bodies exert very ſtrong repulſions to a ſmall diſtance; and therefore, when they are brought by motion ſufficiently near to another body, they repel it, and are equally repelled by it. Thus is motion produced in the other body, and their own motion is diminiſhed. And they then ſhew, by a ſcrupulous conſideration of the ſtate of the bodies while the one is advancing and the other retiring, in what manner the two bodies attain a common velocity, ſo that the quantity of motion before colliſion remains unchanged, the one body gaining as much as the other loſes. They alſo ſhew caſes of ſuch mutual action between bodies, where it is evident that they have never come into contact; and yet the reſult has been preciſely ſimilar to thoſe caſes where the motion appeared to be changed in an inſtant. Therefore they conclude, that there is no ſuch thing as inſtantaneous *communication*, or transfuſion of motion, by contact in colliſion or impulſe. The reaſon why previous motion of the impelling body is neceſſary, is not that it may have a *vis inſita corpori moto*, a force inherent in it *by its being in motion*, but that it may continue to follow the impelled and retiring body, and exert on it a force inherent in itſelf, whether in motion or at reſt.—According to theſe philoſophers, therefore, all moving forces are of that kind which has been named *ſolicitation*; ſuch as gravity. We ſhall know it afterwards by the more familiar and deſcriptive name of Accelerating or Retarding force.

14
Action, Reſiſtance, Reaction.

The exertions of mechanical forces are differently termed, according to the reference that we make to the reſult. If, in boxing or wreſtling, I ſtrike, or endeavour to throw my antagoniſt, I am ſaid to act; but if I only parry his blows, or prevent him from throwing me, I am ſaid to resist. This diſtinction is applied to the exertions of mechanical powers. When one body A changes the motion of another B, we may conſider the change in the motion of B either as the indication and meaſure of A's power of producing motion, or as the indication and meaſure of A's reſiſtance to the being brought to reſt, or having its motion any how changed. The diſtinction is not in the thing itſelf, but only in the reference that we are diſpoſed, by other conſiderations, to make of its effect. They may be diſtinguiſhed in the following manner: If a change of motion follow when one of the powers ceaſes to be exerted, that power is conceived as having reſiſted. The whole language on this ſubject is metaphorical. Reſiſtance, effort, endeavour, &c. are words which cannot be employed in mechanical diſcuſſions without figure, becauſe they all expreſs notions which relate to ſentient beings; and the unguarded indulgence of this figurative language has ſo much affected the imagination of philoſophers, that many have almoſt animated all matter. Perhaps the word Reaction, introduced (we think) by Newton, is the beſt term for expreſſing that mutual force which is perceived in all the operations of nature that we have inveſtigated with ſucceſs. As the magnet attracts iron, and in ſo doing is ſaid to *act* on it; ſo the iron attracts the magnet, and may be ſaid to *react* on it.

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We need not ſuppoſe action at a diſtance.
Tendency.

With reſpect to the difficulty that has been objected to the opinion of thoſe who maintain that all the mechanical phenomena are produced by the agency of attracting or repelling forces; namely, that this ſuppoſes the bodies to act on each other at a diſtance, however ſmall thoſe diſtances may be, which is thought to be abſurd, we may obſerve, that we may aſcribe the mutual approaches or receſſes to tendencies to or from each other. What we call *the attraction of the magnet* may be conſidered as a tendency of the iron to the magnet, ſomewhat ſimilar to the gravitation of a ſtone toward the earth. We ſurely (at leaſt the unlearned) can and do conceive the iron to be affected by the magnet, *without thinking* of any intermedium. The thing is not therefore inconceivable; which is all that we know about abſurdity: and we do not know any thing about the nature or eſſence of matter which renders this tendency to the magnet impoſſible. That we do not ſee intuitively any reaſon why the iron ſhould approach the magnet, muſt be granted; but this is not enough to entitle us to ſay, that ſuch a thing is impoſſible or inconſiſtent with the nature of matter. It appears, therefore, to be very haſty and unwarrantable, to ſuppoſe the impulſe of an inviſible fluid, of which we know nothing, and of the exiſtence of which we have no proof. Nay, if it be true that bodies do not come into contact, even when one ball hits another, and drives it before it, this inviſible fluid will not ſolve the difficulty; becauſe the ſame difficulty occurs in the action of any particle of the fluid on the body. We are obliged to ſay, that the production of motion without any *obſerved* contact, is a much more familiar phenomenon than the production of motion by impulſion. More motion has been produced in this way by the gravitation of a ſmall ſtream of water, running ever ſince the creation, than by all the impulſes in the world twice told. We do not mean by this to ſay, that the giving to this obſerved mutual relation between iron and a loadſtone the name tendency makes it leſs abſurd, than when we ſay that the loadſtone attracts the iron; it only makes it more conceivable: It ſuggeſts a very familiar analogy; but both are equally figurative expreſſions; at leaſt as the word tendency is uſed at preſent. In the language of ancient Rome, there was no metaphor when Virgil's hero ſaid, *Tendimus in Latium. Tendere verſus ſolem* means, in plain Latin, to *approach the ſun*. The ſafe way of conceiving the whole is to ſay, that the condition of the iron depends on the vicinity of the magnet.

16 *Attraction, Repulſion,* are figurative terms

When the exertions of a mechanical power are obſerved to be always directed toward a body, that body is ſaid to attract; but when the other body always moves off from it, it is ſaid to repel. Theſe alſo are metaphorical expreſſions. I attract a boat when I pull it toward me by a rope; this is purely ATTRACTION: and it is pure, unfigurative REPULSION, when I puſh any body from me. The ſame words are applied to the mechanical phenomena, merely becauſe they reſemble the reſults of real attraction or repulſion. We muſt be much on our guard to avoid metaphor in our conceptions, and never allow thoſe words to ſuggeſt to our mind any opinion about the *manner* in which the mechanical forces produce their effects. It is plain, that if the opinion of thoſe who maintain the exiſtence and action of the above-mentioned inviſible fluid be juſt, there is nothing like attraction or repulſion in the univerſe. We muſt always recur to the ſimple phenomenon, the motion to or from the attracting or repelling body; for this is all we ſee, and generally all that we know.

17 Forces are conceived as meaſurable quantities.

We conceive one man to have twice the ſtrength of another man, when we ſee that he can withſtand the united effort of two others. Thus animal force is conceived as a quantity, made up of, and meaſured by, its own parts. But we doubt exceedingly whether this be an accurate conception. We have not a diſtinct notion of one ſtrain added to another; though we have of their being joined or combined. We want words to expreſs the difference of theſe two notions in our own minds; but we imagine that others perceive the ſame difference. We conceive clearly the addition of two lines or of two minutes; we can conceive them apart, and perceive their boundaries, common to both, where one ends and the other begins. We cannot conceive thus of two forces combined; yet we cannot ſay, that two equal forces are *not* double of one of them. We meaſure them by the effects which they are known to produce. Yet there are not wanting many caſes where the action of two men, equally ſtrong, does not produce a double motion.

How meaſured.

In like manner, we conceive all mechanical forces as meaſurable by their effects; and thus they are made the ſubjects of mathematical diſcuſſion. We talk of the proportions of gravity, magnetiſm, electricity, &c.; nay, we talk of the proportion of gravity to magnetiſm:—Yet theſe, conſidered in themſelves, are diſparate, and do not admit of any proportion; but they produce effects, ſome of which are meaſurable, and whoſe aſſumed meaſures are ſuſceptible of compariſon, being quantities of the ſame kind. Thus, one of the effects of gravity is the acceleration of motion in a falling body: magnetiſm will alſo accelerate the motion of a piece of iron; theſe two accelerations are comparable. But we cannot compare magnetiſm with heat; becauſe we do not know any meaſurable effects of magnetiſm that are of the ſame kind with any effects of heat.

By their effects.

When we ſay, that the gravitation of the moon is the 3600th part of the gravitation at the ſea-ſhore, we mean that the fall of a ſtone in a ſecond is 3600 times greater than the fall of the moon in the ſame time. But we alſo mean (and this expreſſes the proportion of the *tendency* of gravitation more purely), that if a ſtone, when hung on a ſpring ſteelyard, draw out the rod of the ſteelyard to the mark 3600, the ſame ſtone, taken up to the diſtance of the moon, will draw it out no further than the mark 1. We alſo mean, that if the ſtone at the ſea-ſhore draw out the rod to any mark, it will require 3600 ſuch ſtones to draw it out to that mark, when the trial is made at the diſtance of the moon. It is not, therefore, in conſequence of any immediate perception of the proportion of the gravitation at the moon to that at the ſurface of the earth that we make ſuch an aſſertion; but theſe motions, which we conſider as its effects in theſe ſituations, being magnitudes of the ſame kind, are ſuſceptible of compariſon, and have a proportion which can be aſcertained by obſervation. It is theſe proportions that we contemplate; although we ſpeak of the proportions of the unſeen cauſes, the forces, or endeavours to deſcend. It will be of material ſervice to the reader to peruſe the judicious and acute diſſertation on *quantity* in the 45th volume of the Philoſophical Tranſactions; or he may ſtudy the article QUANTITY in the *Encyclopædia*, where, we truſt, he will ſee clearly how force, velocity, denſity, and many other magnitudes of very frequent occurrence in mechanical philoſophy, may be made the ſubjects of mathematical diſcuſſion, by means of ſome of thoſe proper quantities, meaſurable by their own parts, which are to be aſſumed as their meaſures. Preſſures are meaſurable only by preſſures. When we conſider them as moving powers, we ſhould be able to meaſure them by *any* moving powers, otherwiſe we cannot compare them; therefore it is not as preſſures that we then meaſure them. This obſervation is momentous.

One circumſtance muſt be carefully attended to. That thoſe aſſumed meaſures may be accurate, they muſt be invariably connected with the magnitudes which they are employed to meaſure, and ſo connected, that the degrees of the one muſt change in the ſame manner with the degrees of the other. This is evident, and is granted by all. But we muſt alſo *know* this of the meaſure we employ; we muſt ſee this conſtant and preciſe relation. How can we know this? We do not perceive force as a ſeparate exiſtence, ſo as to ſee its proportions, and to ſee that theſe are the ſame with the proportions of the meaſures, in the ſame manner that Euclid ſees the proportions of triangles and thoſe of their

their baſes, and that theſe proportions are the ſame, when the triangles are of equal altitudes. How do we diſcover that to every magnitude which we call *force* is invariably attached a correſponding magnitude of acceleration or deflection?—Clearly. In fact, the very exiſtence of the force is an inference that we make from the obſerved acceleration; and the degree of the force is, in like manner, an inference from the obſerved magnitude of the acceleration. Our meaſures are therefore neceſſarily connected with the magnitudes which they meaſure, and their proportions are the ſame; becauſe the one is always an inference from the other, both in ſpecies and in degree.

18 Dynamics is a demonſtrative ſcience.

It is now evident, that theſe diſquiſitions are ſuſceptible of mathematical accuracy. Having ſelected our meaſures, and obſerved certain mathematical relations of thoſe meaſures, every inference that we can draw from the mathematical relations of the proportions of thoſe repreſentations is true of the proportions of the motions; and therefore of the proportions of the forces. And thus dynamics becomes a demonſtrative ſcience, one of the *diſciplinæ accuratæ*.

19. But moving forces are conſidered as differing alſo in kind; that is, in direction. We aſſign to the force the direction of the obſerved change of motion; which is not only the indication, but alſo the characteriſtic, of the changing force. We call it an *accelerating*, *retarding*, *deflecting*, *force*, according as we obſerve the motion to be accelerated, retarded, or deflected.

Theſe denominations ſhew us inconteſtably that we have no knowledge of the forces different from our knowledge of the effects. The denominations are all either deſcriptive of the effects, as when we call them accelerating, penetrating, protruſive, attractive, or repulſive forces; or they are names of reference to the ſubſtances in which the accelerating, protruſive, &c. forces, are ſuppoſed to be inherent, as when we call them *magnetiſm*, *electricity*, *corpuſcular*, &c.

20 Forces are diſcovered by their oppoſition to other forces.

When I ſtruggle with another, and feel, that in order to prevent being thrown, I muſt exert force, I learn that my antagoniſt is exerting force. This notion is transferred to matter; and when a moving power which is *known* to operate, produces no motion, we conceive it to be oppoſed by another equal force; the exiſtence, agency, and intenſity of which is detected and meaſured by theſe means. The quieſcent ſtate of the body is conſidered as a change on the ſtate of things that would have been exhibited in conſequence of the known action of one power, had this other power not acted; and this change is conſidered as the indication, characteriſtic, and meaſure of another power, detected in this way. Thus forces are recogniſed not only by the changes of motion which they produce, but alſo by the changes of motion which they prevent. The coheſion of matter in a ſtring is inferred not only by its giving motion to a ball which I pull toward me by its intervention, but alſo by its ſuſpending that ball, and hindering it from falling. I know that gravity is acting on the ball, which, however, does not fall. The ſolidity of a board is equally inferred from its ſtopping the ball which ſtrikes it, and from the motion of the ball which it drives before it. In this way we learn that the particles of tangible matter cohere by means of moving forces, and that they reſiſt compreſſion with force; and in making this inference, we find that this corpuſcular force exerted between the particles is mutual, oppoſite, and equal: for we muſt apply force equally to *a* or to *b*, in order to produce a ſeparation or a compreſſion. We learn their equality, by obſerving that no motion enſues while theſe mutual forces are known to act on the particles; that is, each is oppoſed by another force, which is neither inferior nor ſuperior to it.

First Law of Motion.

Of the Laws of Motion.

Such, then, being our notions of mechanical forces, the cauſes of the ſenſible changes of motion, there will reſult certain conſequences from them, which may be called axioms or laws of motion. Some of theſe may be intuitive, offering themſelves to the mind as ſoon as the notions which they involve are preſented to it. Others may be as neceſſary reſults from the relations of theſe notions, but may not readily offer themſelves without the mediation of axioms of the firſt claſs. We ſhall ſelect thoſe which are intuitive, and may be taken for the firſt principles of all diſcuſſions in mechanical philoſophy.

First Law of Motion.

Every body continues in a ſtate of reſt, or of uniform rectilineal motion, unleſs affected by ſome mechanical force.

21. This is a propoſition, on the truth of which the whole ſcience of mechanical philoſophy ultimately depends. It is therefore to be eſtabliſhed on the firmeſt foundation; and a ſolicitude on this head is the more juſtifiable, becauſe the opinions of philoſophers have been, and ſtill are, extremely different, both with reſpect to the truth of this law, and with reſpect to the foundation on which it is built. Theſe opinions are, in general, very obſcure and unſatisfactory; and, as is natural, they influence the diſcuſſions of thoſe by whom they are held through the whole ſcience. Although of contradictory opinions one only can be juſt, and it may appear ſufficient that this one be eſtabliſhed and uniformly applied; yet a ſhort expoſition, at leaſt, of the reſt is neceſſary, that the greateſt part of the writings of the philoſophers may be intelligible, and that we may avail ourſelves of much valuable information contained in them, by being able to perceive the truth in the midſt of their imperfect or erroneous conceptions of it.

22 Does continued motion indicate continued action?

It is not only the popular opinion that reſt is the natural ſtate of body, and that motion is ſomething foreign to it, but it has been ſeriouſly maintained by the greateſt part of thoſe who are eſteemed philoſophers. They readily grant that matter will continue at reſt, unleſs ſome moving force act upon it. Nothing ſeems neceſſary for matter's remaining where it is, but its continuing to exiſt. But it is far otherwiſe, ſay they, with reſpect to matter in motion. Here the body is continually changing its relations to other things; therefore the continual agency of a changing cauſe is neceſſary (by the fundamental principle of all philoſophical diſcuſſion), for there is here the continual production of an effect. They ſay that this metaphyſical argument receives complete confirmation (if confirmation of an intuitive truth be neceſſary) from the moſt familiar obſervation. We ſee that all motions, however violent, terminate in reſt, and that the continual exertion of ſome force is neceſſary for their continuance.

23 Whimſical notion of elemental minds.

Theſe philoſophers therefore aſſert, that the continual action of the moving cauſe is *eſſentially* neceſſary

for

for the continuance of the motion: but they differ among themſelves in their notions and opinions about this cauſe. Some maintain, that all the motions in the univerſe are produced and continued by the immediate agency of Deity; others affirm, that in every particle of matter there is inherent a ſort of mind, the φυσις and ὑπερψυχη of Ariſtole, which they call an ELEMENTAL MIND, which is the cauſe of *all* its motions and changes. An overweaning reverence for Greek learning has had a great influence in reviving this doctrine of Ariſtotle. The Greek and Roman languages are affirmed to be more accurate expreſſions of human thought than the modern languages are. In thoſe ancient languages, the verbs which expreſs motion are employed both in the active and paſſive voice; whereas we have only the active verb *to move*, for expreſſing both the ſtate of motion and the act of putting in motion. "The ſtone *moves* down the ſlope, and *moves* all the pebbles which lie in its way;" but in the ancient languages the mere ſtate of motion is always expreſſed by the paſſive or middle voice. The accurate conception of the ſpeakers is therefore extolled. The ſtate of motion is expreſſed as it ought to be, as the reſult of a continual action." Κινειται, *movetur*, is equivalent to "it is moved." According to theſe philoſophers, every thing which *moves* is mind, and every thing that *is moved* is body.

The argument is futile, and it is falſe; for the modern languages are, in general, equally accurate in this inſtance: "*ſe mouvoir*," in French; "*ſich bewegen*," in German; "*dvigatſu*," in Sclavonic; are all paſſive or reflected. And the ancients ſaid, that "rain falls, water runs, ſmoke riſes," juſt as we do. The ingenious author of *Ancient Metaphyſics* has taken much pains to gives us, at length, the procedures of thoſe elementary minds in producing the oſtenſible phenomena of local motion; but it ſeems to be merely an abuſe of language, and a very frivolous abuſe. This elemental mind is known and characteriſed only by the effect which we aſcribe to its action; that is, by the motions or changes of motions. Uniform and unexcepted experience ſhews us that theſe are regulated by laws as preciſe as thoſe of mathematical truth. We conſider nothing as more fixed and determined than the common laws of mechaniſm. There is nothing here that indicates any thing like ſpontaneity, intention, purpoſe; none of thoſe marks by which mind was firſt brought into view: but they are very like the effects which we produce by the exertions of our corporeal forces; and we have accordingly given the name *force* to the cauſes of motion. It is ſurely much more appoſite than the name mind, and conveys with much more readineſs and perſpicuity the very notions that we wiſh to convey.

24
Action not eceſſary or the ontinunce of notion.

We now wiſh to know what reaſon we have to think that the continual action of ſome cauſe is neceſſary for continuing matter in motion, or for thinking that reſt is its natural ſtate. If we pretend to draw any argument from the nature of matter, that matter muſt be known, as far as is neceſſary for being the foundation of argument. Its very exiſtence is known only from obſervation; all our knowledge of it muſt therefore be derived from the ſame ſource.

If we take this way to come at the origin of this opinion, we ſhall find that experience gives us no authority for ſaying that reſt is the natural condition of matter. We cannot ſay that we have ever ſeen a body at reſt; this is evident to every perſon who allows the validity of the Newtonian philoſophy, and the truth of the Copernican ſyſtem of the ſun and planets; all the parts of this ſyſtem are in motion. Nay, it appears from many obſervations, that the ſun, with his attending planets, is carried in a certain direction, with a velocity which is very great. We have no unqueſtionable authority for ſaying that any one of the ſtars is abſolutely fixed: but we are *certain* that many of them are in motion. Reſt is therefore ſo rare a condition of body, that we cannot ſay, from any experience, that it is its natural ſtate.

25.

It is eaſy, however, to ſee, that it is from obſervation that this opinion has been derived; but the obſervation has been limited and careleſs. Our experiments in this ſublunary world do indeed always require continued action of ſome moving force to continue the motion; and if this be not employed, we ſee the motions ſlacken every minute, and terminate in reſt after no long period. Our firſt notions of ſublunary bodies are indicated by their operation in caſes where we have ſome intereſt. Perpetually ſeeing our own exertions neceſſary, we are led to conſider matter as ſomething not only naturally quieſcent and inert, but ſluggiſh, averſe from motion, and prone to reſt (we muſt be pardoned this metaphorical language, becauſe we can find no other term). What is expreſſed by it, on this occaſion, is preciſely one of the erroneous or inadequate conceptions that are ſuggeſted to our thoughts by reaſon of the poverty of language. We animate matter in order to give it motion, and then we endow it with a ſort of moral character in order to explain the appearance of thoſe motions.

26.

But more extended obſervation has made men gradually deſert their firſt opinions, and at laſt allow that matter has no peculiar aptitude to reſt. All the retardations that we *obſerve* have been diſcovered, one after another, to have a diſtinct reference to ſome external circumſtances. The diminution of motion is always obſerved to be accompanied by the removal of obſtacles, as when a ball moves through ſand, or water, or air; or it is owing to oppoſite motions which are deſtroyed; or it is owing to roughneſs of the path, or to friction, &c. We find that the more we can keep thoſe things out of the way, the leſs are the motions diminiſhed. A pendulum will vibrate but a ſhort while in water; much longer in air; and in the exhauſted receiver, it will vibrate a whole day. We know that we cannot remove *all* obſtacles; but we are led by ſuch obſervations to conclude that, if they *could be completely removed*, our motions would continue for ever. And this concluſion is almoſt demonſtrated by the motions of the heavenly bodies, to which we know of no obſtacles, and which we really obſerve to retain their motions for many thouſand years without the ſmalleſt ſenſible diminution.

27
Inactivity of matter denied by Leibnitz.

Another ſet of philoſophers maintain an opinion directly oppoſite to that of the inactivity of matter, and aſſert, that it is eſſentially active, and continually changing its ſtate. Faint traces of this are to be found in the writings of Plato, Ariſtotle, and their commentators. Mr Leibnitz is the perſon who has treated this queſtion moſt ſyſtematically and fully. He ſuppoſes every particle of matter to have a principle of individuality, which he therefore calls a MONAD. This mo-

Monads, what.

nad has a ſort of *perception* of its ſituation in the univerſe, and of its relation to every other part of this univerſe. Laſtly, he ſays that the monad acts on the material particle, much in the ſame way that the ſoul of man acts on his body. It modifies the motion of the material atom (in conformity, however, to unalterable laws), producing all thoſe modifications of motion that we obſerve. Matter therefore, or at leaſt particles of matter, are continually active, and continually changing their ſituation.

This opinion ill founded.

It is quite unneceſſary to enter on a formal confutation of Mr Leibnitz's ſyſtem of monads, which differs very little from the ſyſtem of elemental minds, and is equally whimſical and frivolous; becauſe it only makes the unlearned reader ſtare, without giving him any information. Should it even be granted, it would not, any more than the action of animals, invalidate the general propoſition which we are endeavouring to eſtabliſh as the fundamental law of motion. Thoſe powers of the monads, or of the elemental minds, are the cauſes of all the changes of motion; but the mere material particle is ſubject to the law, and requires the exertion of the monad in order to exhibit a change of motion.

28
Some philoſophers deduce this law of motion from the want of a *determining* cauſe.

A third ſect of philoſophers, at the head of which we may place Sir Iſaac Newton, maintain the doctrine enounced in the propoſition. But they differ much in reſpect of the foundation on which it is built.

Some aſſert that its truth flows from the nature of the thing. If a body be at reſt, and you aſſert that it will not remain at reſt, it muſt move in ſome one direction. If it be in motion in any direction, and with any velocity, and do not continue its equable, rectilineal, motion, it muſt either be accelerated or retarded; it muſt turn either to one ſide, or to ſome other ſide. The event, whatever it be, is individual and determinate; but no cauſe which can determine it is ſuppoſed: therefore the determination cannot take place, and no change will happen in the condition of the body with reſpect to motion. It will continue at reſt, or perſevere in its rectilineal and equable motion.

But conſiderable objections may be made to this argument, of *ſufficient reaſon*, as it is called. In the immenſity and perfect uniformity of ſpace and time, there is no determining cauſe why the viſible univerſe ſhould exiſt in the place in which we ſee it rather than in another, or at this time rather than at another. Nay, the argument ſeems to beg the queſtion. A cauſe of determination is required as eſſentially neceſſary—a determination may be without a cauſe, as well as a motion without a cauſe.

29
Others deduce it from experience.

Other philoſophers, who maintain this doctrine, conſider it merely as an experimental truth; and proofs of its univerſality are innumerable.

When a ſtone is thrown from the hand, we preſs it forward while in the hand, and let it go when the hand has acquired the greateſt rapidity of motion that we can give it. The ſtone continues in that ſtate of motion which it acquired gradually along with the hand. We can throw a ſtone much farther by means of a ſling; becauſe, by a very moderate motion of the hand, we can whirl the ſtone round till it acquire a very great velocity, and then we let go one of the ſtrings, and the ſtone eſcapes, *by continuing* its rapid motion. We ſee it ſtill more diſtinctly in ſhooting an arrow from a bow. The ſtring preſſes hard on the notch of the arrow, and it yields to this preſſure and goes forward. The ſtring alone would go faſter forward. It therefore *continues* to preſs the arrow forward, and accelerates its motion. This goes on till the bow is as much unbent as the ſtring will allow. But the ſtring is now a ſtraight line. It came into this poſition with an accelerated motion, and it therefore goes a little beyond this poſition, but with a retarded motion, being checked by the bow. But there is nothing to check the arrow; therefore the arrow quits the ſtring, and flies away.

Theſe are ſimple caſes of perſeverance in a ſtate of motion, where the procedure of nature is ſo eaſily traced that we perceive it almoſt intuitively. It is no leſs clear in other phenomena which are more complicated; but it requires a little reflection to trace the proceſs. We have often ſeen an equeſtrian ſhowman ride a horſe at a gallop, ſtanding on the ſaddle, and ſtepping from it to the back of another horſe that gallops alongſide at the ſame rate; and he does this ſeemingly with as much eaſe as if the horſes were ſtanding ſtill. The man has the ſame velocity with the horſe that gallops under him, and keeps this velocity while he ſteps to the back of the other. If that other were ſtanding ſtill, the man would fly over his head. And if a man ſhould ſtep from the back of a horſe that is ſtanding ſtill to the back of another that gallops paſt him, he would be left behind. In the ſame manner, a ſlack wire-dancer toſſes oranges from hand to hand while the wire is in full ſwing. The orange, ſwinging along with the hand, retains the velocity; and when in the air follows the hand, and falls into it when it is in the oppoſite extremity of its ſwing. A ball, dropped from the maſt-head of a ſhip that is ſailing briſkly forward, falls at the foot of the maſt. It retains the motion which it had while in the hand of the perſon who dropped it, and follows the maſt during the whole of its fall.

We alſo have familiar inſtances of the perſeverance of a body in a ſtate of reſt. When a veſſel filled with water is drawn ſuddenly along the floor, the water daſhes over the poſterior ſide of the veſſel. It is left behind. In the ſame manner, when a coach or boat is dragged forward, the perſons in it find themſelves ſtrike againſt the hinder part of the carriage or boat. Properly ſpeaking, it is the carriage that ſtrikes on them. In like manner, if we lay a card on the tip of the finger, and a piece of money on the card, we may nick away the card, by hitting it neatly on its edge; but the piece of money will be left behind, lying on the tip of the finger. A ball will go through a wall and fly onward; but the wall is left behind. Buildings are thrown down by earthquakes; ſometimes by being toſſed from their foundations, but more generally by the ground on which they ſtand being haſtily drawn ſidewiſe from under them, &c.

30
Common experience inſufficient.

But common experience ſeems inſufficient for eſtabliſhing this fundamental propoſition of mechanical philoſophy. We muſt, on the faith of the Copernican ſyſtem, grant that we never ſaw a body at reſt, or in uniform rectilineal motion; yet this ſeems abſolutely neceſſary before we can ſay that we have eſtabliſhed this propoſition experimentally.

What we imagine, in our experiments, to be putting a body, formerly at reſt, into motion, is, in fact, only changing a moſt rapid motion, not leſs, and probably much greater, than 90,000 feet per ſecond. Suppoſe a cannon pointed eaſt, and the bullet diſcharged at noon

day

day with 60 times greater velocity than we have ever been able to give it. It would appear to ſet out with this unmeaſurable velocity to the eaſtward; to be gradually retarded by the reſiſtance of the air, and at laſt brought to reſt by hitting the ground. But, by reaſon of the earth's motion round the ſun, the fact is quite the reverſe. Immediately before the diſcharge, the ball was moving to the weſtward with the velocity of 90,000 feet per ſecond nearly. By the exploſion of the powder, and its preſſure on the ball, ſome of this motion is deſtroyed, and at the muzzle of the gun, the ball is moving ſlower, and the cannon is hurried away from it to the weſtward. The air, which is alſo moving to the weſtward 90,000 feet in a ſecond, gradually communicates motion to the ball, in the ſame manner as a hurricane would do. At laſt (the ball dropping all the while) ſome part of the ground hits the ball, and carries it along with it.

Other obſervations muſt therefore be reſorted to, in order to obtain an experimental proof of this propoſition. And ſuch are to be found. Although we cannot meaſure the abſolute motions of bodies, we can obſerve and meaſure accurately their relative motions, which are the differences of their abſolute motions. Now, if we can ſhew experimentally, that bodies ſhew equal tendencies to reſiſt the augmentation and the diminution of their relative motions, they, *ipſo facto*, ſhew equal tendencies to reſiſt the augmentation or diminution of their abſolute motions. Therefore let two bodies, A and B, be put into ſuch a ſituation, that they cannot (by reaſon of their impenetrability, or the actions of their mutual powers) perſevere in their relative motions. The change produced on A is the effect and the meaſure of B's tendency to perſevere in its former ſtate; and therefore the proportion of theſe changes will ſhew the proportion of their tendencies to maintain their former ſtates. Therefore let the following experiment be made at noon.

Experiments proper for the purpoſe.

Let A, apparently moving weſtward three feet per ſecond, hit the equal body B apparently at reſt. Suppoſe, *1ſt*, That A impels B forward, without any diminution of its own velocity. This reſult would ſhew that B manifeſts no tendency to maintain its motion unchanged, but that A retains its motion undiminiſhed.

2dly, Suppoſe that A ſtops, and that B remains at reſt. This would ſhew that A does not reſiſt a diminution of motion, but that B retains its motion unaugmented.

3dly, Suppoſe that both move weſtward with the velocity of one foot per ſecond. The change on A is a diminution of velocity, amounting to two feet per ſecond. This is the effect and the meaſure of B's tendency to maintain its velocity unaugmented. The change on B is an augmentation of one foot per ſecond made on its velocity; and this is the meaſure of A's tendency to maintain its velocity undiminiſhed. This tendency is but half of the former; and this reſult would ſhew, that the reſiſtance to a diminution of velocity is but half of the reſiſtance to augmentation. It is perhaps but one quarter; for the change on B has produced a double change on A.

4thly, Suppoſe that both move weſtward at the rate of 1½ feet per ſecond. It is evident that their tendencies to maintain their ſtates unchanged are now equal.

5thly, Suppoſe A = 2 B, and that both move, after the colliſion, two feet per ſecond, B has received an addition of two feet per ſecond to its former velocity. This is the effect and the meaſure of A's whole tendency to retain its motion undiminiſhed. Half of this change on B meaſures the perſevering tendency of the half of A; but A, which formerly moved with the apparent or relative velocity three, now moves (by the ſuppoſition) with the velocity two, having loſt a velocity of one foot per ſecond. Each half of A therefore has loſt this velocity, and the whole loſs of motion is two. Now this is the meaſure of B's tendency to maintain its former ſtate unaugmented; and this is the ſame with the meaſure of A's tendency to maintain its own former ſtate undiminiſhed. The concluſion from ſuch a reſult would therefore be, that bodies have equal tendencies to maintain their former ſtates of motion without augmentation and without diminution.

What is ſuppoſed in the *4th* and *5th* caſes is really the reſult of all the experiments which have been tried; and this law regulates all the changes of motion which are produced by the mutual actions of bodies in impulſions. This aſſertion is true without exception or qualification. Therefore it appears that bodies have no preferable tendency to reſt, and that no fact can be adduced which ſhould make us ſuppoſe that a motion once begun ſhould ſuffer any diminution without the action of a changing cauſe.

But experience is not the proper foundation of an axiom.

But we muſt now obſerve, that this way of eſtabliſhing the firſt law of motion is very imperfect, and altogether unfit for rendering it the fundamental principle of a whole and extenſive ſcience. It is ſubject to all the inaccuracy that is to be found in our beſt experiments; and it cannot be applied to caſes where ſcrupulous accuracy is wanted, and where no experiment can be made.

Let us therefore examine the propoſition by means of the general principles adopted in the article PHILOSOPHY, *Encycl.* which contain the foundation of all our knowledge of active nature. Theſe principles will, we imagine, give a deciſion of this queſtion that is ſpeedy and accurate, ſhewing the propoſition to be an axiom or intuitive conſequence of the relations of thoſe ideas which we have of motion, and of the cauſes of its production and changes.

31
Logical proof.

It has been fully demonſtrated that the powers or forces, of which we ſpeak ſo much, are never the immediate objects of our perception. Their very exiſtence, their kind, and their degree, are inſtinctive inferences from the motions which we obſerve and claſs. It evidently follows from this experimental and univerſal truth, *1ſt*, That where no change of motion is obſerved, no ſuch inference is made; that is, no power is *ſuppoſed* to act. But whenever any change of motion is obſerved, the inference is made; that is, a power or force is ſuppoſed to have acted.

In the ſame form of logical concluſion, we muſt ſay that, *2dly*, When no change of motion is *ſuppoſed* or thought of, no force is *ſuppoſed*; and that whenever we *ſuppoſe* a change of motion, we, in fact, though not in terms, ſuppoſe a changing force. And, on the other hand, whenever we ſuppoſe the action of a changing force, we ſuppoſe the change of motion; for the action of this force, and the change of motion, is one and the ſame thing. We cannot think of the action without thinking of the indication of that action; that is, the change of motioo.—In the ſame manner, when we do not think of a changing force, or ſuppoſe that there is no action of a changing force, we, in fact, though not in terms, ſuppoſe that there is no indication of this changing force; that is, that there is no change.

It is a law of human thought,

Whenever, therefore, we ſuppoſe that no mechanical force is acting on a body, we, in fact, ſuppoſe that the body continues in its former condition with reſpect to motion. If we ſuppoſe that nothing accelerates, or retards, or deflects the motion, we ſuppoſe that it is not accelerated, nor retarded, nor deflected. Hence follows the propoſition in expreſs terms—*We ſuppoſe that the body continues in its former ſtate of reſt or motion, unleſs we ſuppoſe that it is changed by ſome mechanical force.*

Thus it appears, that this propoſition is not a matter of experience or contingency, depending on the properties which it has pleaſed the Author of Nature to beſtow on body: it is, to us, a neceſſary truth. The propoſition does not ſo much expreſs any thing with regard to body, as it does the operations of our mind when contemplating body. It may perhaps be eſſential to body to move in ſome particular direction. It may be eſſential to body to ſtop as ſoon as the moving cauſe has ceaſed to act; or it may be eſſential to body to diminiſh its motion gradually, and finally come to reſt. But this will not invalidate the truth of this propoſition. Theſe circumſtances in the nature of body, which render thoſe modifications of motion eſſentially neceſſary, are the cauſes of thoſe modifications; and, in our ſtudy of nature, they will be conſidered by us as changing forces, and will be known and called by that name. And if we ſhould ever ſee a particle of matter in ſuch a ſituation that it is affected by thoſe eſſential properties alone, we ſhall, from obſervation of its motion, diſcover what thoſe eſſential properties are.

And almoſt an identical propoſition.

This law turns out at laſt to be little more than a tautological propoſition: But mechanical philoſophy, as we have defined it, requires no other ſenſe of it: for, even if we ſhould ſuppoſe that body, of its own nature, is capable of changing its ſtate, this change muſt be performed according to ſome law which characteriſes the nature of body; and the knowledge of the law can be had in no other way than by obſerving the deviations from uniform rectilineal motion. It is therefore indifferent whether thoſe changes are derived from the nature of the thing, or from external cauſes: for in order to conſider the various motions of bodies, we muſt firſt conſider this nature of matter as a mechanical affection of matter, operating in every inſtance; and thus we are brought back to the law enounced in this propoſition. This becomes more certain when we reflect that the external cauſes (ſuch as gravity or magnetiſm), which are acknowledged to operate changes of motion, are equally unknown to us with this eſſential original property of matter, and are, like it, nothing but inferences from the phenomena.

The above very diffuſe diſcuſſions may appear ſuperfluous to many readers, and even cumberſome; but we truſt that the philoſophical reader will excuſe our anxiety on this head, when he reflects on the complicated, indiſtinct, and inaccurate notions commonly had of the ſubject; and more eſpecially when he obſerves, that of thoſe who maintain the truth of this fundamental propoſition, as we have enounced it, many (and they too of the firſt eminence), reject it in fact, by combining it with other opinions which are inconſiſtent with it, nay, which contradict it in expreſs terms. We may even include Sir Iſaac Newton in the number of thoſe who have at leaſt introduced modes of expreſſion which miſlead the minds of incautious perſons, and ſuggeſt inadequate notions, incompatible with the pure doctrine of the propoſition. Although, in words, they diſclaim the doctrine that reſt is the natural ſtate of body, and that force is neceſſary for the continuation of its motion, yet in words they (and moſt of them in thought) likewiſe abet that doctrine: for they ſay, that there reſides in a moving body a *power* or *force*, by which it perſeveres in its motion. They call it the VIS INSITA, the INHERENT FORCE OF A MOVING BODY. This is ſurely giving up the queſtion: for if the motion is ſuppoſed to be continued in conſequence of a force, that force is *ſuppoſed* to be exerted; and it is ſuppoſed, that if it were not exerted, the motion would ceaſe; and therefore the propoſition muſt be falſe. Indeed it is ſometimes expreſſed ſo as ſeemingly to ward off this objection. It is ſaid that the body continues in uniform rectilineal motion, unleſs affected by ſome *external cauſe*. But this way of ſpeaking obliges us, at firſt ſetting out in natural philoſophy, to aſſert that gravity, magnetiſm, electricity, and a thouſand other mechanical powers, are external to the matter which they put in motion. This is quite improper: It is the buſineſs of philoſophy to diſcover whether they be external or not; and if we aſſert that they are, we have no principles of argumentation with thoſe who deny it. It is this one thing that has filled the ſtudy of nature with all the jargon of æthers and other inviſible intangible fluids, which has diſgraced philoſophy, and greatly retarded its progreſs.

32
Vis inſita, inherent force, are improper terms in their uſual acceptation.

We muſt obſerve, that the terms *vis inſita*, inherent *force*, are very improper. There is no diſpute among philoſophers in calling every thing a force that produces a change of motion, and in inferring the action of ſuch a force whenever we obſerve a change of motion. It is ſurely incongruous to give the ſame name to what has not this quality of producing a change, or to infer (or rather to ſuppoſe) the energy of a force when no change of motion is obſerved. This is one among many inſtances of the danger of miſtake when we indulge in analogical diſcuſſions. All our language, at leaſt, on this ſubject is analogous. I feel, that in order to oppoſe animal force, I muſt exert force. But I muſt exert force in order to oppoſe a body in motion: Therefore I imagine that the moving body poſſeſſes force. A bent ſpring will drive a body forward by unbending: Therefore I ſay that the ſpring exerts force. A moving body impels the body which it hits: Therefore I ſay, that the impelling body poſſeſſes and exerts force. I imagine farther, that it poſſeſſes force only by being in motion, or becauſe it is in motion; becauſe I do not find that a quieſcent body will put another into motion by touching it. But we ſhall ſoon find this to be falſe in many, if not in all caſes, and that the communication of motion depends on the mere vicinity, and not on the motion of the impelling body; yet we aſcribe the exertion of the *vis inſita* to the circumſtance of the continued motion. We therefore conceive the force as ariſing from, or as conſiſting in, the impelling body's being in motion; and, with a very obſcure and indiſtinct conception of the whole matter, we call it *the force by which the body preſerves itſelf in motion.* Thus, taking it for granted that a force reſides in the body, and being obliged to give it ſome office, this is the only one that we can think of.

But philoſophers imagine that they perceive the neceſſity of the exertion of a force in order to the continuation of a motion. Motion (ſay they) is a continued action; the body is every inſtant in a new ſituation; there is the continual production of an effect, therefore the continual action of a cauſe.

33
Motion is not the continual production of an effect.

But this is a very inaccurate way of thinking. We have a diſtinct conception of motion; and we conceive that there is ſuch a thing as a moving cauſe, which we diſtinguiſh from all other cauſes by the name *force*. It produces motion. If it does this, it produces the character of motion, which is a continual change of place. Motion is not action, but the effect of an action; and this action is as incomplete in the inſtant immediately ſucceeding the beginning of the motion as it is a minute after. The ſubſequent change of place is the continuation of an effect already produced. The *immediate* effect of the moving force is a DETERMINATION, by which, if not hindered, the body would go on for ever from place to place. It is in this determination only that the ſtate or condition of the body can differ from a ſtate of reſt; for in any inſtant, the body does not deſcribe any ſpace, but has a determination, by which it will deſcribe a certain ſpace uniformly in a certain time. Motion is a condition, a ſtate, or mode of exiſtence, and no more requires the continued agency of the moving cauſe than yellowneſs or roundneſs does. It requires ſome chemical agency to change the yellowneſs to greenneſs; and it requires a mechanical cauſe or a force to change this motion into reſt. When we ſee a moving body ſtop ſhort in an inſtant, or be gradually, but quickly, brought to reſt, we never fail to ſpeculate about a cauſe of this ceſſation or retardation. The caſe is no way different in itſelf although the retardation ſhould be extremely ſlow. We ſhould always attribute it to a cauſe. It requires a cauſe to put a body out of motion as much as to put it into motion. This cauſe, if not external, muſt be found in the body itſelf; and it muſt have a ſelf-determining power, and may as well be able to put itſelf into motion as out of it.

If this reaſoning be not admitted, we do not ſee how any effect can be produced by any cauſe. Every effect ſuppoſes ſomething *done*: and any thing done implies that the thing done may remain till it be *undone* by ſome other cauſe. Without this, it would have no exiſtence. If a moving cauſe did not produce continued motion by its inſtantaneous action, it could not produce it by any continuance of that action; becauſe in no inſtant of that action does it produce continued motion.

We muſt therefore give up the opinion, that there reſides in a moving body a force by *which it is kept in motion*; and we muſt find ſome other way of explaining that remarkable difference between a moving body and a body at reſt, by which the firſt cauſes other bodies to move by hitting them, while the other does not do this by merely touching them. We ſhall ſee, with the cleareſt evidence, that motion is neceſſary in the impelling body, in order that it may permit the forces inherent in one or both bodies to continue this preſſure long enough for producing a ſenſible or conſiderable motion. But theſe moving forces are inherent in bodies, whether they are in motion or at reſt.

34
Communication of motion is an improper phraſe,

The foregoing obſervations ſhew us the impropriety of the phraſe *communication of motion*. By thus reflecting on the notions that are involved in the general conception of one body being made to move by the impulſe of another, we perceive that there is nothing individual transferred from the one body to the other. The determination to motion, indeed, exiſted only in the impelling body before colliſion; whereas, afterwards, both bodies are ſo conditioned or determined. But we can form no notion of the thing transferred. With the ſame metaphyſical impropriety, we ſpeak of the communication of joy, of fever.

35
So is *vis inertiæ*.

Kepler introduced a term INERTIA, VIS INERTIÆ, into mechanical philoſophy; and it is now in conſtant uſe. But writers are very careleſs and vague in the notions which they affix to theſe terms. Kepler and Newton ſeem generally to employ it for expreſſing the fact, the perſeverance of the body in its preſent ſtate of motion or reſt: but they alſo frequently expreſs by it ſomething like an indifference to motion or reſt, *manifeſted by its requiring the ſame quantity of force to make an augmentation of its motion as to make an equal diminution of it.* The popular notion is like that which we have of actual reſiſtance; and it always implies the notion of force *exerted* by the reſiſting body. We ſuppoſe this to be the exertion of the *vis inſita*, or the *inherent force* of a body in motion. But we have the ſame notion of reſiſtance from a body at reſt which we ſet in motion. Now ſurely it is in direct contradiction to the common uſe of the word *force*, when we ſuppoſe reſiſtance from a body at reſt; yet *vis inertiæ* is a very common expreſſion. Nor is it more abſurd (and it is very abſurd) to ſay, that a body maintains its ſtate of reſt by the exertion of a *vis inertiæ*, than to ſay, that it maintains its ſtate of motion by the exertion of an *inherent force*. We ſhould avoid all ſuch metaphorical expreſſions as *reſiſtance*, *indifference*, *ſluggiſhneſs*, or *proneneſs to reſt* (which ſome expreſs by *inertia*); becauſe they ſeldom fail to make us indulge in metaphorical notions, and thus lead us to miſconceive the *modus operandi*, or procedure of nature.

There is *no reſiſtance whatever obſerved* in theſe phenomena; for the force employed always produces its *complete* effect. When I throw down a man, and find that I have employed no more force than was ſufficient to throw down a ſimilar and equal maſs of dead matter, I know by this that he *has not* reſiſted; but I conclude that he *has* reſiſted, if I have been obliged to employ much more force. There is therefore no reſiſtance, properly ſo called, when the exerted force is obſerved to produce its full effect. To ſay that there *is* reſiſtance, is therefore a real miſconception of the way in which mechanical forces have operated in the colliſion of bodies. There is no more reſiſtance in theſe caſes than in any other natural changes of condition. We are guilty, however, of the ſame impropriety of language in other caſes, where the cauſe of it is more evident. We ſay that colours in grain *reſiſt* the action of ſoap and of the ſun, but that Pruſſian blue does not. We all perceive, that in this expreſſion the word reſiſtance is entirely figurative: and we ſhould ſay that Pruſſian blue *reſiſts* ſoap, if we are right in ſaying that a body reſiſts any force employed to change its ſtate of motion; for ſoap muſt be employed to diſcharge or change the colour; and *it does change it*. Force muſt be employed to change a motion; *and it does change it*. The impropriety, both of thought and language, is *plain* in the one caſe, and it is no leſs *real* in the other. Both of the terms, *inherent force* and *inertia*, may be uſed with ſafety for abbreviating language, if we be careful to employ them only for expreſſing, *either the ſimple fact of perſevering in the former ſtate*, or *the neceſſity of employing a certain determinate force, in order to change that ſtate, and if we avoid all thought of reſiſtance.*

36 Deviations from uniform rectilineal motion are the only indications of force.

From the whole of this diſcuſſion, we learn, that the deviations from uniform motions are the indications of the exiſtence and agency of mechanical forces, and that they are the only indications. The indication is very ſimple, mere change of place; it can therefore indicate nothing but what is very ſimple, the ſomething competent to the production of the very motion that we obſerve. And when two changes of motion are preciſely ſimilar, they indicate the ſame thing. Suppoſe a mariner's compaſs on the table, and that by a ſmall tap with my finger I cauſe the needle to turn off from its quieſcent poſition 10 degrees. I can do the ſame thing by bringing a magnet near it; or by bringing an electrified body near it; or by the unbending of a fine ſpring preſſing it aſide; or by a puff of wind; or by ſeveral other methods. In all theſe caſes, the indication is the ſame; therefore the thing indicated is the ſame, namely, a certain intenſity and direction of a moving power. How it operates, or in what manner it exiſts and exerts itſelf in theſe inſtances, outwardly ſo different, is not under conſideration at preſent. Impulſiveneſs, intenſity, and direction, are all the circumſtances of reſemblance by which the affections of matter are to be characteriſed; and it is to the diſcovery and determination of theſe alone that our attention is now to be directed. We are directed in this reſearch by the

SECOND LAW OF MOTION.

Every change of motion is proportional to the force impreſſed, and is made in the direction of that force.

37. This law alſo may almoſt be conſidered as an identical propoſition; for it is equivalent to ſaying, that the changing force is to be meaſured by the change which it produces, and that the direction of this force is the direction of the change. Of this there can be no doubt, when we conſider the force in no other ſenſe than that of the cauſe of motion, paying no attention to the form or manner of its exertion. Thus, when a pellet of tow is ſhot from a pop-gun by the expanſion of the air compreſſed by the rammer, or where it is ſhot from a toy piſtol by the unbending of the coiled wire, or when it is nicked away by the thumb like a marble—if, in all theſe caſes, it moves off in the ſame direction, and with the ſame velocity, we cannot conſider or think of the force, or at leaſt of its exertion, as any how different. Nay, when it is driven forward by the inſtantaneous percuſſion of a ſmart ſtroke, although the manner of producing this effect (if poſſible) is eſſentially different from what is conceived in the other caſes, we muſt ſtill think that the propelling force, conſidered as a propelling force, is one and the ſame. In ſhort, this law of motion, as thus expreſſed by Sir Iſaac Newton, is equivalent to ſaying, "That we take the changes of motion as the meaſures of the changing forces, and the direction of the change for the indication of the direction of the forces:" For no reflecting perſon can pretend to ſay, that it is a deduction from the acknowledged principle, that effects are proportional to their cauſes. We do not affirm this law, from having obſerved the proportion of the forces and the proportion of the changes, and that theſe proportions are the ſame; and from having obſerved that this has obtained through the whole extent of our ſtudy of nature. This would indeed eſtabliſh it as a phyſical law, an univerſal fact; and it is, in fact, ſo eſtabliſhed. But this does not eſtabliſh it as a law of motion, according to our definition of that term; as a law of human thought, the reſult of the relations of our ideas, as an intuitive truth. The injudicious attempts of philoſophers to prove it as a matter of obſervation, have occaſioned the only diſpute that has ariſen in mechanical philoſophy. It is well known that a bullet, moving with double velocity, penetrates four times as far. Many other ſimilar facts corroborate this: and the philoſophers obſerve, that four times the force has been expended to generate this double velocity in the bullet; it requires four times as much powder. In all the examples of this kind, it would ſeem that the ratio of the forces employed has been very accurately aſcertained; yet this is the invariable reſult. Philoſophers, therefore, have concluded, that moving forces are not proportional to the velocities which they produce, but to the ſquares of thoſe velocities. It is a ſtrong confirmation, to ſee that the bodies in motion ſeem to poſſeſs forces in this very proportion, and produce effects in this proportion; penetrating four times as deep when the velocity is only twice as great, &c.

But if this be a juſt eſtimation, we cannot reconcile it to the conceſſion of the ſame philoſophers, who grant that the velocity is proportional to the force impreſſed, in the caſes where we have no previous obſervation of the ratio of the forces, and of its equality to the ratio of the velocities. This is the caſe with gravity, which theſe philoſophers always meaſure by its accelerating power, or of the velocity which it generates in a given time. And this cannot be refuſed by them; for caſes occur, where the force can be meaſured, in the moſt natural manner, by the actual preſſure which it exerts. Gravity is thus meaſured by the preſſure which a ſtone exerts on its ſupports. A weight which at Quito will pull out the rod of a ſpring ſteelyard to the mark 312, will pull it to 313 at Spitzbergen. And it is a fact, that a body will fall 313 inches at Spitzbergen in the ſame time that it falls 312 at Quito. Gravitation is the cauſe both of the preſſure and the fall; and it is a matter of unexcepted obſervation, that they have always the ſame ratio. The philoſophers who have ſo ſtrenuouſly maintained the other meaſure of forces, are among the moſt eminent of thoſe who have examined the motions produced by gravity, magnetiſm, electricity, &c.; and they never think of meaſuring thoſe forces any other way than by the velocity. It is in this way that the whole of the celeſtial phenomena are explained in perfect uniformity with obſervation, and that the Newtonian philoſophy is conſidered as a demonſtrative ſcience.

There muſt, therefore, be ſome defect in the principle on which the other meaſurement of forces is built, or in the method of applying it. Preſſure is undoubtedly the immediate and natural meaſure of force; yet we know that four ſprings, or a bow four times as ſtrong, give only a double velocity to an arrow.

The truth of our law reſts on this only, that we aſſume the changes of motion as the meaſure of the changing forces; or, at leaſt, as the meaſures of their exertions in producing motion. In fact, they are the meaſures only

of

of a certain circumſtance, in which the actions of very different natural powers may reſemble each other; namely, the competency to produce motion. They do not, perhaps, meaſure their competency to produce heat, or even to bend ſprings. We can ſurely conſider this apart from all other circumſtances; and it is worthy of ſeparate conſideration. Let us ſee what can be, and what ought to be, deduced from this way of treating the ſubject.

38
Change of motion is, itſelf, a motion.

The motion of a body may certainly remain unchanged. If the direction and velocity remain the ſame, we perceive no circumſtance in which its condition, with reſpect to motion, differs. Its change of place or ſituation can make no difference; for this is implied in the very circumſtance of the body's being in motion.

But if either the velocity or direction change, then ſurely is its mechanical condition no longer the ſame; a force has acted on it, either intrinſic or from without, either accelerating, or retarding, or deflecting it. Suppoſing the direction to remain the ſame, its difference of condition can conſiſt in nothing but its difference of velocity. This is the only circumſtance in which its condition can differ, as it paſſes through two different points of its rectilineal path. It is this determination by which the body will deſcribe a certain determinate ſpace uniformly in a given time, which defines its condition as a moving body: the changes of this determination are the meaſures of their own cauſes;—and to thoſe cauſes we have given the name *force*. Thoſe cauſes may reſide in other bodies, which may have other properties, characteriſed and meaſured by other effects. Preſſure may be one of thoſe properties, and may have its own meaſures; theſe may, or may not, have the ſame proportion with that property which is the cauſe of a change of velocity: and therefore changes of velocity may not be a meaſure of preſſure. This is a queſtion of fact, and requires obſervation and experience; but, in the mean time, velocity, and the change of velocity, is the meaſure of moving force and of changing force. When therefore the change of velocity is the ſame, whatever the previous velocity may be, the changing force muſt be conſidered as the ſame: therefore, finally, if the previous velocity is nothing, and conſequently the change on that body is the very velocity or motion that it acquires, we muſt ſay, that the force which produces a certain change in the velocity of a moving body, is the ſame with the force which would impart to a body at reſt a velocity equal to this change or difference of velocity produced on the body already in motion.

39. This manner of eſtimating force is in perfect conformity to our moſt familiar notions on theſe ſubjects. We conceive the weight or downward preſſure of a body as the cauſe of its motion downwards; and we conceive it as belonging to the body at all times, and in all places, whether falling, or riſing upwards, or deſcribing a parabola, or lying on a table; and, accordingly, we obſerve, that in every ſtate of motion it receives equal changes of velocity in the ſame, or an equal time, and all in the direction of its preſſure.

40. All that we have now ſaid of a change of velocity might be repeated of a change of direction. It is ſurely poſſible that the ſame change of direction may be made on any two motions. Let one of the motions be conſidered as growing continually ſlower, and terminating in reſt. In every inſtant of this motion it is poſſible to make one and the ſame change on it. The ſame change may therefore be made at the very inſtant that the motion is at an end. In this caſe, the change is the very motion which the body acquires from the changing force. Therefore, in this caſe alſo, we muſt ſay, that a change of motion is itſelf a motion, and that it is the motion which the force would produce in a body that was previouſly at reſt.

41
How aſcertained and meaſured.

The reſult of theſe obſervations is evidently this, that we muſt aſcertain, in every inſtance, what is the change of motion, and mark it by characters that are conſpicuous and diſtinguiſhing; and this mark and meaſure of change muſt be a motion: Then we muſt ſay, that the changing force is that which would produce this motion in a body previouſly at reſt. We muſt ſee how this is manifeſt, as a motion, in the difference between the former motion and the new motion; and, on the other hand, we muſt ſee how the motion produceable in a quieſcent body may be ſo combined with a motion already exiſting, as to exhibit a new motion, in which the agency of the changing force may appear.

Suppoſe a ſhip at anchor in a ſtream; while one man walks forward on the quarter-deck at the rate of two miles per hour, another walks from ſtem to ſtern at the ſame rate, a third walks athwart ſhip, and a fourth ſtands ſtill. Let the ſhip be ſuppoſed to cut or part her cable, and float down the ſtream at the rate of three miles per hour. We cannot conceive any difference in the change made on each man's motion in abſolute ſpace; but their motions are now exceedingly different from what they were: the firſt man, whom we may ſuppoſe to have been walking weſtward, is now moving eaſtward one mile per hour; the ſecond is moving eaſtward four miles per hour; and the third is moving in an oblique direction, about three points north or ſouth of due eaſt. All have ſuffered the ſame change of condition with the man who had been ſtanding ſtill. He has now got a motion eaſtward three miles per hour. In this inſtance, we ſee very well the circumſtance of ſameneſs that obtains in the change of theſe four conditions. It is the motion of the ſhip, which is blended with the other motions. But this circumſtance is equally preſent whenever the ſame previous motions are changed into the ſame new motions. We muſt learn to expiſcate this; which we ſhall do, by conſidering the manner in which the motion of the ſhip is blended with each of the mens motions.

42
Compoſition of motion.

This kind of combination has been called the Compoſition of motion; becauſe, in every point of the motion really purſued, the two motions are to be found.

The fundamental theorem on this ſubject is this:—Two uniform motions in the ſides of a parallelogram compoſe an uniform motion in the diagonal.

Plate XXI.

Suppoſe that a point A (fig. 1.) deſcribes AB uniformly in ſome given time, while the line AB is carried uniformly along AC in the ſame time, keeping always parallel to its firſt poſition AB. The point A, by the combination of theſe motions, will deſcribe AD, the diagonal of the parallelogram ABDC, uniformly in the ſame time.

For it is plain, that the velocities in AB and AC are proportional to AB and AC, becauſe they are uniformly deſcribed in the ſame time. When the point has got to E, the middle of AB, the line AB has got into the ſituation GH, half way between AB and CD, and

and the point E is in the place *e*, the middle of GH. Draw E *e* L parallel to AC. It is plain that the parallelograms ABDC and AE *e* G are ſimilar; becauſe AE and AG are the halves of AB and AC, and the angle at A is common to both. Therefore, by a propoſition in the Elements, they are about the ſame diagonal, and the point *e* is in the diagonal of AD. In like manner, it may be ſhewn, that when A has deſcribed AF, $\frac{3}{4}$ths of AB, the line AB will be in the ſituation IK, ſo that AI is $\frac{3}{4}$ths of AC, and the point *f*, in which A is now found, is in the diagonal AD. It will be the ſame in whatever point of AB the deſcribing point A be ſuppoſed to be found. The line AB will be on a ſimilar point of AC, and the deſcribing point will be in the diagonal AD.

Moreover, the motion in AD is uniform: for A *e* is deſcribed in the time of deſcribing AE; that is, in half the time of deſcribing AB, or in half the time of deſcribing AD. In like manner, A *f* is deſcribed in $\frac{3}{4}$ths of the time of deſcribing AD, &c. &c.

Laſtly, the velocity in the diagonal AD is to the velocity in either of the ſides as AD is to that ſide. This is evident, becauſe they are uniformly deſcribed in the ſame time.

This is juſtly called *a compoſition of the motions* AB *and* AC, as will appear by conſidering it in the following manner: Let the lines AB, AC be conceived as two material lines like wires. Let AB move uniformly from the ſituation AB into the ſituation CD, while AC moves uniformly into the ſituation BD. It is plain that their interſection will always be found on AD. The point *e*, for example, is a point common to both lines. Conſidered as a point of EL, it is then moving in the direction *e* H or AB; and, conſidered as a point of GH, it is moving in the direction *e* L. Both of theſe motions are therefore blended in the motion of the interſection along AD. We can conceive a ſmall ring at *e*, embracing looſely both of the wires. This material ring will move in the diagonal, and *will really partake* of both motions.

Thus we ſee how the motion of the ſhip is actually blended with the motions of the three men; and the circumſtance of ſameneſs which is to be found in the four changes of motion is this motion of the ſhip, or of the man who was ſtanding ſtill. By compoſition with each of the three former motions, it produces each of the three new motions. Now, when each of two primitive motions is the ſame, and each of the new motions is the ſame, the change is ſurely the ſame. If one of the changes has been brought about by the actual compoſition of motions, we know preciſely what that change is; and this informs us what the other is, in whatever way it was produced. Hence we infer, that,

43
Its mark and meaſure.

When a motion is any how changed, the change is that motion which, when compounded with the former motion, will produce the new motion. Now, becauſe we aſſume the change as the meaſure and characteriſtic of the changing force, we muſt do ſo in the preſent inſtance; and we muſt ſay,

44
Changing force.

That *the changing force is that which will produce in a quieſcent body the motion which, by compoſition with the former motion of a body, will produce the new motion.*

And, on the other hand,

Its effect.

When the motion of a body is changed by the action of any force, the new motion is that which is compounded of the former motion, and of the motion which the force would produce in a quieſcent body.

Deflecting force.

When a force changes the direction of a motion, we ſee that its direction is tranſverſe in ſome angle BAC; becauſe a diagonal AD always ſuppoſes two ſides. As we have diſtinguiſhed any change of direction by the term DEFLECTION, we may call the tranſverſe force a DEFLECTING FORCE.

In this way of eſtimating a change of motion, all the characters of both motions are preſerved, and it expreſſes every circumſtance of the change; the mere change of direction, or the angle BAD, is not enough, becauſe the ſame force will make different angles of deflection, according to the velocity of the former motion, or according to its direction: but in this eſtimation, the full effect of the deflecting force is ſeen; it is ſeen *as a motion;* for when half of the time is elapſed, the body is at *e* inſtead of E; when three-fourths are elapſed, it is at *f* inſtead of F; and at the end of the time it is at D inſtead of B. In ſhort, the body has moved uniformly away from the points at which it would have arrived independent of the change; and this motion has been in the ſame direction, and at the ſame rate, as if it had moved from A to C by the changing force alone. Each force has produced its full effect; for when the body is at D, it is as far from AC as if the force AC had not acted on it; and it is as far from AB as it would have been by the action of AC alone.

For all theſe reaſons, therefore, it is evident, that if we are to abide by our meaſure and character of force as a mere producer of motion, we have ſelected the proper characteriſtic and meaſure of a changing force: and our deſcriptions, in conformity to this ſelection, muſt be agreeable to the phenomena of nature, and retain the accuracy of geometrical procedure; becauſe, on the other hand, the reſults which we deduce from the ſuppoſed influence of thoſe forces are formed in the ſame mould. It is not even requiſite that the real exertions of the natural forces, ſuch as preſſure of various kinds, &c. ſhall follow theſe rules; for their deviations will be conſidered as new forces, although they are only indications of the differences of the real forces from our hypotheſis. We have obtained the precious advantage of mathematical inveſtigation, by which we can examine the law of exertion which characteriſes every force in nature.

On theſe principles we eſtabliſh the following fundamental elementary propoſition, of continual and indiſpenſable uſe in all mechanical inquiries.

45
Fundamental theorem.

If a body or material particle be ſubjected at the ſame time to the action of two moving forces, each of which would ſeparately cauſe it to deſcribe the ſide of a parallelogram uniformly in a given time, the body will deſcribe the diagonal uniformly in the ſame time.

For the body, whoſe motion AB was changed into AD, had gotten its motion by the action of ſome force. It was moving along NAB; and, when it reached the point A, the force AC acted on it. The primitive motion is the ſame, or the body is in the ſame condition in every inſtant of the primitive motion. It may have acquired this motion when it was in N, or when at O, or any other point of NA. In all theſe caſes, if AC act on it when it is in A, it will always deſcribe AD; therefore it will deſcribe AD when it acquires the primitive motion alſo in A; that is, if the two forces

ces act on it at one and the ſame inſtant. The demonſtration may be neatly expreſſed thus: The change induced by each force on the motion produced by the other, is the motion which it would produce in the body if previouſly at reſt. Therefore the motion reſulting from joint action is the motion which is compounded of theſe two motions; or it is a motion in the diagonal of the parallelogram, of which theſe motions are the ſides.

Compoſition of forces. This is called the COMPOSITION OF FORCES. The forces which produce the motions along the ſides of the parallelogram are called the SIMPLE FORCES, or the CONSTITUENT FORCES; and the force which would alone produce the motion along the diagonal is called the COMPOUND FORCE, the RESULTING FORCE, the EQUIVALENT FORCE.

46. On the other hand, the force which produces a motion along any line whatever, may be conceived as reſulting from the combined action of two or more forces. We may *know* or *obſerve* it to be ſo; as when we ſee a lighter dragged along a canal by two horſes, one on each ſide. Each pulls the boat directly toward himſelf in the direction of the track-rope; the boat cannot go both ways, and its real motion, whatever it is, reſults from this combined action. This might be produced by a ſingle force; for example, if the lighter be dragged along the canal by a rope from another lighter which precedes it, being dragged by one horſe, aided by the helm of the foremoſt lighter. Here the real force is not the reſulting, or the compound, but the equivalent force.

Reſolution of forces. This view of a motion, mechanically produced, is called the RESOLUTION OF FORCES. The force in the diagonal is ſaid to be *reſolved* into the two forces, having the directions and velocities repreſented by the ſides. This practice is of the moſt extenſive and multifareous uſe in all mechanical diſquiſitions. It may frequently be exceedingly difficult to manage the complication of the many real forces which concur in producing a phenomenon; and by ſubſtituting others, whoſe combined effects are equivalent, our inveſtigation may be much expedited. But more of this afterwards.

We muſt carefully remember, that when the motion AD is once begun, all compoſition is at an end, and the motion is a ſimple motion. The two determinations, by one of which the body would deſcribe AB, and by the other of which it would deſcribe AC, no longer *co-exiſt* in the body. This was the caſe only *in the inſtant*, in the very act of changing the motion AB into the motion BD; yet is the motion AD equivalent to a motion which is produced by the *actual compoſition* of two motions AB and AC; in which caſe the two motions co-exiſt in every point of AD.

47 Uſual demonſtration inconcluſive. Accordingly this is the way in which the compoſition of forces is uſually illuſtrated, and thought to be demonſtrated. A man is ſuppoſed (for inſtance) to walk uniformly from A to C on a ſheet of ice, while the ice is carried uniformly along AB by the ſtream. The man's real motion is undoubtedly along AD; but this is by no means a demonſtration that the inſtantaneous or ſhort-lived action of two forces would produce that motion; the man muſt continue to exert force in order to walk, and the ice is dragged along by the ſtream. Some indeed expreſs this proof in another way, ſaying, let a body deſcribe AB, while the ſpace in which this motion is performed is carried along AC. The ice may be carried along, and may, by friction, or otherwiſe, drag the man along with it; but a ſpace cannot be removed from one place to another, nor, if it could, would it take the man with it. Should a ſhip ſtart ſuddenly forward while a man is walking acroſs the deck, he would be left behind, and fall toward the ſtern. We muſt *ſuppoſe* a tranſverſe force, and we muſt *ſuppoſe* the compoſition of this force without proof. This is no demonſtration.

We apprehend that the demonſtration given above of this fundamental propoſition is unexceptionable, when the terms force and deflection are uſed in the abſtract ſenſe which we have affixed to them; and we hope, by theſe means, to maintain the rigour of mathematical diſcuſſion in all our future diſquiſitions on theſe ſubjects. The only circumſtance in it which can be the ſubject of diſcuſſion is, whether we have ſelected the proper meaſure and characteriſtic of a change of motion—We never met with any objection to it.

48 Objections to the demonſtration of n° 45. It will not apply to preſſures. But ſome have ſtill maintained, that it does not evidently appear, from theſe principles, that the motion which reſults from the joint action of two natural powers, whoſe known and meaſurable intenſities have the ſame proportions with AB and BC, and which alſo exert themſelves in thoſe directions, will produce a motion, having the direction and proportion of AD. They will not, if the velocities produced by theſe forces are not in the proportion of thoſe intenſities, but in the ſubduplicate ratio of them. Nay, they ſay, that it is not ſo. If a body be impelled along AC by one ſpring, and along AB by two ſprings equally ſtrong, it will not deſcribe the diagonal of a parallelogram, of which the ſide AB is double the ſide AC. Nay, they add, that an indefinite number of examples can be given where a body *does not* deſcribe the diagonal of the parallelogram by the joint action of two forces, which, ſeparately, would cauſe it to deſcribe the ſides. And, laſtly, they ſay that, at any rate, it does not appear evident to the mind, that two *incitements* to motion, having the directions and the ſame proportion of intenſity with that of the ſides of a parallelogram, actually generate a third, which is the immediate cauſe of the motion in the diagonal. An equivalent force is not the ſame with a reſulting force.

49. Yet we ſee numberleſs caſes of the compoſition of incitements to motion, and they ſeem as determinate, and as ſuſceptible of being combined by compoſition, as the things called moving forces, which are meaſured by the velocities: we ſee them actually ſo combined in a thouſand inſtances, as in the example already given of a lighter dragged by two horſes pulling in different directions. Nay, experiment ſhews, that this compoſition follows preciſely the ſame rule as the compoſition of the forces which are meaſured by the velocities; for if the point A (fig. 1.) be pulled by a thread, or preſſed by a ſpring, in the direction AB, and by another in the direction AC, and if the preſſures are proportional to AB and AC, then it will be withheld from moving, if it be pulled or preſſed by a third force, acting in the direction A *d*, oppoſite to AD, the preſſure being alſo proportional to AD. This force, acting in the direction A *d*, would certainly withſtand an equal force acting in the direction AD; therefore we muſt conclude, that the two preſſures AB and AC really generate a force AD. This uniform agreement ſhews that

that the compoſition is deducible from fixed principles; but it does not appear that it can be held as demonſtrated by the arguments employed in the caſe of motions. A demonſtration of the compoſition of preſſures is ſtill wanted, in order to render mechanics a demonſtrative ſcience.

This compoſition is of more difficult inveſtigation.

Accordingly, philoſophers of the firſt eminence have turned their attention to this problem. It is by no means eaſy; being ſo nearly allied to firſt principles, that it muſt be difficult to find axioms of greater ſimplicity by which it may be proved.

Mechanicians generally contented themſelves with the ſolution given by Ariſtotle; but this is merely a compoſition of motions: indeed he does not give it for any thing elſe, and calls it "συνθεσις των φυ αν." The firſt writer who appears to have conſidered it as different from the mere compoſition of motions, was the celebrated Dutch engineer Stevinus in his work *on Sluices*; but his ſolution is obſcure. It was ſufficient, however, to convince Daniel Bernoulli of the neceſſity and the difficulty of the problem. He has given the firſt complete demonſtration of it in the firſt volume of the Commentaries of the Imperial Academy of Sciences at St Peterſburgh. It is extremely ingenious; but it is tedious and intricate, requiring a ſeries of 15 propoſitions to demonſtrate that two preſſures, having the directions and magnitudes of the ſides of any parallelogram, compoſe a third, which has the direction and magnitude of its diagonal. His firſt propoſition is, that *two equal preſſures, acting at right angles, compoſe a third, in the direction of the diagonal of a ſquare, and having to either of the other two the proportion of the diagonal of a ſquare to its ſides.*

Mr D'Alembert has greatly ſimplified and improved this demonſtration, by beginning with a caſe that is ſelf-evident; namely, *If three equal forces are inclined to each other in equal angles of* 120 *degrees, any one of them will balance the combined action of the other two.* Surely; for neither of them can prevail. Therefore *two* equal forces, inclined in an angle of 120 degrees, produce a third, which has the direction and proportion of the diagonal of the rhombus; for this is equal and oppoſite to one of the three above mentioned. He then demonſtrates the ſame thing of two equal forces inclined in *any* angle; and by a ſeries of eight propoſitions more, demonſtrates the general theorem. This diſſertation is in the Memoirs of the Academy at Paris for 1769. He improves it ſtill farther in a ſubſequent memoir.

Mr Riccati and Mr Fonſenex, in the Commentaries of the Academy of Turin, have given analytical demonſtrations, which are alſo very ingenious and conciſe, but require acquaintance with the higher mathematics.—There is another very ingenious demonſtration in the *Journal des Sçavans* for June 1764, but too obſcure for an elementary propoſition. It is ſomewhat ſimplified by Belidor in his *Ingenieur François*. Friſius, in his *Coſmographia*, has given one, which is perhaps the beſt of all thoſe that are eaſily comprehended without acquaintance with the higher mathematics: but we imagine that, although no one can doubt of the concluſion, it has not that intuitive evidence for every ſtep of the proceſs that ſeems neceſſary.

50 *Compoſition of preſſures.*

We here offer another, compoſed by blending together the methods of Bernoulli and D'Alembert; and we imagine that no objection can be made to any ſtep of it. We limit it entirely to preſſures, and do not at all conſider nor employ the motions which they may be ſuppoſed to produce.

(A) If two equal and oppoſite preſſures or incitements to motion act at once on a material particle, it ſuffers no change of motion; for if it yields in either direction by their joint action, one of the preſſures prevails, and they are not equal.

Equal and oppoſite preſſures are ſaid TO BALANCE each other; and ſuch as balance muſt be eſteemed equal and oppoſite.

(B) If a and b are two magnitudes of the ſame kind, proportional to the intenſities of two preſſures which act in the ſame direction, then the magnitude $a+b$ will meaſure the intenſity of the preſſure, which is equivalent, and may be called equal, to the combined effort of the other two; for when we try to form a notion of preſſure as a meaſurable magnitude, diſtinct from motion or any other effect of it, we find nothing that we can meaſure it by, but another preſſure. Nor have we any notion of a double or triple preſſure different from a preſſure that is equivalent to the joint effort of two or three equal preſſures. A preſſure a is accounted triple of a preſſure b, if it balances three preſſures, each equal to b, acting together. Therefore, in all proportions which can be expreſſed by numbers, we muſt acknowledge the legitimacy of this meaſurement; and it would ſurely be affectation to omit thoſe which the mathematicians call *incommenſurable*.

In like manner, the magnitude $a-b$ muſt be acknowledged to meaſure that preſſure which ariſes from the joint action of two preſſures a and b acting in oppoſite directions, of which a is the greateſt.

(C) Let ABCD and $AbCd$ (fig. A) be two rhombuſes, which have the common diagonal AC. Let the angles BAb, DAd, be biſected by the ſtraight lines AE and AF.

If there be drawn from the points E and F the lines EG, EH, Fg, Fh, making equal angles on each ſide of EA and FA, and if Gg, Hh be drawn, cutting the diagonal AC in I and L: then AI + AL will be greater or leſs than AQ, the half of AC, according as the angles GEH, gFh, are greater or leſs than GAH, gAh.

Draw GH, gh, cutting AE, AF, in O and o, and draw Oo, cutting AC in K.

Becauſe the angles AEG and EAG are reſpectively equal to AEH and EAH, and AE is common to both triangles, the ſides AG, GE are reſpectively equal to AH, HE, and GH is perpendicular to AE, and is biſected in O; for the ſame reaſons, gh is biſected in o. Therefore the lines Gg, Oo, Hh, are parallel, and IL is biſected in K. Therefore AI + AL is equal to twice AK. Moreover, if the angle GEH be greater than GAH, AO is greater than EO, and AK is greater than KQ. Therefore AI + AL is greater than AQ; and if the angle GEH be leſs than GAH, AI + AL is leſs than AQ.

(D) Two equal preſſures, acting in the directions AB and AC (fig. 2.), at right angles to each other, compoſe a preſſure in the direction AD, which biſects the right angle; and its intenſity is to the intenſity of each of the conſtituent preſſures as the diagonal of a ſquare to one of the ſides. It is evident that the direction of the preſſure, generated by their joint action,

will

will biſect the angle formed by their directions; becauſe no reaſon can be aſſigned for the direction inclining more to one ſide than to the other.

In the next place, ſince a force in the direction AD does, in fact, ariſe from the joint action of the equal preſſures AB and AC, the preſſure AB may be conceived as ariſing from the joint action of two equal forces ſimilarly inclined and proportioned to it. Draw EAF perpendicular to AD. One of theſe forces muſt be directed along AD, and the other along AE. In like manner, the preſſure AC may ariſe from the joint action of a preſſure in the direction AD, and an equal preſſure in the direction AF. It is alſo plain, that the preſſures in the directions AE and AF, and the two preſſures in the direction AD, muſt be all equal. And alſo, any one of them muſt have the ſame proportion to AB or to AC, that AB or AC has to the force in the direction AD, ariſing from their joint action.

Therefore, if it be ſaid that AD does not meaſure the preſſure ariſing from the joint action of AB and AC, let A *d*, greater than AD, be its juſt meaſure, and make A *d* : AB = AB : A *g* = AB : A *e*. Then A *g* and A *e* have the ſame inclination and proportion to AB that AB and AC have to A *d*. We determine, in like manner, two forces A *f* and A *g* as conſtituents of AC.

Now A *d* is equivalent to AB and AC, and AB is equivalent to A *e* and A *g*; and AC is equivalent to A *f* and A *g*. Therefore A *d* is equivalent to A *e*, A *f*, A *g*, and A *g*. But (A) A *e* and A *f* balance each other, or annihilate each other's effect; and there remain only the two forces or preſſures A *g*, A *g*. Therefore (B) their meaſure is a magnitude equal to twice A *g*. But if A *d* be greater than the diagonal AD of the ſquare, whoſe ſides are AB and AC; then A *g* muſt be leſs than AI, the ſide of the ſquare whoſe diagonal is AB. But twice A *g* is leſs than AD, and much leſs than A *d*. Therefore the meaſure of the equivalent of AB and AC cannot be a line A *d* greater than AD. In like manner, it cannot be a line A *δ* that is leſs than AD. Therefore it muſt be equal to AD, and the propoſition is demonſtrated.

(E) *Cor.* Two equal forces AB, AC, acting at right angles, will be balanced by a force AO, equal and oppoſite to AD, the diagonal of the ſquare whoſe ſides are AB and AC; for AO would balance AD, which is the equivalent of AB and AC.

(F) Let AECF (fig. 3.) be a rhombus, the acute angle of which EAF is half of a right angle. Two equal preſſures, which have the directions and meaſures AE, AF, compoſe a preſſure, having the direction and meaſure AC, which is the diagonal of the rhombus.

It is evident, in the firſt place, that the compound force has the direction AC, which biſects the angle EAF. If AC be not its juſt meaſure, let it be AP leſs than AC. Let ABCD be a ſquare deſcribed on the ſame diagonal, and make AP : AQ = AE : AO, = AF : A *o*. Draw KOG, K *o g* perpendicular to AE, AF; draw GI *g*, OH *o*, EG, EK, F *g*, FK, PF, and PE.

The angles CAB and FAE are equal, each being half of a right angle. Alſo the figures AEPF and AGEK are ſimilar, becauſe AP : AQ = AE : AO. Therefore FA : AP = KA : AE, and EA : AP = GA : AE. Therefore, in the ſame manner that the forces AE, AF are affirmed to compoſe AP, the forces AG and AK may compoſe the force AE, and the forces A *g* and AK may compoſe the force AF. Therefore (B) the force AP is equivalent to the four forces AG, AK, A *g*, AK. But (D) AG and A *g* are the ſides of a ſquare, whoſe diagonal is equal to twice AI: and the two forces AK, AK are equal to, or are meaſured by, twice AK. Therefore the four forces AG, AK, A *g*, AK, are equivalent to 2 AI + 2 AK, = 4 AH.

But becauſe AP was ſuppoſed leſs than AC, the angle FPE is greater than FAE, and GEK is greater than GAK, AO is greater than OE, and AH is greater than HQ, and 2 AH is greater than AQ; and therefore 4 AH is greater than AC, and much greater than AP. Therefore AP is not the juſt meaſure of the force compoſed of AE and AF.

In like manner, it is ſhewn, that AE and AF do not compoſe a force whoſe meaſure is greater than AC. It is therefore equal to AC; and the propoſition is demonſtrated.

(G) By the ſame proceſs it may be demonſtrated, that if BAD be half a right angle, and EAF be the fourth of a right angle, two forces AE, AF will compoſe a force meaſured by AC. And the proceſs may be repeated for a rhombus whoſe acute angle is $\frac{1}{8}$th, $\frac{1}{16}$th, &c. of a right angle; that is, any portion of a right angle that is produced by continual biſection. Two forces, forming the ſides of ſuch a rhombus, compoſe a force meaſured by the diagonal.

(H) Let ABCD, A *b c d* (fig. 4.) be two rhombuſes formed by two conſecutive biſections of a right angle. Let AECF be another rhombus, whoſe ſides AE and AF biſect the angles BA *b* and DA *d*.

The two forces AE, AF, compoſe a force AC.

Biſect AE and AF in O and *o*. Draw the perpendiculars GOH, *g o h*, and the lines GI *g*, OK *o*, HL *h*, and the lines EG, EH, F *g*, F *h*.

It is evident, that AGEH and A *g* F *h* are rhombuſes; becauſe AO = OE, and A *o* = *o* F. It is alſo plain, that ſince *b* A *d* is half of BAD, the angle GAH is half of *b* A *d*. It is therefore formed by a continual biſection of a right angle. Therefore (G) the forces AG, AH, compoſe a force AE; and A *g*, A *h*, compoſe the force AF. Therefore the forces AG, AH, A *g*, A *h*, acting together, are equivalent to the forces AE, AF acting together. But AG, A *g* compoſe a force = 2 AI; and the forces AH, A *h* compoſe a force = 2 AL. Therefore the four forces acting together are equivalent to 2 AI + 2 AL. or to 4 AK. But becauſe AO is $\frac{1}{2}$ AE, and the lines G *g*, O *o*, H *h*, are evidently parallel, 4 AK is equal to 2 AQ, or to AC; and the propoſition is demonſtrated.

(I) *Cor.* Let us now ſuppoſe, that by continual biſection of a right angle we have obtained a very ſmall angle *a* of a rhombus; and let us name the rhombus by the multiple of *a* which forms its acute angle.

The propoſition (G) is true of *a*, 2 *a*, 4 *a*, &c. The propoſition (H) is true of 3 *a*. In like manner, becauſe (G) is true of 4 *a* and 8 *a*, propoſition (H) is true of 6 *a*; and becauſe it is true of 4 *a*, 6 *a*, and 8 *a*, it is true of 5 *a* and 7 *a*. And ſo on continually till we have demonſtrated it of every multiple of *a* that is leſs than a right angle.

(K) Let RAS (fig. 5.) be perpendicular to AC, and

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 bR, dS parallel to BA, DA. It is evident, that AR b B and AS d D are rhombuſes, whoſe acute angles are multiples of a that are each leſs than a right angle. Therefore (I) the forces AR and AB compoſe the force A b, and AS, AD compoſe A d; but AR and AS annihilate each other's effect, and there remains only the forces AB, AD. Therefore A b and A d are equivalent to AB and AD, which compoſe the force AC; and the propoſition is demonſtrated.

(L) *Cor.* Thus is the corrollary of laſt propoſition extended to every rhombus, whoſe angle at A is ſome multiple of a leſs than two right angles. And ſince a may be taken leſs than any angle that can be named, the propoſition may be conſidered as demonſtrated of every rhombus: and we may ſay,

(M) *Two equal forces, inclined to each other in any angle, compoſe a force which is meaſured by the diagonal of the rhombus, whoſe ſides are the meaſures of the conſtituent forces.*

(N) Two forces AB, AC (fig. 6.), having the direction and proportion of the ſides of a rectangle, compoſe a force AD, having the direction and proportion of the diagonal.

Draw the other diagonal CB, and draw EAF parallel to it; draw BE, CF parallel to DA.

AEBG is a rhombus; and therefore the forces AE and AG compoſe the force AB. AFCG is alſo a rhombus, and the force AC is equivalent to AF and AG. Therefore the forces AB and AC, acting together, are equivalent to the forces AE, AF, AG, and AG acting together, or to AE, AF, and AD acting together: But AE and AF annihilate each other's action, being oppoſite and equal (for each is equal to the half of BC). Therefore AB and AC acting together, are equivalent to AD, or compoſe the force AD.

(O) Two forces, which have the direction and proportions of AB, AC (fig. 7.) the ſides of any parallelogram, compoſe a force, having the direction and proportion of the diagonal AD.

Draw AF perpendicular to BD, and BG and DE perpendicular to AC.

Then AFBG is a rectangle, as is alſo AFDE; and AG is equal to CE. Therefore (N) AB is equivalent to AF and AG. Therefore AB and AC acting together, are equivalent to AF, AG, and AC acting together; that is, to AF and AE acting together; that is (N) to AD; or the forces AB and AC compoſe the force AD.

Hence ariſes the moſt general propoſition,

51
Compoſition of all incitements to motion.

If a material particle be urged at once by two preſſures or incitements to motion, whoſe intenſities are proportional to the ſides of any parallelogram, and which act in the directions of thoſe ſides, it is affected in the ſame manner as if it were acted on by a ſingle force, whoſe intenſity is meaſured by the diagonal of the parallelogram, and which acts in its direction: Or, two preſſures, having the direction and proportion of the ſides of a parallelogram, generate a preſſure, having the direction and proportion of the diagonal.

52
Seeming difference of the compoſitions of motion and of preſſure diſappear when carefully examined.

Thus have we endeavoured to demonſtrate from abſtract principles the perfect ſimilarity of the compoſition of preſſures, and the compoſition of forces meaſured by the motions which they produce. We cannot help being of the opinion, that a ſeparate demonſtration is indiſpenſably neceſſary. What may be fairly deduced from the one caſe, cannot always be applied to the other. No compoſition of preſſures can explain the change produced by a deflecting force on a motion already exiſting; for the changing preſſure is the only one that exiſts, and there is none to be compounded with it. And, on the other hand, our notions and obſervations of the compoſition of motions will not explain the compoſition of preſſures, unleſs we take it for granted that the preſſures are proportional to the velocities; but this is perhaps a gratuitous aſſumption. At any rate, it is not an intuitive propoſition; and we have mentioned ſome facts where it ſeems that they do not follow the ſame proportion. The preſſure of four equal ſprings produces only a double velocity. It would appear, therefore, that there are circumſtances which oblige us to ſay, that the *exertion* of preſſure, as a cauſe of motion, is not (always at leaſt) proportional to the real meaſurable preſſure. We are therefore anxious to diſcover in what the difference conſiſts; and in the mean time muſt allow, that the preſſure exerted on a body at reſt is different from its exertion in producing motion. We cannot indeed ſtate any immediate compariſon between preſſure and motion, nor have we any clear conception of the connection between them. It is only by our ſenſations of touch that we have any notion of preſſure, and it is experience that teaches us that it always accompanies every cauſe of motion. We can, however, obſerve the proportions of preſſures, and compare them with the proportions of motion. We very often obſerve them different; and therefore it was indiſpenſably neceſſary to inveſtigate the laws of combined preſſure as we did the laws of combined motion in conſequence of preſſure. Yet we ſhould err, if we haſtily aſſerted that preſſures are not proportional to the motions which they produce; all that we are intitled to call in doubt is, whether the preſſures in their exertion, while they actually produce motion, or changes of motion, continue to be the ſame as when they do not produce motion, being withſtood or balanced by oppoſite preſſures. Conſidered as cauſes of motion, we ought to think that they do not vary while they produce motion, and that the actual preſſure, while it produces a double motion, is really double, although it may be quadruple when the body exerting it is made to act on a body that it cannot move. We are confirmed in this opinion by obſerving, that other facts ſhew us, that even while producing motion, the preſſure which we call quadruple, becauſe we have meaſured it by four equal preſſures balancing it, is really quadruple, conſidered as the cauſe of motion, and produces a quadruple motion. A bow which requires four times the force to draw it to any given extent, will communicate the ſame velocity to a bundle of four arrows that a bow four times eaſier drawn communicates to one arrow, and will therefore produce a quadruple motion. Yet it will only produce a double velocity in the arrow that acquired a ſimple velocity from a bow having one fourth of the ſtrength.

Theſe diſcrepancies ſhould excite the endeavours of mechanicians to inveſtigate the laws obſerved in the action of preſſures in producing motion. Had this been done with care and with candour, we ſhould not have had

had the great difference of opinion, which ſtill divides philoſophers, about the meaſures of moving forces. But a ſpirit of party, which had ariſen from other cauſes, gave importance to what was at firſt only a difference of expreſſion, and made the partiſans of Mr Leibnitz avail themſelves of the figurative language which has done ſo much harm in all the departments of philoſophy. Notwithſtanding all our caution, it is hardly poſſible to avoid metaphorical conceptions when we employ the language of metaphor. The abettors of the Leibnitzian meaſure of moving forces, or perhaps, to ſpeak more properly, the abettors of the Leibnitzian meaſure of that force which is ſuppoſed to preſerve bodies in their condition of motion—inſiſt, that the force which is exerted in producing any change of motion is greater in proportion as the motion changed is greater: and they give a very ſpecious argument for their aſſertion. They appeal to the exertions which we ourſelves make. Here we are conſcious of the fact. Then they give ſimilar examples of the action of bodies. A clay ball, moving ſix feet per ſecond, will make the addition of one foot to the velocity of an equal clay ball that is already moving four feet per ſecond in the ſame direction. But if this laſt ball be already moving ten feet per ſecond, we muſt follow it with a velocity of twelve feet in order to increaſe its velocity one foot. But, without inſiſting on the numberleſs paralogiſms and inconſiſtencies which this way of conceiving the matter would lead us into, it ſuffices to obſerve, that the phenomena give us abundant aſſurance that there has been the ſame exertion in both theſe caſes. This acceleration is always accompanied by a compreſſion of the balls, and the compreſſion is the ſame in both. This compreſſion is a very good meaſure of the force employed to produce it; and in the preſent caſe, we need not even trouble ourſelves with any rule for its meaſurement: for ſurely when the compreſſion is not different, but the ſame, the force exerted is the ſame. This is farther confirmed by obſerving, that it requires the ſame force to make the ſame pit, or to give the ſame motion, to a piece of clay lying on the table of a ſhip's cabin, whether the ſhip be ſailing two miles or ten miles per hour.

Thus we ſee that there are ſtrong reaſons for believing, that the exertions of preſſure in producing motion, or that the preſſures *actually exerted*, are proportional to the changes of motion obſerved, and that they coincide in this reſpect with our abſtract conceptions of moving forces.

But we have ſtill better arguments. None of the Leibnitzians think of denying the equal exertions of gravity, or of any of thoſe powers which they call *ſolicitations* or *accelerating forces*. They all admit, that gravity, or any conſtant accelerating force, produces equal increments of velocity in equal times, and that a double gravity will produce a double increment in an equal time, and an equal increment in half of the time; and that a quadruple gravity will produce a double velocity in half the time. All theſe things are granted by them, and their writings are full of reaſonings from this principle. Now from the fact, acknowledged by the Leibnitzians, that the quadruple force of a bow gives a double velocity to the arrow, in every inſtant of its action, it indiſputably follows, that it has acted on it only for half the time of the action of the four times weaker bow, which gives the arrow only half the velocity; and thus has the diſcrepancy between the effects of preſſures and of our abſtract moving forces entirely diſappeared. For this circumſtance of the difference in the time of acting will be found, on ſtrict examination, in all the caſes of the change of motion by preſſures which we meaſure by their effects on a body at reſt. When this and the appreciable changes of actual preſſure, during the time of producing the motion, are taken into conſideration, all difference vaniſhes, and the compoſition of preſſures is in perfect harmony with the compoſition of motions, or of abſtract moving forces. DYNAMICS is thus made a demonſtrative ſcience, and affords the opportunity of inveſtigating, by obſervation and experiment, the nature of thoſe mechanical powers which reſide in bodies, and which appear to us under the form of preſſure, inducing us to conſider preſſure as a cauſe of motion.

In this, however, we are rather inaccurate. Preſſure is one of the ſenſible effects of that property which is alſo the cauſe of motion. It is not the preſſure of a piece of lead, but its heavineſs, that is the reaſon that it gives motion to a kitchen jack. Preſſure is merely a generic name, borrowed from a familiar inſtance, and given to moving forces, which have the ſame nature, but different names that ſerve to mark their connection with certain ſubſtances, in which they may be ſuppoſed to reſide. Natural philoſophy is almoſt entirely employed in examining the nature of theſe various preſſures or accelerative forces; and the general doctrines of dynamics, by aſcertaining what is common to them all, enable us to mark with preciſion what is characteriſtic of each.

53
General corollaries.

We have now advanced very far in this inveſtigation; for we have obtained the criterion by which we learn the direction and the magnitude of every changing force: and, on the other hand, we ſee how to ſtate what will be the effect of the exertion of any force that is known or ſuſpected to act. All this we learn by the compoſition of forces; and the greateſt part of mechanical diſquiſition conſiſts in the application of this doctrine. For ſuch reaſons it merits minute conſideration; and therefore we muſt point out ſome general concluſions from the properties of figure, which will greatly facilitate the uſe of the parallelogram of forces.

1. The conſtituent and the reſulting forces, or the ſimple and compound forces, act in the ſame plane; for the ſides and diagonal of a parallelogram are in one plane. 54.

2. The ſimple and the compound forces are proportional to the ſides of any triangle which are parallel to their directions. For if any three lines, *ab*, *bd*, *ad*, be drawn parallel to AB, AC, and AD (fig. 7, n° 2.), they will form a triangle ſimilar to the triangle ABD. For the ſame reaſons they are proportional to the ſides of a triangle *a'b'd*, which are reſpectively perpendicular to their directions. 55.

3. Therefore each is proportional to the ſine of the oppoſite angle of this triangle; for the ſides of any triangle are proportional to the ſines of the oppoſite angles. 56.

4. Each is proportional to the ſine of the angle contained by the directions of the other two; for AD is to AB as the ſine of the angle ABD to the ſine of the angle ADB. Now the ſine of ABD is the ſame with 57.

with the ſine of BAC contained between the directions AB and AC, and the ſine of ADB is the ſame with the ſine of CAD; alſo AB is to AC, or BD, as the ſine of ADB (or CAD) to the ſine of BAD.

58 Some ſpecial uſes of the parallelogram of forces.

We now proceed to the application of this fundamental propoſition. And we obſerve, in the firſt place, that ſince AD may be the diagonal of an indefinite number of parallelograms, the motion or the preſſure AD may reſult from the joint action of many pairs of forces. It may be produced by forces which would ſeparately produce the motions AF and AG. This generally gives us the means of diſcovering the forces which concur in its production. If one of them, AB, is known in direction and intenſity, the direction AC, parallel to BD, and the intenſity, are diſcovered. Sometimes we know the directions of both. Then, by drawing the parallelogram or triangle, we learn their proportions. The force which deflects any motion AB into a motion AD, is had by ſimply drawing a line from the point B (to which the body would have moved from A in the time of really moving from A to D) to the point D. The deflecting force is ſuch as would have cauſed the body move from B to D in the ſame time. And, in the ſame manner, we get the compound motion AD, which ariſes from any two ſimple motions AB and AC, by ſuppoſing both of the motions to be accompliſhed in ſucceſſion. The final place of the body is the ſame, whether it moves along AD or along AB and BD in ſucceſſion.

59 Equivalent of many forces.

This theorem is not limited to the compoſition of two motions or two forces only; for ſince the combined action of two forces puts the body into the ſame ſtate as if their equivalent alone had acted on it, we may ſuppoſe this to have been the caſe, and then the action of a third force will produce a change on this equivalent motion. The reſulting motion will be the ſame as if only this third force and the equivalent of the other two had acted on the body. Thus, in fig. 8. the three forces AB, AC, AE, may act at once on a particle of matter. Complete the parallelogram ABDC; the diagonal AD is the force which is generated by AB and AC. Complete the parallelogram AEFD; the diagonal AF is the force reſulting from the combined action of the forces AB, AC, and AE. In like manner, completing the parallelogram AGHF, the diagonal AH is the force reſulting from the combined action of AB, AC, AE, and AG, and ſo on of any number of forces.

Plate XXII.

This reſulting force and the reſulting motion may be much more expeditiouſly determined, in any degree of compoſition, by drawing lines in the proportion and direction of the forces in ſucceſſion, each from the end of the preceding. Thus, draw AB, BD, DF, FH, and join AH; AH is the reſulting force. The demonſtration is evident.

60.

It is to be noticed here, that in the compoſition of more than two forces, we are not limited to one plane. The force AD is in the ſame plane with AB and AC; but AE may be elevated above this plane, and AG may lead below it. AF is in the plane of AD and AE, and AH is in the plane of AF and AG.

Complete the parallelograms ABLE, ACKE, ELFK. It is evident that ABLFKCD is a parallelopiped, and that AF is one of its diagonals. Hence we derive a more general theorem of great uſe.

Three forces having the proportion and direction of the three ſides of a parallelopiped, compoſe a force having the proportion and direction of the diagonal.

61 One force may balance many acting together.

Any number of forces acting together on one particle of matter are balanced by a force that is equal and oppoſite to their reſulting force; for this force would balance their reſulting force which is equivalent to them in action. When this is duly conſidered, we perceive that each force is then in equilibrio with the equivalent of all the others; for a force can balance only what is equal and oppoſite to it. It appears very readily by the geometrical conſtruction. If, inſtead of the circuit A, B, D, F, H, we take B, D, F, H, A, we have BA for the equivalent of the forces AC, AE, AG; but AB is equal and oppoſite to BA. Therefore the force AB is in equilibrio with the equivalent of all the others.

62.

When any number of forces act on one particle of matter, and are in equilibrio, if they be conſidered as acting in parcels, the equivalents of theſe parcels are in equilibrio; for let the forces AB, AC, AE, AG, A*h*, be in equilibrio, and let them be conſidered in the two parcels AB, AC, and AE, AG, A*h*; then AD is the equivalent of AB, BD (or AC), and DA is the equivalent of DF, FH, HA (or A*h*): now AD and DA balance each other. This corollary enables us to ſimplify many intricate complications of force; it alſo enables us to draw accurate concluſions from very imperfect obſervations. In moſt of our practical diſcuſſions we know, or at leaſt we attend to, a part only of the forces which are acting on a material particle; and in ſuch caſes we reaſon as if we ſaw the whole: yet is our mathematical reaſoning good with reſpect to the equivalent of all the parcels which we are contemplating, and the equivalents of the ſmaller parcels of which it conſiſts; and the neglected force, or parcel of forces, induces no error on our concluſions.

63. Expeditious methods for obtaining the reſulting motion in complicated caſes.

In the ſpontaneous phenomena of nature, the inveſtigation and diſcovery of our ultimate object of ſearch is frequently very difficult, on account of the multiplicity of directions and intenſities of the operating forces or motions. We may generally facilitate the proceſs, by ſubſtituting equivalent forces or motions acting in convenient directions. It is in this way that the navigator computes the ſhip's place with very little trouble, by ſubſtituting equivalent motions in the meridional and equatoreal directions for the real oblique courſes of the ſhip. Inſtead of ſetting down ten miles on a courſe, S. 36. 52. W. he ſuppoſes that the ſhip has ſailed eight miles due ſouth, and ſix miles due weſt, which brings her near to the ſame place. Then, inſtead of fourteen miles ſouth-weſt, he ſets down ten miles ſouth and ten miles weſt; and he proceeds in the ſame way for every other courſe and diſtance. He does this expeditiouſly by means of a traverſe table, in which are ready calculated the meridional and equatoreal ſides of right angled triangles, correſponding to every courſe and diſtance. Having done this for the courſe of a whole day, he adds all the ſouthings into one ſum and all the weſtings into another: he conſiders theſe as forming the ſides of a right angled triangle; he looks for them, paired together, in his traverſe table, and then notices what angle and what diſtance correſponds to this pair. This gives him the poſition and magnitude of the ſtraight line joining the beginning and end of his day's work.

Second Law of Motion.

The miner proceeds in the ſame way when he takes the plan of ſubterraneous workings, meaſuring, as he goes along, and noticing the bearing of each line by the compaſs, and ſetting down, from his traverſe table, the northing or ſouthing, and the eaſting or weſting, for each oblique line: but there is another circumſtance which he muſt attend to, namely, the ſlope of the various drifts, galleries, and other workings. This he does by noting the riſe or the dip of each ſloping line. He adds all theſe into two ſums; and taking the riſings from the dips, he obtains the whole dip. Thus he learns how far the workings proceed to the north, how far to the eaſt, and how far to the dip.

The reflecting reader will perceive that the line joining the two extremities of this progreſſion will form the diagonal of a rectangular parallelopiped; one of whoſe ſides lies north and ſouth, the other lies eaſt and weſt, and the third is right up and down.

The mechanician proceeds in the very ſame way in the inveſtigation of the very complicated phenomena which frequently engage his attention. He conſiders every motion as compounded of three motions in ſome convenient directions, at right angles to each other. He alſo conſiders every force as reſulting from the joint action of three forces, at right angles to each other, and takes the ſum or difference of theſe in the ſame or oppoſite directions. From this proceſs he obtains the three ſides of a parallelopiped, and from theſe computes the poſition and magnitude of the diagonal. This is the motion or force reſulting from the compoſition of all the partial ones.

Forces may be eſtimated by, or reduced to,

This procedure is called the Estimation or Reduction of motions and forces.

64
A given direction,

A motion or force AB (fig. 9.) is ſaid to be *eſtimated* in the direction EF, or to be *reduced* to this direction when it is conceived as compounded of the motions or forces AC, AD, one of which AC is parallel to EF, and the other AD is perpendicular to it. This expreſſion is abundantly ſignificant; for it is plain that the motion AD neither promotes nor hinders the progreſs along EF, and that AC expreſſes the whole progreſs in this direction.

65
Or a given plane.

In like manner, a force AB (fig. 10.) is ſaid to be *eſtimated in*, or *reduced to*, a given plane EFGH, when it is conceived as reſulting from the joint action of two forces AC, AD, one of which is parallel to a line *a b* drawn in that plane, and the other AD is perpendicular to it. The poſition of the line *a b* is determined by letting fall B *b* perpendicular to the plane, and drawing *b* P to the point P, in which BA meets the plane; then A *a* heing drawn parallel to B *b*, will cut off *b a*, which is the reduction of the motion AB to the plane. Drawing C parallel to *a b*, and completing the parallelogram ACBD, it is evident that the motion AB is equivalent to AD and AC, which is parallel to *a b*, and the three forces AB, AC, AD, are, as they ſhould be, in one plane perpendicular to the plane EG.

66
Equilibrium of forces ſo eſtimated or reduced.

If three forces AB, AC, AD (fig. 11.), are in equilibrio, and are reduced to any one direction *d* A *l*, or to one plane EFGH, the reduced forces are alſo in equilibrio.

Firſt, Let them be reduced to one direction *d l* by drawing the perpendiculars B *b*, C *c*, D *d*; make AL equal to AD, and join BL, CL, and draw the perpendiculars L *l*, C *c*; then, becauſe the forces AB, AC, AD, are in equilibrio, ABLC muſt be a parallelogram, and AL is the force equivalent to AB and AC combined; then, becauſe the lines D *d*, B *b*, C *c*, L*l*, are parallel, *d* A is equal to A *l*, and A *b* to C *o*, or to *c l*; therefore A *l* is equal to the ſum of A *b* and A *c*, which are the reductions of AB and AC; therefore *d* A is equal to the ſame ſum, and in equilibrio with them.

Second Law of Motion.

Secondly, Let them be reduced to one plane EFGH, and let $\alpha\beta$, $\alpha\kappa$, $\alpha\delta$, be the reduced forces. The lines D δ, A α, B β, C κ, L λ, are all parallel, being perpendicular to the plane; therefore the planes AB $\beta\alpha$ and CL $\lambda\kappa$ are parallel, and $\alpha\beta$, $\kappa\lambda$, are parallel. For ſimilar reaſons $\beta\lambda$, $\alpha\kappa$, are parallel; therefore $\alpha\beta\lambda\kappa$ is a parallelogram. Alſo, becauſe the lines D δ, A α, L λ, are parallel, and DA is equal to AL; therefore $\delta\alpha$ is equal to $\alpha\lambda$. But becauſe $\alpha\beta\lambda\kappa$ is a parallelogram, the forces $\alpha\beta$, $\alpha\kappa$, are equivalent to $\alpha\lambda$; and $\alpha\delta$ is equal and oppoſite to $\alpha\lambda$, and will balance it; and therefore will balance $\alpha\beta$ and $\alpha\kappa$, which are the reductions of AB and AC to the plane EFGH, while $\alpha\delta$ is the reduction of AD; therefore the propoſition is demonſtrated.

The moſt uſeful mode of reduction to their co-ordinates.

The moſt uſual and the moſt uſeful mode of reduction is to eſtimate all forces in the directions of three lines drawn from one point, at right angles to each other, like the three plane angles of a rectangular cheſt, forming the length, the breadth, and the depth of the cheſt. Theſe are commonly called the three co ordinates. The reſulting force will be the diagonal of this parallelopiped. This proceſs occurs in all diſquiſitions in which the mutual action of ſolids and fluids is conſidered, and when the oſcillation or rotation of detached free bodies is the ſubject of diſcuſſion.

67
Relative motions of bodies not affected by any extraneous equal and parallel force.

The only other general theorem that remains to be deduced from this law of motion is, that if a number of bodies are moving in any manner whatever, and an equal force act on every particle of matter in the ſame or parallel directions, their relative motions will ſuffer no change; for the motion of any body A (fig. 12.), relative to another body B, which is alſo in motion, is compounded of the real motion of A, and the oppoſite to the real motion of B; for let A move uniformly from A to C, while B deſcribes BD uniformly, draw AB, alſo draw AE equal and parallel to BD, join EC, DC, ED. The motion of A, relative to B, conſiſts in its change of poſition and diſtance. Had A deſcribed AE, while B deſcribed BD, there would have been no change of relative place or diſtance; but A is now at C, and DC is its new direction and diſtance. The relative or apparent motion of A therefore is EC. Complete the parallelogram ACFE; it is plain that the motion EC is compounded of EF, which is equal and parallel to AC, the real motion of A, and of EA, the equal and oppoſite to BD, the real motion of B.

Now let the motions of A and B ſuſtain the ſame change; let the equal and parallel motions AG, BH, be compounded with the motions AC and BD; or let forces act at once on A and B, in the parallel directions AG, BH, and with equal intenſities; in either ſuppoſition, the reſulting motions will be A *c*, B *d*, the diagonals of the parallelograms A G *c* C, and B H *d* D. Conſtruct the figure as before, and we ſee that the relative motion is now *e c*, and that it is the ſame with EC both in reſpect of magnitude and poſition.

Here we ſtill ſee the conſtant analogy between the compoſition of motions and the compoſition of forces.

In the firſt caſe, the relative motions of things are not changed, whatever common motion be compounded with them all; or, as it is uſually, but inaccurately, expreſſed, although the ſpace in which they move be carried along with any motion whatever. In the ſecond caſe, the relative motions and actions are not changed by any external force, however great, when equally exerted on every particle in parallel directions.

Thus it is that the evolutions of a fleet in a uniform current are the ſame, and produced by the ſame means, as in ſtill water. Thus it is that we walk about on the ſurface of this globe in the ſame manner as if it neither revolved round the ſun, nor turned round its axis. Thus it is that the ſame ſtrength of a bow will communicate a certain velocity to an arrow, whether it is ſhot eaſt, or weſt, or north, or ſouth. Thus it is that the mutual actions of ſublunary bodies are the ſame, in whatever directions they are exerted, and notwithſtanding the very great changes in their velocities by reaſon of the earth's rotation and orbital revolution. The real velocity of a body on the earth's equator is about 3000 feet per ſecond greater at midnight than at midday. For at midnight the motion of rotation nearly conſpires with the orbital motion, and at midday it nearly oppoſes it. The difference between the velocities at the beginning of January and the beginning of July is vaſtly greater. And at other times of the day, and other ſeaſons of the year, both motions of the earth are tranſverſely compounded with the eaſterly or weſterly motion of an arrow or cannon bullet. Yet we can obſerve no change in the effects of the mutual actions of bodies.

68
This affords a demonſtration of the proportionality of moving forces to the motions produced by them,

This is an important obſervation; becauſe it proves that forces are to be meaſured by no other ſcale than by the motions which they produce. We have had repeated occaſions to mention the very different eſtimation of moving forces by Mr Leibnitz; and have ſhewn how, by a very partial conſideration of the action of thoſe natural powers called *preſſures*, he has attempted to prove that moving forces are proportional to the ſquares of the velocities; and we ſhewed briefly, in what manner a right conſideration of what paſſes when motion is produced by meaſurable preſſures, proves that the forces really exerted are as the velocities produced. But the moſt copious proof is had from the preſent obſervation, that, in fact, the mutual actions of bodies depend on their relative motions alone.

69
And is incompatible with their proportionality to the ſquares of thoſe motions.

The Leibnitzian meaſure of moving force is altogether incompatible with the univerſal fact now mentioned, *viz.* that the relative motions of bodies, reſulting from their mutual actions, are not affected by any common motion, or the action of any equal and parallel force on both bodies: for this univerſal fact imports, that when two bodies are moving with equal velocities in the ſame direction, a force applied to one of them, ſo as to increaſe its velocity, gives it the ſame motion relative to the other, as if both bodies had been at reſt. Here it is plain that the ſpace deſcribed by the body in conſequence of the primitive force, and of the force now added, is the ſum of the ſpaces which each of them would generate in a body at reſt. Therefore the forces are proportional to the velocities or changes of motion which they produce, and not to the ſquares of thoſe velocities. This meaſure of forces, or the poſition that a force makes the ſame change on any velocity whatever, and the dependence of the relative motions on any motion that is the ſame on all the bodies of a ſyſtem, are counterparts of each other. Since this independence is a matter of obſervation in all terreſtrial bodies, we are intitled to ſay, that the powers which the Author of Nature has imparted to natural bodies are no way different from what are competent to matter once called into exiſtence. And it alſo follows from this, that we muſt always remain ignorant of the abſolute motions of bodies. The fact, that it has required the unremitted ſtudy of ages to diſcover even the relative motions of our ſolar ſyſtem, is an argument to prove that the influence of this mechanical principle extends far beyond the limits of this ſublunary world; nor has any phenomenon yet been exhibited which ſhould lead us to imagine that it is not univerſal.

So Bernoulli's defence of this laſt opinion is without force.

When we have made uſe of theſe arguments with ſome zealous partizans of Mr Leibnitz's doctrine, they have anſwered, that if indeed this independence of the relative motions of terreſtrial bodies were obſerved to obtain exactly, it would be a concluſive argument. But the motion with which all is carried along is ſo great in compariſon with the motions which we can produce in our experiments, that the ſmall additions or diminutions that we can make to the velocity of this common motion muſt obſerve very nearly the proportions of the additions or diminutions of their ſquares. The differences of the ſquares of 2, 3, and 4, are very unequal; but the differences of the ſquares of 9, 10, 11, are much nearer to the ratio of equality; and the differences of the ſquares of 1000001, 1000002, 1000003, do not ſenſibly deviate from this ratio. But it is not fact that we cannot produce motions which have a very ſenſible proportion to the common motion. The motion of a cannon ball, diſcharged with one-third of its weight of powder, is nearly equal to that of the rotation of the earth's equator. When, therefore, we diſcharge the ball eaſtward, we double its motion; when to the weſtward, we deſtroy it. Therefore, according to Leibnitz, the action in the firſt caſe is three times the action in the ſecond. In the firſt caſe it changes the ſquare of the velocity (which we may call 1) from 1 to 4; and, in the ſecond, it changes it from 1 to 0. But ſay the Leibnitzians, the velocity of rotation is but $\frac{1}{63}$ of the orbital velocity of the earth, and our obſervations of the velocities of cannon bullets are not ſufficiently exact to enſure us againſt an error of $\frac{1}{31\frac{1}{2}}$. But the later obſervations on the peculiar motions of the fixed ſtars concur in ſhewing, that the ſun, with his attending planets, are carried along with a very great motion, which, in all probability, has a ſenſible ratio to the orbital motion of the earth. This muſt make a prodigious change on the earth's abſolute motion, according as her orbital motion conſpires with, oppoſes, or croſſes, this other motion: the earth may even be at abſolute reſt in ſome points of its orbit. Thus will the compoſition with the motions produced in our experiments be ſo varied, that caſes *muſt* occur when the difference of the reſults of the two meaſures of force will be very ſenſible.

But, farther, they have not attended to the agreement of our experiments, when the diſcharges of cannon are made in a direction tranſverſe to that of the common motion. Here the immenſity of the common motion, and the minuteneſs of our experimental velocities, can have no effect in diminiſhing the difference of the reſults of the two doctrines. This will appear diſtinctly

tinctly to every reader who is much converſant in diſquiſitions of this kind ; and it is in theſe more moderate motions that the complete independence of the relative motions on the common motions moſt accurately appears. Pendulum clocks and watches have been often executed which do not deviate from perfect equability of motion one part in 86400. This could not be obtained in all directions of the oſcillations, if the forces deviated from the ratio of the velocities one part in 86400.

Perfect agreement of the abſtract notion of force with all our accurate obſervations of the exertions of natural powers.

On the whole, we may conſider it as eſtabliſhed on the ſureſt foundation, that the action of thoſe powers of natural bodies which we call *preſſure*, ſuch as the force of ſprings, the exertions of animals, the coheſion of bodies, as well as the action of thoſe other incitements to motion which we call *attractions* and *repulſions*, ſuch as gravitation, magnetiſm, and electricity—is proportional to the change of velocity produced by it. And we muſt obſerve here, that this is not a mere mode of conception, the reſult of the laws of human thought, which cannot conceive a natural power as the cauſe of motion otherwiſe than by its producing motion, and which cannot conceive any degree of *moving* power different from the degree of the motion. This is the abſtract doctrine, and is true whether the preſſures are proportional to the velocities or to the ſquares of the velocities. But we ſee farther, that whatever is the preſſure of a ſpring (for example) on a quieſcent body, yet the preſſure actually exerted in producing a double velocity is only double, and not quadruple, as our firſt imperfect obſervations make us imagine.

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Newton's third law of motion is founded on experience alone, and is not a neceſſary truth.

Sir Iſaac Newton has added another propoſition to the number of laws of motion ; namely, that *every action is accompanied by an equal and contrary reaction.* But in affirming this to be a law of nature, he only means that it is an univerſal fact : And he makes this affirmation on the authority of what he conceives to be a law of human thought ; namely, that thoſe qualities which we find in all bodies on which we can make experiments and obſervations, are to be conſidered as univerſal qualities of body. But we have limited the term *law of motion* to thoſe conſequences that neceſſarily flow from our notions of motion, of the cauſes of its production and changes. Now this third Newtonian propoſition is not ſuch a reſult. A magnet is ſaid to act on a piece of iron when, and only when, the vicinity of the magnet is obſerved to be accompanied by certain motions of the iron. But it by no means follows from this obſervation, that the preſence of the iron ſhall be accompanied by any motion, or any change of ſtate whatever of the magnet, or any appearance that can ſuggeſt the notion that the iron acts on the magnet. When this was obſerved, it was accounted a diſcovery. Newton *diſcovered* that the ſun acts on the planets, and that the earth acts on the moon ; and Kepler *diſcovered* that the moon reacts on the earth. Newton had obſerved that the iron reacts on the magnet ; that the actions of electrified bodies were mutual ; and that every action of ſublunary bodies was, in fact, accompanied by an equal and contrary reaction. On the authority of his rule of philoſophizing, 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. He pointed out ſeveral conſequences of this reaction. Aſtronomers examined the celeſtial motions more narrowly, and found that thoſe conſequences do really obtain, and diſturb all the planetary motions. It is now found that this reciprocity of action obtains throughout the ſolar ſyſtem with the utmoſt preciſion, and that the third Newtonian propoſition is really a law of nature, although it is not a law of human thought. It is a diſcovery. The contrary involves no abſurdity or contradiction. It would indeed be contrary to experience ; but things might have been otherwiſe. It is conceivable, and poſſible, that a ball A ſhall ſtrike another equal ball B, and carry it along with it, without any diminution of its velocity. The fact, that the velocity of A is reduced to one-half, is the indication of a force reſiding in B, which force changes the motion of A; and the intenſity of this force is learned from the change which it produces. This *is found* to be equal to the change produced by A on B. And thus the reaction of B is *diſcovered* to be equal to the action of A.

It is highly probable, that this univerſality and equality of reaction to action is the conſequence of ſome general principle, which we may in time diſcover ; meanwhile we are intitled to ſuppoſe it univerſal, and to reaſon from this topic in our diſquiſitions about the actions of bodies on each other.

Maupertuis, Leibnitz, and other philoſophers, have entertained very inadequate opinions concerning the foundation of the laws of motion.

Although the celebrated philoſophers of Europe have at laſt agreed in the reception of the two propoſitions ſo largely diſcuſſed by us as the laws of motion, they have differed exceedingly in their opinion about their origin and validity : Some aſſerted that they are entirely matters of experience ; while others affirmed them to be neceſſary truths. The royal academy of Berlin made this queſtion the ſubject of their prize diſſertation in the year 1744. Mr Maupertuis, preſident of the academy, publiſhed a diſſertation ; in which he endeavoured to prove that they are neceſſary truths, only becauſe *they are ſuch as make the quantity of action the leaſt poſſible* an economy which is worthy of infinite wiſdom ; and therefore certainly directs the choice of the Author of Nature. On this account alone are they neceſſary truths.

But this is not the way to conſider a queſtion of this kind. We know too little about infinite wiſdom to be able to ſay with Meſſrs Leibnitz and Maupertuis, that the Deity ſhould or ſhould not impreſs on bodies laws different from thoſe which are eſſential to matter ; and we are not to inquire whether God could or could not do this. We know from our own experience, that matter, when ſubjected to the action of intelligence, may be moved in a way extremely different from what it would follow if left to itſelf, and that its motions may either be regulated by fixed, but contingent, laws, or may be without any conſtancy whatever, and vary in every inſtance. When we ſuppoſe the exiſtence of matter and motion, a variety of truths are involved in the ſuppoſition, in the ſame manner as all the theorems in the third book of Euclid's Elements are involved in the conception of a circle and a ſtraight line. Our firſt employment ſhould be to evolve thoſe truths. We can do this in no way but by firſt noticing the relations of the ideas that we have of the different objects of contemplation, and then following the laws of human thought in our judgments concerning thoſe relations. This proceſs of the mind is expreſſed in the train of a geometrical demonſtration. The different parts or argumentations of this train are not the cauſes of our concluſions, but the means by which we form our judgement; not the reaſons of the truth of our ultimate concluſion, but the ſteps by which we arrive at the knowledge of it. The young geometer generally thinks otherwiſe: But that this is the matter of fact is plain from this, that more than one demonſtration, and often very different, can be given of the ſame theorem. We muſt proceed in the ſame manner in the preſent queſtion; and the firſt general truths which we find involved in the notions of matter, motion, and force, muſt be received as *neceſſary* truths. The ſteps by which we arrive at the diſcovery are the laws of human thought; and the expreſſion of the diſcovery, involving both the truth itſelf and the manner of conceiving it, is a neceſſary law of motion. There may be other facts, perhaps as general as any of thoſe neceſſary laws, but which do not neceſſarily reſult from the relations of our notions of motion and of force. Theſe are diſcovered by obſervation only; and they ſerve to characteriſe the forces which nature preſents to our view. Theſe facts are *contingent* laws of motion.

We apprehend that this method has been followed in treating this article. The firſt propoſition, termed *a law of motion*, is only a more convenient way of expreſſing our contemplation of motion in body as an effect of the general cauſe which we term *force*. The ſecond propoſition does nothing but expreſs more diſtinctly the relation between this cauſe and its effect; it expreſſes what we mean by the magnitude and the kind of the cauſe. The propoſition, ſtating the compoſition of forces, is but another form of the ſame law, better ſuited to the ordinary procedure in geometrical diſquiſitions.

These propoſitions might have completed the doctrines of dynamics; but it appears that, in order to the production of a material univerſe which ſhould accompliſh the purpoſes of the Creator, it was neceſſary that there be certain characteriſtic differences between the forces inherent in the various collections of matter which compoſe this univerſe. The facts or phyſical laws (for the above-mentioned laws are metaphyſical) of motion may be different from thoſe which would have been obſerved had matter been left entirely to itſelf. This difference may have introduced other laws of motion as neceſſarily reſulting from the nature of the forces. We have occaſionally mentioned ſome inſtances where this appears to obtain, but gave good reaſons for affirming, that a due examination of all circumſtances which may be obſerved in the production or variation of motion by thoſe forces, has demonſtrated that there are no ſuch deviations from the two laws of motion already determined, but that all the mechanical powers of bodies, when conſidered merely as cauſes of motion, act agreeably to the ſame laws. Careful examination was, however, ſaid to be neceſſary.

This examination muſt conſiſt in diſtinctly noticing the circumſtances that occur in the production of motion by any force whatever. It is by no means enough to ſtate ſimply the intenſity of the force and the direction of its exertion. If a force continue to act, it continues to vary the motion already produced. Should the force change its intenſity or direction while it is acting, theſe circumſtances muſt induce ſtill farther changes in the motion; and it is not till all action has ceaſed that the motion is brought to its oſtenſible ſtate, in which it is the object of our attention and our future diſcuſſions. Inſtances of the effects of ſuch continued and ſuch varied actions are to be ſeen in moſt of the phenomena of nature or art. The communication of motion by impulſe is perhaps the only inſtance (very frequent indeed) that can be produced where this is not neceſſary: Nay, we ſhall perhaps find reaſon to conclude, that this inſtance is not an exception, and that even the communication of motion from one billiard ball to another is brought about by an action continued for ſome time, and greatly varied during that time. Much preparation is therefore neceſſary before we can apply the general laws of motion to the ſolution of moſt of the queſtions which come before us in the courſe even of our elementary diſquiſitions. We muſt lay down ſome general propoſitions which determine the reſults of the continued, and perhaps varied, actions of moving forces; and we muſt mark the different effects of the ſimple continuation of action, and alſo thoſe of the variations in this continued action, both in reſpect of intenſity and direction. The effect of a mere continuance of action muſt be an acceleration of the motion; or a retardation of it, if the force continue to act in the oppoſite direction. The effect of the continued action of a tranſverſe force muſt be a continual deflection, that is, a curvelineal motion. Theſe muſt therefore now occupy our attention in their order.

Of Accelerated and Retarded Motions.

71 Circumſtantial expoſition of our conception of the condition of a body in reſpect to motion.

All men can perceive, that a ſtone dropped from the hand, or ſliding down an uniform ſlope, has its motion continually accelerated, and that the motion of an arrow riſing perpendicularly through the air is continually retarded; and they feel no difficulty in conceiving theſe changes of motion as the effects of the continual operation of their weight or heavineſs. The falling ſtone is in a different condition in reſpect of motion in the beginning and the end of its fall. In what reſpect do theſe ſtates of the body differ? Only in reſpect to what we call its *velocity*. This is an affection of motion; it is an expreſſion of the relation between the two notions or ideas which concur to form the idea of motion; namely, the ſpace and the time. Theſe are all the circumſtances that we obſerve in a motion. Time elapſes, and during its currency a ſpace is deſcribed. The term *velocity* expreſſes the magnitude of the ſpace which correſponds to ſome unit of time. Thus, the rate of a ſhip's motion is determined, when we ſay that it is nine miles in an hour, or nine miles per hour. We ſometimes ſay (but aukwardly) "The motion is at the rate, or with the velocity, of a mile in three days." It is moſt conveniently expreſſed by a number of ſome given units of length, which completely make up the line deſcribed during this unit of time. But the mechanicians expreſs it in a way more general by a fraction, of which the numerator is a number of inches, feet, yards, fathoms, or miles, and the denominator is the number of ſeconds, minutes, or hours, employed in moving along this line. This is a very proper expreſſion; for when we ſpeak of any velocity, and continue to reaſon from it, we conceive ourſelves to ſpeak of ſomething that remains the ſame, in the different occaſions of uſing the term. Now if the velocity be conſtant, it is indifferent how

how long the line may be; becauſe the time of its deſcription will be lengthened in the ſame proportion. Thus if 48 feet be deſcribed in 12 seconds, 36 feet will be deſcribed in 9 ſeconds, 16 feet will be deſcribed in 4 ſeconds, &c. Now $\frac{48}{12}$, $\frac{16}{9}$, and $\frac{16}{4}$, are fractions of equal value, being equal to $\frac{4}{1}$, or 4, that is, to the velocity of 4 feet per ſecond. The value of this fraction, or the quotient of the number of the units of length, divided by the number of units of time, is the number of thoſe units of length deſcribed uniformly in one unit of time.

Magnitude of a velocity of which we have no actual meaſure.

But how ſhall we determine the velocity of any inſtant or in any point of a motion that is continually changing? Suppoſe that a body has fallen 144 feet, and that we would aſcertain its velocity in that point of its fall, or the velocity which it has in paſſing through that point? In the next ſecond the body falls 112 feet farther. This cannot be the meaſure of the velocity at the beginning of the fourth or the end of the third ſecond. It is too great. The fall during the preceding ſecond was 80 feet. This is too ſmall. The mean of theſe two, or $\frac{80+112}{2}$, $=\frac{192}{2}$, $=96$, is probably more exact. Due attention to the nature of this motion ſhews us, that 96 is the proper meaſure, or that the motion at that inſtant is at the rate of 96 feet per ſecond. But it is peculiar to this kind of motion that the half ſum of the ſpaces deſcribed in two ſucceeding equal moments is the meaſure of the velocity in the middle inſtant. Therefore this method will not generally give an accurate meaſure. Yet it is indiſpenſably neceſſary to obtain ſome accurate meaſure; for it is in this particular alone that the ſtate of the body differs from its ſimilar ſtate in another inſtant. The difference of place makes no diſtinction; for if a body continue its motion unchanged, its condition in every different inſtant of time, or point of ſpace, is unchanged or the ſame. The change of place is not a change of motion, but is involved in the very conception of the continuation of the motion. The change of condition conſiſts, therefore, in the change of velocity. Therefore the change of velocity is the only indication, and the only meaſure of the action (perhaps accumulated) of the changing force. It is therefore the chief object of our ſearch; and accurate meaſures of velocity are abſolutely neceſſary.

When the velocity changes continually, there can be no *actual* meaſure of it. In what then does the magnitude of a velocity conſiſt, when there is no actual meaſure of it? It is a certain undeſcribable DETERMINATION; by which, if not changed, a certain ſpace *would* be uniformly deſcribed in a given unit of time. Thus we know, that if, when a ſtone has fallen 16 feet, its motion be directed along a horizontal plane, without diminution, it will move on for ever at the rate of 32 feet per ſecond. The ſpace which would be thus deſcribed is not the velocity, but the meaſure of the velocity. But the proportions of thoſe ſpaces, being the proportions of thoſe meaſures, are the proportions of the velocities themſelves. We may diſcover theſe proportions in the following manner:

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Momentary proportion of velocities that are continually changing.

Fundamental requiſite in all mechanical diſquiſitions.

Let ACG (fig. 13.) be a line deſcribed by a body with a motion anyhow continually, but gradually, varied; and let it be required to determine the proportion of the velocity in any point C to the velocity in any other point F.

AXIOM.—If A be to B in a ratio that is greater than any ratio leſs than that of C to D, but leſs than any ratio greater than that of C to D, then A is to B as C to D.

Take the ſtraight line *a c g* to repreſent the time of the body's motion along ACG, ſo that the points *a*, *c*, *f*, *g*, may repreſent the inſtants of time in which the body paſſes through the points A, C, F, G; and the portions *a c*, *c f*, *f g*, of the line *a g*, may repreſent the times employed in deſcribing the portions AC, CF, FG; and therefore *a c* is to *a f* as the time of deſcribing AC to the time of deſcribing AF.

Moreover, let *b k n o* be a line ſo related to the ſtraight line *a c f g*, by the perpendicular ordinates *a h*, *c k*, *f n*, *g o*, and the areas *a c k h*, *a f n h*, *a g o h*, may be proportional to the portions AC, AF, AG, of the line deſcribed by the moving body; and let this relation be true with reſpect to every point B, D, E, &c. and the correſponding points *b*, *d*, *e*, &c.

Then it is affirmed, that *the velocity in the point* C *is to the velocity in the point* F *as c k is to f n.*

Let the equal lines *b c*, *c d*, *e f*, *f g*, repreſent equal moments of time, and let B, D, E, G, be the points through which the body is paſſing at the inſtants *b*, *d*, *e g*. Then the areas *b i k c*, *c k l d*, *e m n f*, *f n o g*, will repreſent, and be proportional to, the ſpaces BC, CD, EF, FG, which are deſcribed during the moments *b c*, *c d*, *e f*, *f g*.

Draw *t p* parallel to *a g*, ſo as to make the rectangle *b t p c* equal to the trapezium *b i k c*; and draw the lines *q v*, *u r*, *s x*, in the ſame manner, ſo that each rectangle may be equal to its correſponding trapezium.

If the motions had been uniform during the moments *b c* and *f g*, that is, if the ſpaces BC and FG had been uniformly deſcribed, then the velocity in the point C would have been to the velocity in the point F as *c p* to *f s*: For ſince the rectangles *b t p c* and *f s x g* are reſpectively equal to the trapeziums *b i k c* and *f n o g*; and ſince *b i k c* is to *f n o g* as BC is to FG, the rectangle *b t p c* is to the rectangle *f s x g* as BC to FG. But becauſe theſe two rectangles have equal altitudes *b c* and *f g*, they are to each other in the proportion of their baſes *c p* and *g x*, or *c p* and *f s*. Therefore BC is to FG as *c p* to *f s*. But if BC and FG are uniformly deſcribed in equal times, they are proportional to the velocities of thoſe uniform motions. Therefore *c p* is to *f s* as the velocity with which BC is uniformly deſcribed to the velocity with which FG is uniformly deſcribed in an equal time.

But the motion expreſſed by the figure is not uniform, becauſe the line *b l o* recedes from the axis *a g*, and the areas, cut off by the parallel ordinates, increaſe in a greater proportion than the correſponding parts of the axis; that is, the ſpaces increaſe faſter than the times: for the moments *b c*, *c d*, *e f*, *f g*, being all equal, it is evident that the correſponding ſlips of the area continually augment. The motion is ſwifter at the inſtant *c* than at the inſtant *b*, and the velocity at the inſtant *c* is *greater* than that with which the ſpace BC would be uniformly deſcribed in the ſame time. For the ſame reaſon, the velocity at the inſtant *f* is *leſs* than that with which the ſpace FG would be uniformly deſcribed in the ſame time. Therefore the velocity at the inſtant *c* is to the velocity at the inſtant *f* in a greater ratio than that of *c p* to *f s*. In the very ſame manner, it will appear by comparing the motion during the moment

c d

cd with the motion during the moment ef, that the velocity at the inſtant c is to the velocity at the inſtant f in a leſs ratio than that of cq to fr.

Therefore the velocity in the point C is to the velocity in the point F in a greater ratio than that of cp to fs, but in a leſs ratio than that of cq to fr.

But by continually diminiſhing the equal moments. bc, cd, ef. fg, it is evident that cp and cq continually approach to equality with ck; and fr and fs, continually approach to equality with fn, that when cp is leſs than ck, fs is greater than fn, and when cq is greater than ch, fr is leſs than fn.

Therefore the velocity in the point C is to the velocity in the point F in a ratio that is greater than the ratio of *any* line leſs than ck to *any* line greater than fn, but which is leſs than the ratio of any line greater than ck to any line leſs than fn. Therefore the ratio of the velocity in C to the velocity in F is greater than any ratio that is leſs than that of ck to fn; but it is leſs than any ratio that is greater than that of ck to fn. Therefore the velocity in the point C is to the velocity in the point F as ck to fn.

This important theorem may be expreſſed in more general terms as follows:

If the abſciſſa ag *of a line* hko *repreſent the time of any motion, and if the areas bounded by parallel ordinates be proportional to the ſpaces deſcribed, the ordinates are proportional to the velocities.*

Remark. The propriety or aptitude of expreſſing the time by the portions of the axis acg, will, perhaps, appear more clearly in the following manner.

Let acg be any ſtraight line, and let hkv be another line, ſtraight or curved. Let the ſtraight line ahz, perpendicular to ag, be carried uniformly down along this line, keeping always perpendicular to it, and therefore always parallel to its firſt poſition ahz. In its various ſituations ckz, emz, &c. it will cut off areas $ackh$, $aemh$, &c. bounded by the axis by the ordinates ah and ck, or by the ordinates ah and em, &c. and by the line hkg. By this motion the moveable ordinate is ſaid, in the language of modern geometry, to *generate* the areas $ackh$, $aemh$, &c. At the ſame time, let a point A move along the line ACG, ſetting out from A at the inſtant when the line az ſets out from a; and let the motion of the point A be ſo regulated, that the ſpaces AB, AC, AD, &c. generated by this motion, may increaſe at the ſame rate with the areas, ab, ih, $ackh$, $adlh$, &c. or ſuch that we ſhall have AB to AC as $abih$, to $ackh$, &c. It is plain, that the motion along AG is the ſame with that deſcribed in the enunciation of the propoſition: for becauſe the motion of the ordinate az, along the axis ag, is ſuppoſed to be uniform, the ſpaces ab, ac, ad, &c. are proportional to the times in which they are deſcribed, and may therefore be taken to meaſure or to repreſent thoſe times.

73. Cor. 1. *In a motion continually varied, the velocities in the different points of the path are to each other in the limiting or ultimate ratio of the ſpaces deſcribed in equal times*, thoſe times being ſuppoſed to diminiſh continually: for it is evident, that if the equal moments bc, cd, ef, fg, are ſuppoſed to diminiſh continually, till the inſtants b and d coaleſce with c, and the inſtants e and g coaleſce with f; then the ratio of ck to fn is the limit of the continually increaſing ratio of cp to fs, or of the continually diminiſhing ratio of cq to fr. Sir Iſaac Newton calls this the ultimate ratio of cp to fs, or of cq to fr. Now the ratio of cp to fs is, by conſtruction, the ſame with the ratio of the rectangle $btpc$ to the rectangle $fsxg$, and the ratio of cq to fr is the ſame with the ratio of the rectangle $cqvd$ to the rectangle $eurf$. But the ratio of the rectangle $btpc$ to the rectangle $fsxg$ is the ſame with the ratio of the ſpace $bikc$ to the ſpace $fnog$; that is (by hypotheſis), the ſame with the ratio of the ſpace BC to the ſpace FG; and the ratio of the rectangles $cqvd$ and $eurf$ is the ſame with that of the ſpaces CD and EF. Therefore the ratio of the velocity at C to the velocity at F is the ſame with the ultimate ratio of the ſmall increments BC, FG, or CD, EF of the ſpaces generated in very ſmall and equal times.

It is alſo evident, that becauſe the ratio of ck to fn is the limit both of the ratio of cp to fs and of the ratio of cq to fr, theſe ultimate ratios are the ſame, and that we may ſay that the velocity in C is to the velocity in F in the ultimate ratio of BC to EF, or in the ultimate ratio of CD to FG.

We alſo can eaſily perceive, that the ratio of the area $bikc$ to the area $emnf$ approaches more near to the ratio of ck to fn as we take the moments bc and ef ſmaller. Therefore, in many caſes of practice, where it may be eaſy to meaſure the ſpaces deſcribed in the different ſmall moments of the motion, but difficult to aſcertain their ultimate ratio, ſo as to obtain accurate meaſures of the proportions of the velocities, we may reduce the errors of meaſurement to ſomething very inſignificant, by taking theſe moments extremely ſmall; and we ſhall diminiſh the error ſtill more, by taking the proportion of the half ſum of BC and CD to the half ſum of EF and FG for the proportion of the velocities in C and F.

It often happens that we have it not in our power to compare the ſpaces deſcribed in ſmall moments which are preciſely equal. Still we can find the exact proportion of the velocities, if we can aſcertain the ultimate ratio of the increments of the ſpaces, and the ultimate ratio of the moments of time in which theſe increments are deſcribed: for it is plain, by conſidering the gradual approach of the points p and r to the points k and n, that the ratio of ck to fn is ſtill the ultimate ratio of the baſes of rectangles equal to the mixtilineal areas, whether the altitudes (repreſenting the moments) are equal or not. Now the baſes of two rectangles are in the proportion of the rectangles directly, and of their altitudes inverſely. But the ultimate ratio of the altitudes is the ultimate ratio of the moments, and the ultimate ratio of the rectangles is the ultimate ratio of the ſpaces deſcribed in thoſe unequal moments. Therefore, in ſuch caſes, we have,

74. Cor. 2. *The velocities are in the ratio compounded of the direct ultimate ratio of the momentary increments of the ſpaces, and the inverſe ultimate ratio of the increments (or moments) of the times in which theſe increments of the ſpaces are made.*

If s, v, and t, are taken to repreſent the magnitudes of the ſpaces, velocities, and times, and if $\dot{s}$, $\dot{v}$, and $\dot{t}$, are taken always in the limiting or ultimate ratio of their momentary increments, we ſhall have v always in the

the proportion of $\dot s$ directly, and of $\dot t$ inverſely. We expreſs this by the proportional equation $v \doteq \frac{\dot s}{\dot t}$, which is equivalent to the analogy $V : v = \frac{\dot S}{\dot T} : \frac{\dot s}{\dot t}$, or $V : v = \dot S \dot t : \dot s \dot T$.

75. *N. B.* Here obſerve, that this is not the only way of ſtating the relation of ſpace and time—the abſciſſa may be made the time, and the ordinate the ſpace; then the velocity $= \frac{\dot y}{\dot x}$.

The converſe of this propoſition may be thus expreſſed.

76
Converſe
heorem.

If the axis a g *of the line* h k o *repreſent the time of a varied motion along the line* AG, *and if the ordinates* a h, b i, c k, *&c. be as the velocities in the inſtants* a, b, c, *or in the points* A, B, C; *then the areas* a b i h, a c k h, a d l h, *&c. are proportional to the ſpaces* AB, AC, AD, *&c.*

This may be demonſtrated in the ſame way with the former; but the indirect demonſtration is more brief, and equally ſtrict.

If the ſpaces AC, AF, &c. are not proportional to the areas *a c k h*, *a f n h*, &c. they are proportional to ſome other areas *a c k h'*, *a f n' h'*, &c. which are bounded by the ſame ordinates, and by another line *h' k n'*. But becauſe the areas *a c k h'*, *a f n' h'*, &c. are always proportional to the ſpaces AC, AF, &c. deſcribed on the line AG, the velocity in the point C is to the velocity in the point F as the ordinate *c k* is to the ordinate *f n'*. But, by hypotheſis, the velocity in C is to the velocity in F as *c k* to *f n*, and *f n'* is equal to *f n*; which is abſurd. Therefore the ſpaces AC, AF, are not proportional to any other areas, &c.

77. Cor. *The ultimate ratio of the momentary increments of the ſpaces is compounded of the ratio of the velocities, and the ultimate ratio of the increments of the times:* for when the moments *b c*, *e f*, are equal, it is evident that the ultimate ratio of the rectangles *b c p t*, *e f r u* is the ſame with the ultimate ratio of the increments of the ſpaces. But the ultimate ratio of theſe rectangles is the ſame with their baſes *c p* and *f r*; that is, the ratio of *c k* to *f n*, that is, the ratio of the velocities. And when the moments are unequal, the ratio of the rectangles is compounded of the ratio of their baſes and the ratio of their altitudes; that is, compounded of the ratio of the velocities and the ultimate ratio of the moments of time.

We have, therefore, $\dot S : \dot s = V\dot T : v\dot t$, and $\dot s \doteq v\dot t$.

It moſt commonly happens, that we can only obſerve the accumulated reſults of varied motions; and in them we only obſerve a ſpace paſſed over, and a certain portion of time that has elapſed during the motion. But being able to diſtinguiſh the portions of the whole ſpace which are deſcribed in known portions of the whole time, and having made ſuch obſervations in ſeveral parts of the motion, we diſcover the general law that the motion affects, and we affirm this law to hold univerſally, even though we have not obſerved it in *every* point. We do this with a degree of probability and confidence proportioned to the frequency of our obſervation. It is not till we have done this that we can make uſe of the firſt of theſe two propoſitions, which enables us to aſcertain the velocity of the motion in its different moments. Thus if we obſerve, that a ſtone in falling deſcends one foot in the quarter of a ſecond, 16 feet in a ſecond, 64 feet in two ſeconds, and 144 feet in three ſeconds; the general law immediately obſerved is, "that the ſpaces deſcribed are as the ſquares of the times;" for 1 is to 16 as the ſquare of $\frac{1}{4}$th to the ſquare of 1. Again, 16 is to 64 as 1^2 to 2^2; and 16 is to 144 as 1^2 to 3^2. Hence we infer, with great probability, that the ſtone would fall 36 feet in a ſecond and a half; for 16 is to 36 as 1^2 to $1\frac{1}{2}^2$; and we conclude in the ſame way for all other parts of the motion.

78
A good example of the geometrical method.

This immediate obſervation of the analogy between the ſpaces and the ſquares of the times ſuggeſts an eaſy determination of the velocity in this particular kind of motion; and it merits particular notice, being very often referred to. We can take *a g* to repreſent the time; and then, becauſe the areas which are to repreſent the ſpaces deſcribed muſt be proportioned to the ſquares of the portions of *a g*, we perceive that the line which comes in place of *h k o* muſt be a ſtraight line drawn from *a*. For example, the ſtraight line $a\,\delta\,\gamma$. For this is the only boundary which will give areas $a\,b\,\beta$, $a\,c\,\gamma$, $a\,d\,\delta$, &c. proportional to $a\,b^2$, $a\,c^2$, $a\,d^2$, &c. And we perceive that *any* ſtraight line drawn from *a* will have this property.

Having thus got our repreſentations of the times and the ſpaces, we ſay, on the authority of our theorem, that the velocity at the inſtant *b* is to the velocity at the inſtant *d* as $b\,\beta$ to $d\,\delta$, &c. And now we begin to make inferences, purely geometrical, and expreſs our diſcovery of the velocities in a very general and ſimple manner. We remark, that $b\,\beta$ is to $d\,\delta$ as *a b* is to *a d*; and we make the ſame affirmation concerning the magnitudes repreſented by theſe lines. We ſay that the velocity at the inſtant *b* is to the velocity at the inſtant *d* as the time *a b* is to the time *a d*. We ſay, in terms ſtill more general, that the velocities are proportional to the times from the beginning of the motion. We moreover perceive, that the ſpaces are alſo proportional to the ſquares of the acquired velocities; or the velocities are as the ſquare roots of the ſpaces.

We can farther infer, from the properties of the triangle, that the momentary increments of the ſpaces are proportional to the momentary increments of the ſquares of the times, or of the ſquares of the velocities.

We alſo obſerve, that not only the whole acquired velocities are proportional to the whole elapſed times, but that the increments of the velocities are proportional to the times in which they are acquired; for $\pi\,\kappa$ is to $\rho\,\varphi$ as *b c* to *d f*, &c. Equal increments of velocity are therefore acquired in equal times. Therefore ſuch a motion may, in great propriety of language, be denominated a UNIFORMLY ACCELERATED MOTION; that is, *a motion in which we obſerve the ſpaces proportioned to the ſquares of the times, is a motion uniformly accelerated*; and ſpaces in the duplicate ratio of the times form the oſtenſible characteriſtic of an uniformly accelerated motion.

79. Laſtly, if we draw $\varepsilon\,\lambda$ parallel to the axis *a b*, we perceive that the rectangle $a\,e\,\varepsilon\,\lambda$ is double of the triangle $a\,e\,\varepsilon$. Now becauſe *a e* repreſents the time of the motion, and $e\,\varepsilon$ repreſents the acquired velocity, the rectangle $a\,e\,\varepsilon\,\lambda$ will repreſent the ſpace which would be uniformly deſcribed with the velocity $e\,\varepsilon$ during the time

a e. But the triangle *a e i* repreſents the ſpace really deſcribed with the uniformly accelerated motion during the ſame time. Hence we infer, that the ſpace that is deſcribed in any time, with a motion increaſing uniformly from nothing, is one-half of the ſpace which would be uniformly deſcribed during the ſame time with the final velocity.

Theſe are but a part of the inferences which we may draw from the geometrical properties of thoſe repreſentations which we had ſelected of the different meaſureable affections of motion. We may affirm, with reſpect to the motions themſelves, all the inferences which relate to magnitude and proportion, and thus improve our knowledge of the motions.

We took the opportunity of this very ſimple and perſpicuous axample, to give our young readers a juſt conception of the *mathematical method* of proſecuting mechanical knowledge, and to make them ſenſible of the unqueſtionable authority for every theorem deduced in this manner.

One of the moſt important is, to diſcover the accumulated reſult of a motion of which we only obſerve the momentary increments. This is to be done by finding the area, or portions of the area, of the mixtilineal ſpace *a g o h*; and it is evidently analogous to the inverſe method of fluxions, or the integral calculus.

In moſt caſes, we muſt avail ourſelves of the corollary $\dot{s} \doteq v\,\dot{t}$, and we obtain the ſolution of our queſtion only in the caſes where our knowledge of the quantities $\dot{s}$, $\dot{t}$, and v (conſidered as geometrical magnitudes, that is, as lines and ſurfaces), enables us to diſcover s and t.

Of Accelerating and Retarding Forces.

80 Having thus diſcovered the proportions of the velocities in motions varying in any manner whatever, we can obſerve the variations which happen in them. Theſe variations are the effects, and the only marks and meaſures, of the changing forces. They are the characteriſtics of their kinds (conſidered merely as moving forces); that is, the indications of the directions in which they act; for this is the only difference *in kind* of which they are ſuſceptible in this general point of view. If they increaſe the velocity, their direction muſt be conceived as the ſame with that of the previous motion; becauſe the reſult of the action of a force is equivalent to the compoſition of the motion which that force would produce in a quieſcent body with the motion already exiſting: and an increaſe of velocity is equivalent to the compoſition of a motion in the ſame direction.

Having no other mark of the force but the acceleration, we have no other name for it in the abſtract doctrines of dynamics, and we call it an ACCELERATING FORCE. Had it retarded the motion, we ſhould have called it a RETARDING FORCE.

In like manner, we have no meaſure of the *magnitude* or *intenſity* of an accelerating force, but the acceleration which it produces. In order therefore to inveſtigate the powers which produce all the changes of motion, we muſt endeavour to obtain meaſures of the acceleration.

A continual increaſe of velocity is the effect of the continued action of accelerating forces. If equal increments of velocity are produced in every ſucceeding equal moment of time, we cannot conceive that there is any change in the accelerating force. Therefore a uniformly accelerated motion is the mark of the unvaried action of an accelerating force, that is, of the continued action of a conſtant force; of a force whoſe intenſity is always the ſame. When therefore we obſerve a body deſcribe ſpaces proportional to the ſquares of the times, we muſt infer that it is urged forward by a force whoſe intenſity does not change; and, on the other hand, a conſtant force muſt produce a uniformly accelerated motion by its continued action. And if any previous circumſtances aſſure us of this continued action of an invaried force, we may make all the inferences which were mentioned under the article of uniformly accelerated motion.

81
Meaſure of an accelerating force.

That force muſt ſurely be accounted double which produces a double increment of velocity in the ſame time hy its uniform action, we can form no other eſtimation of its magnitude. And, in general, *accelerating forces muſt be accounted proportional to the increments of velocity which they produce, by acting uniformly during the ſame or equal times.*

Another meaſure.

Suppoſing them to act on a body at reſt. Then the velocity produced is itſelf the increment; and we muſt ſay, that accelerating forces are proportional to the velocities which they generate in a body in equal times. And becauſe we found (n 79.), that the ſpace deſcribed with a uniformly accelerated motion is half the ſpace which would be uniformly deſcribed in the ſame time with the final velocity, which ſpace is the direct meaſure of this velocity, and becauſe halves have the ſame proportion with the wholes—we may ſay that *accelerating forces are proportional to the ſpaces through which they impel a body from reſt in equal times by their uniform action.*

This is an important remark; becauſe it gives us an eaſy meaſure of the force, without the trouble of firſt computing the velocities. It alſo gives us the only diſtinct notion that we have of the meaſurement of forces by the motions which they produce. When ſpeaking of the compoſition of forces we diſtinguiſhed or denominated them by the ſides and diagonal of a parallelogram These lines muſt be conceived as proportional to the ſpaces through which the forces urge the body *uniformly* during the ſmall and inſenſible time of their action, which time is ſuppoſed to be the ſame for both forces; for the ſides of the parallelogram are ſuppoſed to be ſeparately deſcribed in equal times, and therefore to be proportional to the velocities generated by the conſtituent forces. If indeed the forces do not act uniformly, nor ſimilarly, nor during equal times, we cannot ſay (without farther inveſtigation) what is the proportion of the intenſity of the forces, nor can we infer the compoſition of their action. We muſt at leaſt ſuppoſe, that in every inſtant of this very ſmall time of their joint action, their direction remains unchanged, and that their intenſities are in the ſame ratio. We ſhall ſee by and bye, that with theſe conditions the ſides of the parallelogram are ſtill proportional to the velocities generated. In the mean time, we may take the ſpaces through which a body is uniformly impelled from reſt (that is, with a uniformly accelerated motion) as the meaſures of the forces; yet theſe ſpaces are but the halves of the meaſures of the velocities. Then, if a body be moving with the velocity of 32 feet per ſecond, and an accelerating force acts on it during a ſecond,

and

Of Accelerating and Retarding Forces.

and if this force be ſuch that it would impel the body (from a ſtate of reſt) 16 feet, it will add to the body a velocity of 32 feet per ſecond. Accordingly, this is the effect of gravity—the weight of a pound of lead may be conſidered as a force which does not vary in its intenſity. We know that it will cauſe the lead to fall 16 feet in a ſecond; but if the body has already fallen 16 feet, we know that it is then moving with the velocity of 32 feet per ſecond. And the fact is, that it will fall 48 feet farther in the next ſecond, and will have acquired the velocity of 64 feet per ſecond. It has therefore received an augmentation of 32 feet of velocity by the action of gravity during the 2d ſecond; and gravity is in fact a conſtant force, cauſing equal increments of velocity in equal times, however great the velocities may be. It does not act like a ſtream of fluid, whoſe impulſe or action diminiſhes as the ſolid body withdraws from it by yielding.

But ſuppoſing that we have not compared the increments of velocity uniformly acquired during equal times, in what manner ſhall we meaſure the accelerating forces? In ſuch a caſe, that force muſt be accounted double which generates the ſame velocity, by acting uniformly during half the time; for when the force is ſuppoſed invariable, the changes of velocity which it produces are proportional to the times of its action; therefore if it produces an equal velocity in half the time, it will produce a double velocity in an equal time, and is therefore a double force. The ſame may be ſaid of every proportion of time in which an equal change of velocity is produced by the uniform action of an accelerating force. The force muſt be accounted greater in the ſame proportion that the time required for the production of a given velocity in a body is leſs. Hence we infer, that *accelerating forces are inverſely proportional to the times in which a given change of velocity is produced by their uniform action.*

By combining theſe two propoſitions we eſtabliſh this general theorem:

82
Meaſure of accelerating force,

Accelerating forces are proportional to the changes of velocity which they produce in a body by their uniform action directly, and to the times in which theſe changes are produced inverſely.

If, therefore, A and a are the forces, V' and v' the changes of velocity, and T' and t' the portions of time in which they are uniformly produced, we have

$$A : a = V't' : v'T', = \frac{V'}{T'} : \frac{v'}{t'}$$

$$\text{And } a \doteq \frac{v'}{t'}.$$

The formula $a \doteq \frac{v'}{t'}$ is not reſtricted to any particular magnitude of v' and t'. It is true, therefore, when the portion of time is diminiſhed without end; for ſince the action is ſuppoſed uniform, the increment of velocity is leſſened in the ſame proportion, and the value of the fraction $\frac{v'}{t'}$ remains the ſame. The characters or ſymbols v' and t' are commonly uſed to expreſs *finite* portions of v and t. The ſymbols $\dot{v}$ and $\dot{t}$ are uſed by Newton to expreſs the ſame things taken in the ultimate or limiting ratio. They are uſually conſidered as *indefinitely ſmall* portions of v and t. We ſhall abide by the formula $a \doteq \frac{\dot{v}}{\dot{t}}$.

Of Accelerating and Retarding Forces.

It muſt always be kept in mind, that v and t are abſtract numbers; and that v refers to ſome unit of ſpace, ſuch as a foot, an inch, a yard; and that t refers to ſome unit of time, ſuch as an hour, a minute, a ſecond; and eſpecially that a is the number of the ſame units of ſpace, which will be uniformly deſcribed in *one* unit of the time with the velocity generated, by the force acting uniformly during *that* unit. It is twice the ſpace actually deſcribed by the body during that unit when impelled from reſt by the accelerating force. It is neceſſary to keep hold of theſe clear ideas of the quantities expreſſed by the ſymbols.

83
Is an abſtract number.

Meaſure of a change of velocity.

On the other hand, when the meaſure of the accelerating force is previouſly known, we employ the theorem $a\,t' = v'$; that is, the addition made to the velocity during the whole, or any part, of the time of the action of the force is obtained by multiplying the acceleration of one unit of time by the number of ſuch units contained in t'.

Theſe meaſures expreſs the greateſt part of our knowledge of mechanical nature.

Theſe are evidently leading theorems in dynamics; becauſe all the mechanical powers of nature come under the predicament of accelerating or retarding forces. It is the collection of theſe in any ſubject, and the manner in which they accompany, or are inherent in it, which determine the mechanical character of that ſubject; and therefore the phenomena by which they are brought into view are the the characteriſtic phenomena. Nay, it may even be queſtioned, whether the phenomena bring any thing more into view. This force, of which we ſpeak ſo familiarly, is no object of diſtinct contemplation; it is merely a ſomething that is proportional to $\frac{\dot{v}}{t}$. And when we obſerve, that the $\frac{\dot{V}}{T}$, found in the motions that reſult from the vicinity of a body A, is double of the $\frac{\dot{v}}{t}$, which reſults from the vicinity of another body B; we ſay that a force reſides in A, and that it is double of the force reſiding in B. The accelerations are the things immediately and truly expreſſed by theſe ſymbols. And the whole ſcience of dynamics may be completely taught without once employing the word *force*, or the conception which we imagine that we form of it. It is of no uſe till we come to ſtudy the mechanical hiſtory of bodies. Then, indeed, we muſt have ſome way of expreſſing the fact, that an acceleration $= \frac{32 \text{ feet}}{1''}$ is obſerved in every thing on the ſurface of this globe; and that an acceleration $= \frac{418 \text{ feet}}{1''}$ is obſerved over all the ſurface of the ſun. Theſe facts are characteriſtic of this earth and of the ſun; and we expreſs them ſhortly by ſaying, that ſuch and ſuch forces reſide in the earth and in the ſun. It will preſerve us from many miſtakes and puzzling doubts, if we reſolutely adhere to this meaning of the term *force*; and this will carry mathematical evidence through the whole of our inveſtigations.

84
Another meaſure of accelerating force.

As velocity is not an immediate object of contemplation, and all that we obſerve of motion is a ſpace and a time, it may be proper to give an expreſſion of this meaſure of accelerating force which involves no other idea. Suppoſing the body to have been previouſly at reſt, we have $a \doteq \frac{v}{t}$. Multiply both parts of the fraction by t, which does not change its value, and we have $a \doteqdot \frac{v\,t}{t^2}$. But $v\,t = s$; and therefore $a \doteqdot \frac{s}{t^2}$.

The formula $a = \frac{s}{t^2}$ is equivalent to the proportion $t^2 : 1 = s : a$; and a would then be the ſpace through which the accelerating force would impel the body in one unit of the time t. But this is only half of the meaſure of the velocity which the accelerating force generates during that unit of time. For this reaſon we did not expreſs the accelerating force by an ordinary equation, but uſed the ſymbol $\doteqdot$. In this caſe, therefore, of uniform action, we may expreſs the accelerating force by $a = \frac{2\,s}{t^2}$.

The following theorem is of ſtill more extenſive uſe in all dynamical diſquiſitions.

85
Moſt general meaſure of accelerating force.

Accelerating forces are proportional to the momentary increments of the ſquares of the velocities directly, and as the ſpaces along which they are uniformly acquired inverſely.

Let A′B, A′C, and AD (fig. 14.), be three lines, deſcribed in the ſame or equal times by the uniform action of accelerating forces; the motions along theſe lines will be uniformly accelerated, and the lines themſelves will be proportional to the forces, and may be employed as their meaſures. On the greateſt of them AD, deſcribe the ſemicircle ABCD, and apply the other two lines A′B, A′C as chords AB, AC. Draw EB, FC perpendicular to AD. Take any ſmall portions B b, C c of AB and AC, and draw b e, c f perpendicular to AD, and E h and F k parallel to AB and AC.

Then, becauſe the triangles DAB and BAE are ſimilar, we have $AD : AE = AD^2 : AB^2$. And becauſe AD is to AB as the velocity generated at D is to the velocity generated at B (the times being equal), we have AD to AE as the ſquare of the velocity at D to the ſquare of the velocity at B; which we may expreſs thus:

$$AD : AE = V^2, D : V^2, B.$$

For the ſame reaſons we have alſo

$$AD : AF = V^2, D : V^2, C. \quad \text{Therefore}$$
$$AE : AF = V^2, B : V^2, C.$$

But becauſe in any uniformly accelerated motion, the ſpaces are as the ſquares of the acquired velocities, we have alſo

$$AE : A\,e = V^2, B : V^2\,b, \text{ and}$$
$$AF : A\,f = V^2, C : V^2\,c.$$

Therefore E e is to F f as the increment of the ſquare of the velocity acquired in the motion along B b to the increment of the ſquare of the velocity acquired along C c.

But, by ſimilarity of the triangles ABD and E e h, we have

$$AB : AD = E\,e : E\,h; \text{ and, in like manner,}$$
$$AD : AC = F\,k : F\,f. \quad \text{Therefore}$$
$$AB : AC = E\,e \times F\,k : F\,f \times E\,h.$$

Now AB and AC are proportional to the forces which accelerate the body along the lines A′B and A′C; E e and F f are proportional to the increments of the ſquares of the velocities acquired in the motions along the portions B b and C c; and E h and F k are equal to thoſe portions reſpectively. The ratio of AB to AC is compounded of the direct ratio of E e to F f; and the inverſe ratio of E h to F k. The propoſition is therefore demonſtrated.

The proportion may be expreſſed thus:

$AB : AC = \frac{E\,e}{E\,h} : \frac{F\,f}{F\,k}$, and may be expreſſed by the proportional equation $AB \doteqdot \frac{E\,e}{E\,h}$ or, ſymbolically, $a \doteqdot \frac{\dot{(v^2)}}{s}$.

$\dot{v}v$ is but one-half of the increment of v^2.

REMARK. Becauſe the motion along any of theſe three lines is uniformly accelerated, the relation between ſpaces, times, and velocities, may be repreſented by means of the triangle ABC (fig. 15.); where AB repreſents the time, BC the velocity, and ABC the ſpace. If BC be taken equal to AB, the triangle is half of the ſquare ABCF of the velocity BC; and the triangle ADE is half of the ſquare ADEG of the velocity DE. Let D d and B b be two moments of time, equal or unequal. Then D d e E and B b c C are half the increments of the ſquares of the velocities DE and BC, acquired during the moments D d and B b. It was demonſtrated, that the ratio of the area D d e E to the area B b c C is compounded of the ratio of DE to BC, and the ultimate ratio of D d to B b. But D d and B b are reſpectively equal to ε e and × c. Therefore D d e E is to B b c C, in the ratio compounded of the ratio of DE to BC, and the ultimate ratio of ε e to × c. If we repreſent DE and BC by V and v, then ε e and × c muſt be repreſented by V' and v', the increments of V and v; and then the compounded ratio will be the ratio of VV' to $v\,v'$; and if we take the ultimate ratio of the moments, and conſequently the ultimate ratio of the increments of the velocities, we have the ratio of $V\dot{V}$ to $v\,\dot{v}$. If, therefore, V^2 and v^2 repreſent the ſquares of the velocities, $V\dot{V}$ and $v\,\dot{v}$ will repreſent not the increments of thoſe ſquares, but half the increments of them.

We may now repreſent this propoſition concerning accelerating forces by the proportional equation $a \doteqdot \frac{\dot{v}v}{s}$; and we muſt conſider this as equivalent with $a = \frac{V^2 - v^2}{2\,(S - s)}$; keeping always in mind, that a, V, and v, relate to the ſame units of time and ſpace, and that a is that number of units of the ſcale on which S and s are meaſured, which is run over in *one* unit of time.

Meaſure of gravity conſidered as an accelerating force.

This will be more clearly conceived by taking an example. Let us aſcertain the accelerative power of gravity, ſuppoſing it to act uniformly on a body. Let the ſpaces be meaſured in feet and the time in ſeconds. It is a matter of obſervation, that when a body has fallen 64 feet, it has acquired a velocity of 64 feet per ſecond: and that when it has fallen 144 feet, it has acquired the velocity of 96 feet per ſecond. We want to determine what velocity gravity communicated to it by acting on it during one ſecond. We have $V^2 = 9216$, and $v^2 = 4096$; and therefore $V'^2 - v^2 = 5120$. $S = 144$, and $s = 64$, and $S - s = 80$, and $2\,(S - s) = 160$. Now $a = \frac{5120}{160}, = 32$. Therefore gravi-

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ty has generated the velocity 32 feet per ſecond by acting uniformly during one ſecond.

86. *The augmentation of the ſquare of the velocity is proportional to the force and to the ſpace jointly.* For, becauſe $a = \frac{v\dot{v}}{\dot{s}}$, we have $a\dot{s} = v\dot{v}$.

Thus we learn, that a given force acting uniformly on a body along a given ſpace, produces the ſame increment of the ſquare of the velocity, whatever the previous velocity may have been. Alſo, in the ſame manner as we formerly found that the augmentation of the velocity was proportioned to the time during which the force has acted, ſo the augmentation of the ſquare of the velocity is proportional to the ſpace along which it has acted.

Theorems reſpecting retarding forces. It is pretty plain, that all that we have ſaid of the uniform action of an *accelerating* force may be affirmed of a *retarding force*, taking a diminution or decrement of velocity in place of an increment. A uniformly retarded motion is that in which the decrements of velocity in equal times are equal. and the whole decrements are proportional to the whole times of action. Such a motion is the indication of a conſtant or invariable force acting in a direction oppoſite to that of the motion. We conceive this to be the caſe when an arrow is ſhot perpendicularly upwards; its weight is conceived as a force continually preſſing it perpendicularly downwards.

In ſuch motions, however great the initial velocity may be, the body will come to reſt; becauſe a certain determined velocity will be taken from the body in each equal ſucceſſive moment, and ſome multiple of this will exceed the initial velocity. Therefore the velocity will be extinguiſhed before the end of a time that is the ſame multiple of the time in which the velocity was diminiſhed by the quantity above mentioned. It is no leſs evident, that the time in which any velocity will be extinguiſhed by an oppoſing or retarding force, is equal to the time in which the ſame force would generate this velocity in the body previouſly at reſt. Therefore,

87. 1. The times in which different initial velocities will be extinguiſhed by the ſame oppoſing force are proportional to the initial velocities.

88. 2. The diſtances to which the body will go till the extinction of its velocity are as the ſquares of the initial velocities.

3. They are alſo as the ſquares of the times elapſed.

89. 4. The diſtance to which a body, projected with any velocity, will go till its motion be extinguiſhed by the uniform action of a retarding force, is one half of the ſpace which it would deſcribe uniformly during the ſame time with the initial velocity.

Forces generally variable in their intenſity. It very rarely happens, that the force which accelerates the body acts uniformly, or with an unvaried intenſity. The attraction of a magnet, for example, increaſes as the iron approaches it. The preſſure of a ſpring diminiſhes as it unbends. The impulſe of a ſtream of water or wind diminiſhes as the impelled ſurface retires from it by yielding. Therefore the effects of accelerating forces are very imperfectly explained, till we have ſhewn what motions reſult from any given variation of force, and how to diſcover the variation of force from the obſerved motion. This laſt queſtion is perhaps the moſt important in the ſtudy of mechanical nature. It is only thus that we learn what is uſually called *the nature of a mechanical force.* This chiefly conſiſts in the relation ſubſiſting between the intenſity of the force and the diſtance of the ſubſtance in which it reſides. Thus the nature of that power which produces all the planetary motions, is conſidered as aſcertained when we have demonſtrated that its preſſure or intenſity is inverſely as the ſquare of the diſtance from the body in which it is ſuppoſed to reſide.

Acceleration expreſſes ſome relation of the velocity and time. This relation may be geometrically expreſſed in a variety of ways. In figure 13. the uniform acceleration or the unvaried relation between the velocity and the time is very aptly expreſſed by the conſtant ratio of the ordinates and abſciſſes of the triangle $a\,g\,\nu$. The ratio of $d\,\delta$ to $a\,d$ is the ſame with that of $c\,\varepsilon$ to $a\,e$, or that of $f\,\varphi$ to $a\,f$, &c.; or the ratio of the increment of velocity $\varpi\,\varkappa$ to the increment of the time $\beta\,\varpi$ or $b\,c$, or that of $i\,\varphi$ to $\varepsilon\,i$, &c. This ratio $\varpi\,\varkappa : \beta\,\varpi$ is equivalent to the ſymbol $\frac{\dot{v}}{\dot{t}}$

But when the ſpaces deſcribed in a varied motion are repreſented by the areas bounded by a curve line $b\,k\,o$, we no longer have that conſtant ratio of the increments of the ordinates and abſciſſes.

90 Their meaſures in ſuch caſes how obtained? Theorems of moſt extenſive uſe. Therefore in order to obtain meaſures of the accelerating forces, or at leaſt of their proportions, let the abſciſſa $a\,e\,g$ (fig. 13.) of the line $b\,k\,o$ again repreſent the time of a motion. But let the areas bounded by parallel ordinates now repreſent the velocities, that is, let the whole area increaſe during the time $a\,g$ at the ſame rate with the velocities of the motion along the line AG. In this caſe the ordinates $b\,i$, $c\,k$, $d\,l$, &c. will be as the accelerations at the inſtants b, c, d, &c. or in the points B, C, D, &c.

This is demonſtrated in the ſame way as the former propoſition (n° 72.). If the accelerating force be ſuppoſed conſtant during any two equal moments $b\,c$ and $f\,g$, the rectangles $b\,c\,p\,t$ and $f\,g\,x\,s$ would expreſs the increments of velocity uniformly acquired in equal times, and their baſes $c\,p$ and $f\,s$ would have the ratio of the accelerations, or of the accelerating forces. But as the velocities expreſſed by the figure increaſe faſter than the times during every moment, the force at the inſtant c is to the force at the inſtant f in a greater ratio than that of $c\,p$ to $f\,s$; but, for ſimilar reaſons, it is in a leſs ratio than that of $c\,q$ to $f\,r$; and therefore (as in the other propoſition) the force at the inſtant c is to the force at the inſtant f as $c\,k$ to $f\,n$.

91. *Cor.* Becauſe $c\,p$ is to $f\,s$ in the ratio compounded of the direct ratio of the rectangle $c\,p\,t\,b$ to the rectangle $f\,s\,x\,g$, and the inverſe ratio of the altitude $b\,c$ to the altitude $f\,g$; and becauſe theſe rectangles are proportional to the increments of velocity, and the ultimate ratio of the altitudes is the ultimate ratio of the moments or increments of the time—we muſt ſay, that *the accelerating forces (that is, their intenſities or preſſures producing acceleration) are directly as the increments of velocity, and inverſely as the increments of the times:* Which propoſition may be expreſſed, in regard to two accelerations A and a, by this analogy:

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

Or by the proportional equation $a \doteq \frac{\dot{v}}{\dot{t}}$. Alſo $a\,\dot{t} \doteq \dot{v}$, and $\int a\,\dot{t} = v'$. And thus do theſe theorems extend even to the caſes where there cannot be obſerved an immediate meaſure, either of velocity or of acceleration; becauſe neither the ſpace nor the velocity increaſes uniformly.

See *Barrow's Lect. Geometr.* paſſim.

The theorem $a \doteq \frac{\dot{v}}{\dot{t}}$ is employed when we would diſcover the variation in the intenſity of ſome natural power. We obſerve the motion and repreſent it by a figure analogous to fig. 13. where the abſciſſa repreſents the times, and the area is made to increaſe at the ſame rate with the ſpaces deſcribed. Then the ordinates will repreſent the velocities, or have the proportion of the velocities. Then we may draw a ſecond curve on the other ſide of the ſame abſciſſa, ſuch that the areas of this laſt curve ſhall be proportioned to the ordinates of the firſt. The ordinates of this laſt curve are proportional to the accelerating forces.

92. On the other hand, when we know from other circumſtances that a force, varying according to ſome known law, acts on a body, we can determine its motion. The intenſity of the force in every inſtant being known, we can draw a line ſo related to another line repreſenting the time that the ordinates ſhall be proportional to the forces: The areas will be proportional to the velocities. We can draw another curve to the ſame abſciſs, ſuch that the ordinates of this ſhall be proportional to the areas of the other, that is, to the velocities of the motion. The areas of this ſecond curve will be proportional to the ſpaces deſcribed.

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All theſe theorems relate to *changes* of velocity; by which means they indicate *immediately* the operation of natural powers.

We muſt now obſerve, that all that has been ſaid concerning the effects of accelerating forces continually varying, relates to *changes* of motion, independent of what the abſolute motions may be. The areas of the line whoſe ordinates repreſent the velocities do not neceſſarily repreſent the ſpaces deſcribed, but the change made on the ſpaces deſcribed in the ſame time, not the motions, but the changes of motion. If, indeed, the body be ſuppoſed to be at reſt when the forces begin to act, theſe areas repreſent the very ſpaces that are paſſed over, and the ordinates are the very velocities. In every caſe, however, the accelerations are the real increments of the velocities.

This circumſtance gives a great extenſion to our theorems, and enables us to aſcertain the diſturbances of any ſpecies of regular motion, apart from the motions themſelves, and thus avoid a complication which would frequently be inextricable in any other way. And this proceſs, which is merely mathematical, is perfectly conformable to mechanical principles. It is in fact an application of the doctrine of the compoſition of motion; a doctrine rigidly demonſtrated when we meaſure a mechanical force by the *change* of motion which it produces. Acceleration is the continual compoſition of a new motion with the motion already produced.

No finite change of velocity can be produced in an inſtant by any accelerating force.

We may learn from this inveſtigation of the value of an accelerating force, that no finite change of velocity is effected in an inſtant by the action of an accelerating force. When the fig. 13. is uſed for the ſcale of accelerations, and they are repreſented by the ordinates of the line *h k o*, the increment of velocity is repreſented by an area, that is, by a ſlip of the whole area; which ſlip muſt have ſome altitude, or muſt occupy ſome portion of the abſciſſa which repreſents time. Some portion of time, however ſmall it may be, muſt elapſe before any meaſurable addition can be made to the velocity. The velocity muſt change *continually*. As no motion can be conceived as inſtantaneous, becauſe this would be to conceive, that in one inſtant the moving particle is in every point of its momentary path; ſo no velocity can change, by a finite quantity, in one inſtant; becauſe this would be to conceive, that in that inſtant the particle had all the intervening velocities. The inſtant of change is at once the laſt inſtant of the preceding velocity, and the firſt of the ſucceeding, and therefore muſt belong to both. This cannot be conceived, or is abſurd. As a body, in paſſing from one part of ſpace to another, muſt paſs in ſucceſſion through all the intermediate places; ſo, in paſſing from one velocity to another, it muſt in ſucceſſion have all the intermediate velocities. It muſt be *continually* accelerated; we muſt not ſay *gradually*, however ſmall the ſteps.

But to return from this digreſſion:

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More convenient manner of conſidering the action of forces, and more frequently coming into view.

The moſt frequent caſes which come under examination do not ſhew us the relation between the forces and times, but the relation between the forces and ſpaces. Thus, when a piece of iron is in the neighbourhood of a magnet, or a planet is conſidered in the neighbourhood of the ſun, a force is acting on it in every point of its path, and we have diſcovered that the intenſity of this force varies in a certain proportion. Thus, a ſpring varies in its preſſure as it unbends; gunpowder preſſes leſs violently as it expands, &c. &c.

Our knowledge is generally confined to ſome ſuch effect as this. We know, that while a body is moving along a line ADE (fig. 16.), it is urged forward by a force, of which the intenſity varies in the proportion of the ordinates BF, CG, DH, EI, &c. of the line FGHI.

To inveſtigate the motion or change of motion produced by the action of this force, let CD be ſuppoſed a very ſmall portion of the ſpace s, which we may expreſs by s'. Draw GK perpendicular to DH. Then, if we ſuppoſe that the force acts with the unvaried intenſity CG through the whole ſpace CD, the rectangle CDKG will expreſs half of the increment of the ſquare of the velocity (n° 85). We may ſuppoſe that the force acts uniformly along the adjoining ſmall ſpace D*r* with the intenſity DH. The rectangle DH *o r* will in like manner expreſs another half increment of the ſquare of the velocity. And in like manner we may obtain a ſucceſſion of ſuch increments. The aggregate or ſum of them all will be half the difference between the ſquare of the velocity at B and the ſquare of the velocity at E.

If we employ f to expreſs the indetermined or variable intenſity of the accelerating force, and v to expreſs the variable velocity, and v' its increment *uniformly* acquired; then the rectangle CDKG will be expreſſed by $f\,s'$. We have ſeen that this is equal to $v\,v'$. Therefore, in every caſe where we can tell the aggregate of all the quantities $f\,s$, it is plain that we will obtain half the difference between the ſquares of the velocities in B and E, on the ſuppoſition that the intenſity of the force was conſtant along each little ſpace, and

varied

varied by ſtarts. Then, by increaſing the number, and diminiſhing the magnitude, of thoſe little portions of the ſpace without end, it is evident that we terminate in the expreſſion of the real ſtate of the caſe, *i. e.* of a force varying continually; and that in this caſe the aggregate of theſe rectangles occupies the whole area AEIF, and is equivalent to the fluent of $f\dot{s}$, or to the ſymbol $\int f s$, uſed by the foreign mathematicians to expreſs this fluent, which they indeed conceive as an aggregate of ſmall rectangles $f s'$. And we ſee that this area expreſſes half of the augmentation of the ſquare of the velocity. Therefore,

95 Moſt important theorem (*Newton's Principia*, I. 39.)

If the abſciſſa AE (fig. 16.) *of a line* FGI *is the path along which a body is urged by any accelerating force, and if the ordinates* BF, CG, DH, *&c. are proportional to the forces acting on the points* B, C, D, *&c. the intercepted areas* BCGF, BEIF, *&c. are proportional to the augmentations of the ſquare of the velocity.*

Obſerve that the areas BCGF and DEIH are alſo proportional to the augmentations made on the ſquares of the velocities in B and D.

Obſerve alſo, that it is indifferent what may have been the original velocity. The action of the forces repreſented by the ordinates make always the ſame addition to its ſquare; and this addition is half the ſquare of the velocity which thoſe forces would generate in the body by impelling it from reſt in the point A.

96. Laſtly, on this head, obſerve, that we can ſtate what conſtant or variable force will make the ſame augmentation of the ſquare of the velocity by impelling the body uniformly along the ſame ſpace BE; or along what ſpace a given force muſt impel the body, in order to produce the ſame increaſe of the ſquare of its velocity. In the firſt caſe, we have only to make a rectangle BENφ, equal to the area BEIF, and then Bφ is the intenſity of the conſtant force wanted. In the ſecond caſe, in which the force EO is given, we muſt make the rectangle AαOE equal to the area BEIF, and AE is the ſpace required.

97 Converſe. The converſe of this propoſition, *viz. If the areas are as the increments of the ſquare of the velocity, the ordinates are, as the forces*, is eaſily demonſtrated in the ſame way; for if the elementary areas CDKG and EIM*e* repreſent increments of the ſquares of the velocity, the accelerating forces are in the ratio compounded of the direct ratio of theſe rectangles and the inverſe ratio of their altitudes, becauſe theſe altitudes are the increments of the ſpace (n° 85.). Now the baſe CG of the rectangle CDKG, is to the baſe EI of the rectangle EIM*e* in the ſame compounded ratio; therefore the force in C is to the force in E as CG to EI.

98 *Scales* of force, velocity, acceleration, time, &c. The line *h k o* (fig. 13.) was called by Dr Barrow (who firſt introduced this extenſive employment of motion into geometry), the SCALE *of velocities*; and the line FHL (fig. 16.) was named by him the *ſcale of accelerations*. Hermann, in his *Phoronomia*, calls it the *ſcale of forces*. We ſhall retain this name, and we may call *h k o* of fig. 13. the *ſcale of* accelerations, when the areas repreſent the velocities. Sir Iſaac Newton added another ſcale of very great uſe, viz. a ſcale of times. It is conſtructed as follows.

99. Let ABE (fig. 16.) be the line along which a body is accelerated, and let FHI be the ſcale of forces, that is, having its ordinates FB, HD, IE, &c. proportional to the forces acting at B, D, E, F, &c.; let *f h i* be another line ſo related to ABE, that C*g* is to E*i* in the inverſe ſubduplicate ratio of the area BFGC to the area BFIE; or, to expreſs it more generally, let the ſquares of the ordinates to the line *f g i* be inverſely, as the areas of the line FHI intercepted between theſe ordinates and the firſt ordinate drawn through B; then the times of the bodies moving from a ſtate of reſt in B are as the intercepted areas of the curve *f g i*.

For let CD and E*e* be two very ſmall portions of the ſpace deſcribed in equal times. They will be ultimately as the velocities in C and E. The area FBCG is to the area FBEI as the ſquare of E*i* to the ſquare of C*g* (by conſtruction); but the area FBCG is to FBEI as the ſquare of the velocity at C is to the ſquare of the velocity at E (by the propoſition); therefore the ſquare of the velocity at C is to the ſquare of the velocity at E as the ſquare of E*i* to the ſquare of C*g*; therefore E*i* is to C*g* as the velocity at C to the velocity at E, that is, as CD to E*e*: but ſince $Ei : Cg = CD : Ee$, we have $Ei \times Ee = Cg \times CD$, and the elementary rectangles C*g k* D and E*i m e* are equal, and may repreſent the equal moments of time in which CD and E*e* were deſcribed. Thus the areas of the line *f g l* will repreſent or expreſs the times of deſcribing the correſponding portions of the abſciſſa..

We may expreſs the nature of this ſcale more briefly thus. Let BE be the ſpace deſcribed with any varied motion, and *f g l* a curve, ſuch that its ordinates are inverſely as the velocities in the different points of the abſciſſa, then the area will be as the times of deſcribing the correſponding portions of the abſciſſa.

100 Examples of the application of n° 95. In all the caſes where our mathematical knowledge enables us to aſſign the values of the ordinates of the figure 16, we can obtain the law of action of the forces, or the nature of the force; and where we can aſſign the value of the areas from our knowledge of the proportions of the ordinates or forces, we can aſcertain the velocities of the motion. We ſhall give an example or two, which will ſhew the way in which we avail ourſelves of the geometrical properties of figure, in order to aſcertain the effects of mechanical forces.

1. Let the accelerating force which impels the body along the line AB be conſtant, and let the body be previouſly at reſt in B; the line which bounds the ordinates that repreſent the forces muſt be ſome line φHN parallel to AB. The area BDHφ is to the area BENφ as the ſquare of the velocity at D to the ſquare of the velocity at E. Theſe areas, having equal baſes DH and EN, are as their altitudes BD and BE; that is, the ſpaces deſcribed are as the ſquares of the acquired velocities. And we ſee that this characteriſtic mark of uniformly accelerated motion is included in this general propoſition.

101 Example ſecond of peculiar importance. 2. Let us ſuppoſe that the body is impelled from A (fig. 17.) towards the point C, by a force proportional to its diſtance from that point. This force may be repreſented by the ordinates DA, EB, *e b*, &c. to the ſtraight line DC. We may take any magnitude of theſe ordinates; that is, the line DC may make any angle with AC. It will ſimplify the inveſtigation if we make the firſt force AD = AC. About C deſcribe the circle AH*a*, cutting the ordinate EB in F; let *e b* be another ordinate, cutting the circle in *f* very near

to F; draw CH perpendicular to AC, and make the arch $Hb = fF$, and draw bc parallel to HC; join FC and DH, and draw Fg perpendicular to fb. Let IML be another ordinate.

The area DABE is to the area DAKL as the ſquare of the velocity at B to the ſquare of the velocity at K. But DABE is the exceſs of the triangle ADC above the triangle EBC, or it is half of the exceſs of the ſquare of CA or CF above the ſquare of CB, that is, half the ſquare of BF. In like manner, the area DAKL is equal to half the ſquare of KM; but halves have the ſame ratio as the integers; therefore the ſquare of BF is to the ſquare of KM as the ſquare of the velocity at B to the ſquare of the velocity at K; therefore the velocity at B is to the velocity at K as BF is to KM. The velocities are proportional to the ſines of the arches of the quadrant AFH deſcribed on AC.

Cor. 1. The final velocity with which the body arrives at C, is to the velocity in any other point B as radius to the ſine of the arch AF.

Cor. 2. The final velocity is to the velocity which the body would acquire by the uniform action of the initial force at A as 1 to $\sqrt{2}$; for the rectangle DACH expreſſes the ſquare of the velocity acquired by the uniform action of the force DA; and this is double of the triangle DAC; therefore the ſquares of theſe velocities are as 1 and 2, and the velocities are as $\sqrt{1}$ and $\sqrt{2}$, or as 1 to $\sqrt{2}$.

Cor. 3. The time of deſcribing AB is to the time of deſcribing AC as the arch AF to the quadrant AFH.

102. For when the arch Ff is diminiſhed continually, it is plain that the triangle fiF is ultimately ſimilar to CFB, by reaſon of the equal angles Cib (or CFB) and fiF, and the right angles CBF and fFi; therefore the triangles fgF and CBF are alſo ſimilar. Moreover, Bb is equal to Fg, Ff is equal to bH, which is ultimately equal to cC; therefore ſince the triangles fgF and CFB are ſimilar, we have $Fg : Ff = FB : FC, = FB : HC$; therefore Bb is to cC as FB to HC, that is, as the velocity at B to the velocity at C; therefore Bb and cC are deſcribed in equal moments when indefinitely ſmall; therefore equal portions Ff, bH, of the quadrant correſpond to equal moments of the accelerated motion, along the radius AC; and the arches AF, FM, MH, &c. are proportional to the times of deſcribing AB, BK, KC, &c.

Cor. 4. The time of deſcribing AC with the unequally accelerated motion, is to the time of deſcribing it uniformly with the final velocity as the quadrantal arch is to the radius of a circle; for if a point move in the quadrantal arch ſo as to be in F, f, M, H, &c. when the body is in B, b, K, C, it will be moving uniformly, becauſe the arches are proportional to the times of deſcribing thoſe portions of AC; and it will be moving with the velocity with which the body arrives at C, becauſe the arch bH is ultimately $= Cc$. Now if two bodies move uniformly with this velocity, one in the arch AFH, and the other in the radius AC, the times will be proportional to the ſpaces uniformly deſcribed; but the time of deſcribing AFH is equal to the time of the accelerated motion along AC; therefore the propoſition is manifeſt.

103. *Cor.* 5. If the body proceed in the line Ca, and be retarded in the ſame manner that it was accelerated along AC, the time of deſcribing AC uniformly with the velocity which it acquires in C is to the time of deſcribing ACa with the varied motion, as the diameter of a circle to the circumference; for becauſe the momentary retardations at K′, B′, &c. are equal to the accelerations at K and B, &c. the time of deſcribing ACa is the ſame with that of deſcribing AHa uniformly with the greateſt velocity. That is, to the time of deſcribing AC uniformly as AHa to AC, or as the circumference of a circle to the diameter. Therefore, &c. *N. B.* In this caſe of retarding forces it is convenient to repreſent them by ordinates K′L, B′E, aD′, lying on the other ſide of the axis ACa; and to conſider the areas bounded by theſe ordinates as ſubtractive from the others. Thus the ſquare of the velocity at K′ is expreſſed by the whole area DACK′L′D, the part C′K′L being negative in reſpect of the point DAC. This obſervation is general (See alſo Optics, nº 125, *Encycl.*)

Cor. 6. The time of moving along KC, the half of AC, by the uniform action of the force at A, is to that of deſcribing ACa by the varied action of the force directed to C, and proportional to the diſtance from it, as the diameter of a circle to the circumference; for when the body is uniformly impelled along KC by the conſtant force IK, the ſquare of the velocity acquired at C is repreſented by half the rectangle IKCH, and therefore it is equal to the velocity which the variable force generates by impelling it along AC (by the way, an important obſervation). The body will deſcribe AC uniformly with this velocity in the ſame time that it is uniformly accelerated along KC. Therefore by *Cor.* 5. the propoſition is manifeſt.

Cor. 7. If two bodies deſcribe AC and KC by the action of forces which are every where proportional to the diſtances from C, their final velocities will be proportional to the diſtances run over, and the times will be equal.

For the ſquares of the final velocities are proportional to the triangles ADC, LKC, that is, to AC^2, KC^2, and therefore the velocities are as AC, KC. The times of deſcribing AC and KC uniformly, with velocities proportional to AC and KC, muſt be equal; and theſe times are in the ſame ratio (*viz.* that of radius to $\frac{1}{4}$th of the circumference) to the times of deſcribing AC and KC with the accelerated motion. Therefore, &c.

Thus, by availing ourſelves of the properties of the circle, we have diſcovered all the properties or characters of a motion produced by a force always directed to a fixed point, and proportional to the diſtance from it.

Some of theſe are remarkable, ſuch as the laſt corollary; and they are all important; for there are innumerable caſes where this law of action obtains in Nature. It is nearly the law of action of a bow ſtring, and of all elaſtic bodies, when their change of figure during their mutual action is moderate; and it has been by the help of this propoſition, firſt demonſtrated in a particular caſe by Lord Brouncker and Mr Huyghens, that we have been able to obtain preciſe meaſures of time, and conſequently of actual motions, and conſequently of any of the mechanical powers of Nature. It is for this reaſon, as well as for the eaſy and perſpicuous employment of the mathematical method of proceeding, that we have ſelected it.

Inſtead of giving any more particular caſes, we may obſerve

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obſerve in general, that if the intenſity of the force be proportional to any power whoſe index is $n - 1$ of the diſtance, and if a be the diſtance from the fixed point at which the body begins to be accelerated, and x its diſtance from that point in any part of the motion, the velocity will be $\doteqdot \sqrt{a^n - x^n}$. This is very plain, becauſe the increment CGHD of the area of fig. 16. which is alſo the increment of the ſquare of the velocity, is $\doteqdot x^{n-1}\dot{x}$, and the area is $\doteqdot x^n$; and the whole area, correſponding to the diſtance a, is a^n. Therefore the portion of the area lying beyond the diſtance x is $a^n - x^n$. This is as the ſquare of the velocity, and therefore the velocity is as the ſquare root $\sqrt{a^n - x^n}$ of this quantity.

This propoſition, $f\dot{s} \doteqdot v\dot{v}$, or $f \doteqdot \frac{v\dot{v}}{\dot{s}}$, is the 39th of the firſt book of Newton's *Principia*, and is perhaps the moſt important in the whole doctrine of dynamics, whether employed for the inveſtigation of forces or for the explanation of motions. It furniſhes the moſt immediate data for both purpoſes, but more eſpecially for the laſt. By its help Sir Iſaac Newton was able to point out the numerous diſturbances of the planetary motions, and to ſeparate them from each other; thus unravelling, as it were, that moſt intricate motion in which all are blended together. He has given a moſt wonderful ſpecimen of its application in his Lunar Theory.

We now are able to explain all the puzzling facts which were adduced by Leibnitz and his partiſans in ſupport of their meaſure of the forces of bodies in motion. We ſee why four ſprings, equally bent, communicate but a double velocity, and nine ſprings but a triple velocity; why a bullet moving twice as faſt will penetrate an earthen rampart to a quadruple depth, &c. &c.

Conſervatio virium vivarum.

This theorem alſo gives a moſt perſpicuous explanation of the famous doctrine called *conſervatio virium vivarum*. When perfectly elaſtic bodies act on each other, it is found that the ſum of the maſſes multiplied by the ſquares of the velocities is always the ſame. This has been ſubſtituted, with great encomiums, by the German philoſophers in place of Des Cartes's principle, that the quantity of motion in the univerſe, eſtimated in one direction, remains always the ſame. They are obliged, however, to acknowledge, that in the actions of perfectly hard bodies, there is always a loſs of *vis viva*, and therefore have denied the exiſtence of ſuch bodies But there is the ſame loſs in the mutual actions of all ſoft or ductile, or even imperfectly elaſtic, bodies; and they are miſerably puzzled how to explain the fact; but both the *conſervatio* and the *amiſſio* are neceſſary conſequences of this theorem.

In the colliſion of elaſtic bodies, the whole change of motion is produced during the ſhort time that the bodies are compreſſed, and while they regain their figure. When this is completed, the bodies are at the ſame diſtance from each other as when the mutual action began. Therefore the preceding body has been accelerated, and the following body has been retarded, along equal ſpaces; and in every point of this ſpace the accelerating and the retarding force has been equal. Conſequently the ſame area of fig. 17. expreſſes the change made on the ſquare of the velocity of both bodies. Therefore, if V and U are the velocities before colliſion, and v and u the velocities after colliſion, of the two bodies A and B, we muſt have $A \times \overline{V^2 - v^2} = B \times \overline{u^2 - V^2}$, and therefore $A \times V^2 + B \times U^2 = A \times v^2 + B \times u^2$.

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But in the other claſs of bodies, which do not completely regain their figure, but remain compreſſed, they are nearer to each other when their mutual action is ended than when it began. The foremoſt body has been accelerated along a ſhorter ſpace than that along which the other has been retarded. The mutual forces have, in every inſtant, been equal and oppoſite. Therefore the area which expreſſes the diminution of the ſquare of the velocity, muſt exceed the area expreſſing the augmentation by a quantity that is always the ſame when the permanent compreſſion is the ſame; that is, when the relative motion is the ſame. $A \times \overline{V^2 - v^2}$ muſt exceed $B \times \overline{u^2 - U^2}$, and $A \times V^2 + B \times U^2$ muſt exceed $A \times v^2 + B \times u^2$.

This ſame theorem is of the moſt extenſive uſe in all practical queſtions in mechanic arts; and without it mechanics can go no farther than the mere ſtatement of equilibrium.

Hiſtory of n° 95. is curious.

Hermann, profeſſor of mathematics at Pavia, one of the ornaments of the mathematical claſs of philoſophers, has given a pretty demonſtration of this valuable propoſition in the *Acta Eruditorum Lipſiæ* for 1709; and ſays, that having ſearched the writings of the mathematicians with great care, he found himſelf warranted to ſay, that Newton was the undoubted author, and boaſts of his own as the firſt ſynthetical demonſtration. The purpoſe of this aſſertion was not very apparent at the time; but long after, in 1746, when Hermann's papers, preſerved in the town-houſe of Pavia, were examined, in order to determine a diſpute between Maupertuis and Koenig about the claim to the diſcovery of *the principle of leaſt action*, letters of Leibnitz's were found, requeſting Hermann to ſearch for any traces of this propoſition in the writings of the mathematicians of Europe. Leibnitz was by this time the envious detractor from Newton's reputation; and could not but perceive, that all his contorted arguments for his doctrine received a clear explanation by means of this propoſition, in perfect conformity to the uſual meaſure of moving forces. Newton had diſcovered this theorem long before the publication of the *Principia*, and even before the diſcovery of the chief propoſition of that book in 1666; for in his Optical Lectures, the materials of which were in his poſſeſſion in 1664, he makes frequent uſe of a propoſition founded on this (ſee n° 42.) We may here remark, that Hermann's demonſtration is, in every ſtep, the ſame with Dr Barrow's demonſtration of it as a theorem merely geometrical, without ſpeaking of moving forces (ſee *Lect. Geomtr.* xi. p. 85. edit. 16), but giving it as an inſtance of the transformation of curves, which he calls SCALES of velocity, of time, of acceleration, &c. It is very true that Barrow, in theſe mathematical lectures, approached very near to both of Newton's diſcoveries, the fluxionary geometry, and the principles of dynamics; and the junto on the continent, who were his continual detractors, charge him with impudent plagiariſm from Dr Barrow, and even ſay that he has added nothing to the diſcoveries of his teacher. But ſurely Dr Barrow was the beſt judge of this matter;

ter; and ſo far from reſenting the uſe which Newton has made of what he had taught him, he was charmed with the genius of the *juvenis ſpectatiſſimus* his ſcholar, and of his own accord gave him his profeſſorial chair, and ever after lived in the utmoſt harmony and friendſhip with him. Nay, it would even appear, from ſome expreſſions in thoſe very lectures, that Dr Barrow owed to young Newton the firſt thought of making ſuch extenſive uſe of motion in geometry. We recommend this work of Barrow's to the ſerious peruſal of our readers, who wiſh to acquire clear notions of the ſcience of motion, and an elegant taſte in their mechanical diſquiſitions. After all the cultivation of this ſcience by the commentators and followers of Newton, after the *Phoronomia* of Hermann, the *Mechanica* of Euler, the *Dynamique* of D'Alembert, and the *Mechanique Analytique* of De la Grange, which are undoubtedly works of tranſcendent merit and utility, the *Principia* of Newton will ſtill remain the moſt pleaſing, perſpicuous, and elegant ſpecimen of the application of mathematics to the ſcience of *univerſal mechanics*, or what we call DYNAMICS.

The two fundamental theorems $f \dot{t} = \dot{v}$, and $f \dot{s} = v \dot{v}$, enable us to ſolve every queſtion of motion accelerated or retarded by the action of the mechanical powers of nature. But the employment of them may be greatly expedited and ſimplified by noticing two or three general caſes which occur very frequently.

104
Similar inſtants and points, what?

Theſe may be called ſimilar inſtants of time, and *ſimilar points of ſpace which divide given portions of time*, and *of ſpace in the ſame ratio.* Thus the middle is a ſimilar inſtant of an hour or of a day, and is the ſimilarly ſituated point of a foot or of a yard. The beginning of the 21ſt minute, and of the 9th hour, are ſimilar inſtants of an hour and of a day. The beginning of the 5th inch, and of the 2d foot, are ſimilar points of a foot and of a yard.

105
Similar actions, what?

Forces may be ſaid to act ſimilarly when their intenſities in ſimilar inſtants of time, or in ſimilar points of ſpace, are in a conſtant ratio. Thus in fig. 17. when one body is impelled towards C from A, and another from K, each with a force proportional to the diſtance of every point of its motion from C, theſe forces may be ſaid to act ſimilarly along the ſpaces AC and KC, or during the times repreſented by the quadrantal arches AFH, KNO. The following propoſitions on ſimilar actions will be found very uſeful on many occaſions; but we muſt premiſe a geometrical lemma.

106. If there be two lines EFGH (fig. 18.), *e f g h*, ſo related to their abſciſſes AD, *a d*, that the ordinates IK, *i k*, drawn from ſimilar points I and *i* of the abſciſſes, are in the conſtant ratio of AE to *a e*; then the area ADHE is to the area *a d h e* as the rectangle of $AD \times AE$ to the rectangle $ad \times ae$.

For let each abſciſſa be divided into the ſame number of equal and very ſmall parts, of which let CD and *c d* be one in each. Inſcribe the rectangles CGID, *c g i d*. Then becauſe the number of parts in each axis is the ſame, the lengths of the portions CD and *c d* will be proportional to the whole abſciſſes AD and *a d*. And becauſe C and *c* are ſimilar points CG is to *c g* as AE is to *a e*. Therefore $CD \times CG : cd \times cg = AD\ AE : ad \times ae$ This is true of each pair of correſponding rectangles; and therefore it is true of their ſums. But when the number of theſe rectangles is increaſed, and their breadth diminiſhed without end, it is evident that the ultimate ratio of the ſum of all the rectangles, ſuch as CDHG to the ſum of all the rectangles *c d h g*, is the ſame with that of the area ADHE to the area *a d h e*, and the propoſition is manifeſt.

107 *If two particles of matter are ſimilarly impelled during given times, the changes of velocity are as the times and as the forces jointly.*

Let the times be repreſented by the ſtraight lines ABC (fig. 19.) and *a b c*, and the forces by the ordinates AD, BE, CF, and *a d*, *b e*, *c f*. Then if B and *b* are ſimilar inſtants (ſuppoſe the middles) of the whole times, we have $BE : be = AD : ad$. Therefore, by the lemma, the area ACDF is to *a c f d* as $AC \times AD$ to $ac \times ad$. But theſe areas are proportional to the velocities (n° 72), and the propoſition is demonſtrated. For the ſame reaſon the change of velocity during the time AB is to the change during *a b* as $AB \times AD$ to $ab \times ad$.

Cor. 1. If the times and forces are reciprocally proportional, the changes of velocity are equal; and if the forces are inverſely as the times, the changes of velocity are equal.

108. *If two particles be ſimilarly urged along given ſpaces, the changes made on the ſquares of the velocities are as the forces and ſpaces jointly.*

For if AC (fig. 19.) and *a c* are the ſpaces along which the particles are impelled, and the forces are as the ordinates AD and *a d*, the areas ACFD and *a c f d* are as the changes on the ſquares of the velocities. But theſe areas are as $AC \times AD$, and $ac \times ad$. Therefore, &c.

Cor. 2. If the ſpaces are inverſely as the forces, the changes of the ſquares of the velocities are equal; and if theſe are equal, the ſpaces are inverſely as the forces.

Cor. 3. If the ſpaces, along which the particles have been impelled from a previous ſtate of reſt, are directly as the forces, the velocities are alſo as the forces. For, becauſe the changes of the ſquares of the velocities are as the ſpaces and forces jointly, they are in this caſe as the ſquares of the forces or of the ſpaces; but the changes of the ſquares of the velocities are in this caſe the whole ſquares of the velocities; therefore the ſquares of the velocities are as the ſquares of the forces, and the velocities are as the forces. *N. B.* This includes the motions repreſented in fig. 17.

109. *If two particles be ſimilarly impelled along given ſpaces, from a ſtate of reſt, the ſquares of the times are proportional to the ſpaces directly, and to the forces inverſely.*

Let ABC (fig. 19.) *a b c* be the ſpaces deſcribed, and AD, *a d*, the accelerating forces at A and *a* Let V, B expreſs the velocity at B, and *v*, *b* the velocity at *b*.

Let GHK and *g h k* be curves whoſe ordinates are inverſely as the velocities at the correſponding points of the abſciſſa. Theſe curves are therefore exponents of the times (n° 99.) Then, becauſe the forces act ſimilarly, we have, by the laſt theorem, $AC \times AD : ac \times ad = V^2, B : v^2, b, = hb^2 : HB^2$. Therefore $HB : hb = \sqrt{ac \times ad} : \sqrt{AC \times AD}$, and therefore in a conſtant ratio. Call this the ratio of *m* to *n*. But, ſince the ordinates of the lines GHK, *g h k* are inverſely as the velocities, the areas are as the times (n° 99); and

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and ſince theſe ordinates are in the conſtant ratio of m to n, the areas are in the ratio of AC × m to ac × n. Therefore (calling the times of the motions T and t), we have

$$T : t = m\,AC : n\,ac;\text{ and therefore}$$
$$T^2 : t^2 = m^2 \times AC^2 : n^2 \times ac^2.\quad\text{But}$$
$$m^2 : n^2 = ac \times ad : AC \times AD.\quad\text{Therefore}$$
$$T^2 : t^2 = ac \times ad \times AC^2 : AC \times AD \times ac^2,$$
$$\text{Or } T^2 : t^2 = ad \times AC : AD \times ac.$$
$$\text{Or } T^2 : t^2 = \frac{AC}{AD} : \frac{ac}{ad}.$$

The attentive reader will obſerve that theſe three propoſitions give a great extenſion to the theorems which were formerly deduced from the nature of uniformly accelerated motion, or of uniform action of the forces, and were afterwards demonſtrated to obtain in the momentary action of forces any how variable.

The firſt of the three propoſitions, $V : v = F \times T : f \times t$, is the extenſion of the theorem $f \times \dot{t} = \dot{v}$. The ſecond, $V^2 : v^2 = F \times S : f \times s$, is the extenſion of the theorem $f \times \dot{s} = v\,\dot{v}$. And the third, $T^2 : t^2 = \frac{S}{F} : \frac{s}{f}$, is the extenſion of $f = \frac{\dot{s}}{(t^2)^{\cdot}}$, or of $f \times (t^2) = \dot{s}$. Theſe theorems hold true of all *ſimilar* actions; and only for this reaſon, are true of uniformly accelerated motions, or uniform actions.

Aggregate of many equal accelerating forces.

There remains one thing more to be ſaid concerning the action of accelerating forces. Their magnitude is aſcertained by their effect. Therefore that is to be conſidered as a double force which produces a double quantity of motion. Therefore when a body A contains twice the number of equal atoms of matter, and acquires the ſame velocity from the action of the force F that another body a, containing half the number of atoms, acquires from the action of a force f, we conceive F to be double of f. That this is a legitimate inference appears clearly from this, that we conceive the ſenſible weight of a body, or that preſſure which it exerts on its ſupports, as the aggregate of the equal preſſure, of every atom, accumulated perhaps on one point; as when the body hangs by a thread, and, by its intervention, pulls at ſome machine. Without inquiring in what manner, or by what intervention, this accumulation of preſſure is brought about, we ſee clearly that it reſults from the equal accelerating force of gravity acting immediatly on each atom. When this weight is thus employed to move another body by the intervention of the thread, which is attached to one point perhaps of that body, it puts the whole into motion, generating a certain velocity v in every atom, by acting uniformly during the time t. We conceive each atom to have ſuſtained the action of an equal accelerating force, whoſe meaſure is $\frac{v}{t}$. Without conſidering how this force is exerted on each atom, or by what it is immediately exerted, or how it is diffuſed through the body from the point to which the weight of the other body is applied by means of the thread; we ſtill conſider it as the aggregate of the action of gravity on each atom of that other body. Moreover, attending only to the motion produced by it, and perhaps not knowing the weight of the impelling body, we meaſure it, as a moving force, by conſidering it as the aggregate of the forces propagated to each atom of the impelled body, and meaſured by $\frac{v}{t}$. If we know that the impelled body contains the number m of atoms, the aggregate of forces is $m\frac{v}{t}$, or $\frac{mv}{t}$.

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But ſince we meaſure forces by the quantity of motion which they produce, we muſt conceive, that when the ſame force is applied to a body which conſiſts of n particles, and produces the velocity u, by acting uniformly during the ſame time t, the force $n\frac{u}{t}$ is equal to the force $m\frac{v}{t}$.

110 Moving force, motive force, vis motrix, as diſtinguiſhed from accelerating force.

Sir Iſaac Newton found it abſolutely neceſſary, in the diſquiſitions of natural philoſophy, to keep this circumſtance of acceleration clear of all notions of quantity of matter, or other conſiderations, and to contemplate the affections of motion only. He therefore conſidered $\frac{v}{t}$ as the true original meaſure of accelerating force, and $m\frac{v}{t}$ as an aggregate. He therefore calls the aggregate a *vis motrix*, a *moving force*, meaſured by the *quantity of motion* that it generates. And he confines the term *accelerating force* to the quantity $\frac{v}{t}$, meaſured by the *acceleration* or *velocity* only. It would be convenient, therefore, alſo to confine the ſymbol f to $m\frac{v}{t}$, and to retain the ſymbol a for expreſſing the accelerating force $\frac{v}{t}$.

This appellation of *motive force* is perfectly juſt and ſimple; for we may conceive it as the ſame with the accelerating force which produces the velocity m times v in one particle, by acting on it uniformly during the time t. This motion of one particle having the velocity $m\,v$, is the ſame with that of m particles having each the velocity v.

If therefore a motive force f acts on a body conſiſting of m particles, the accelerating force a is $= \frac{f}{m}\frac{v}{t}$.

Therefore the three laſt propoſitions concerning the ſimilar, the uniform, or the momentary actions of *moving* forces, when expreſſed in the moſt general terms, are,

$$v' \doteqdot \frac{f}{m\,t'}$$
$$vv' \doteqdot \frac{f\,s'}{m},\ \text{or } v\dot{v} = \frac{f\,\dot{s}}{m}$$
$$t^2 \doteqdot \frac{m\,s'}{f}.$$

Of Deflecting Forces.

111 Deflecting forces.

When we obſerve the direction of a body to change, we unavoidably infer the agency of a force which acts in a direction that does not coincide with that of the body's motion; and we may diſtinguiſh this circumſtance by calling it a DEFLECTING FORCE. We have already ſhewn how to eſtimate and meaſure this deflecting force, by conſidering it as competent to the pro-

production of that motion which, when compounded with the former motion, will produce the new motion (n° 44.) Now, as all changes of motion are really compoſitions of motions or forces, it is evident that we ſhall explain the action of deflecting forces when we ſhew this compoſition.

Alteration of deflections are continual, and produce curvilineal motions.

We may almoſt venture to ſay *à priori*, that all deflections muſt be continual, or exhibit curvilineal motions: for as no finite velocity, or change of velocity, can be produced in an inſtant by the action of an accelerating force, no polygonal or angular deflection can be produced; becauſe this is the compoſition of a finite velocity produced in an inſtant. Deflective motions are all produced by the compoſition of the former motion, having a finite velocity, with a tranſverſe motion continually accelerated from a ſtate of reſt. Of this we can form a very diſtinct notion, by taking the ſimpleſt caſe of ſuch accelerated motion, namely, an uniformly accelerated motion.

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Example Determination of the path,

Let a body be moving in the direction AC (fig. 20.) with any conſtant velocity, and when it comes to A, let it be expoſed to the action of an accelerating force, acting uniformly in any other direction AE. This alone would cauſe the body to deſcribe AE with a uniformly accelerated motion, ſo that the ſpaces AD, AE would be as the ſquares of the times in which they are deſcribed. Therefore, if AB be the ſpace which it would have deſcribed uniformly in the time that it deſcribes AD by the action of the accelerating force, and AC the ſpace which it would have deſcribed uniformly while it deſcribes AE by the action of the accelerating force—nothing more is wanted for aſcertaining the real motion of the body but to compound the uniform motion in the direction AC with the uniformly accelerated motion in the direction AE. AD is to AE as the ſquare of the time of deſcribing AD to the ſquare of the time of deſcribing AE; that is, as the ſquare of the time of deſcribing AB to the ſquare of the time of deſcribing AC; that is, as AB^2 to AC^2 (by reaſon of the uniform motion in AC). This compoſition is performed by taking the ſimultaneous points B, D, and the ſimultaneous points C, E, and completing the parallelograms ABFD, ACGE. The body will be found in the points F and G in the inſtants in which it would have been found at B and C by the uniform motion, or in D and E by the accelerated motion. In the ſame manner may be found as many points of the real path as we pleaſe. It is plain that theſe points will be in a line AFG, ſo related to AE that $AD : AE = DF^2 : EG^2$; or ſo related to the original motion AC, that $AB^2 : AC^2 = BF : CG$, &c. This line is therefore a parabola, of which AE is a diameter, DF and EG are ordinates, and which touches AC in A.

And of the motion in this path.

Having thus aſcertained the path of the body, we can alſo aſcertain the motion in that path; that is, the velocity in any point of it. We know that the velocity in the point G is to the velocity of the uniform motion in the direction AC as the tangent TG is to the ordinate EG; becauſe this is the ultimate ratio of the momentary increment of the arch AFG to the momentary increment of the ordinate EG. Thus is the velocity in every point of the curve determined. We have taken it for granted, that the line of projection touches the path, and that the direction in every point is that of the tangent. To ſuppoſe that the curve, in any portion of it, coincides with the tangent, is to ſuppoſe that the body is not deflected; that is, is not acted on by a tranſverſe accelerating force: And to ſuppoſe that the tangent makes a finite angle with any part of the path, is to ſuppoſe that the deflection is not continual, but by ſtarts—both of which are contrary to the conditions of the caſe. No ſtraight line can be drawn between the direction of the body and the ſucceeding portion of the path, otherwiſe we muſt again ſuppoſe that the deflection is ſubſultory, and the motion angular.

113.

But while the inveſtigation is ſo eaſy when the direction and intenſity of the deflecting force in every point of the curve are known, the inveſtigation of the deflecting force from the obſerved motion is by no means eaſy. The obſerved curvilineal motion always ariſes from a compoſition of a uniform motion in the tangent with ſome tranſverſe motion. But the ſame curvilineal motion may be produced by compounding the uniform motion in the tangent with an infinity of tranſverſe motions; and the law of action will be different in theſe tranſverſe motions according as their directions differ. We muſt learn, not only the intenſity of the deflecting force, and the law of its variation, but alſo its direction in every point of the curve. It is not eaſy to find general rules for diſcovering the direction of the tranſverſe force; moſt commonly this is indicated by extrinſic circumſtances. The deflecting force is frequently obſerved to reſide in, or to accompany, ſome other body. It may be preſumed, therefore, that it acts in the direction of the line drawn to or from that body; yet even this is uncertain. The moſt general rule for this inveſtigation is to obſerve the place of the body at ſeveral intervals of time before and after its paſſing through the point of the curve, where we are intereſted to find its preciſe direction. We then draw lines, joining thoſe places with the places of the tangent where the body would have been by the uniform motion only. We ſhall perhaps obſerve theſe lines of junction keep in parallel poſitions: we may be aſſured that the direction of the tranſverſe force is the ſame with that of any of theſe lines. This is the caſe in the example juſt now given of a parabolic motion. But when theſe lines change poſition, they will change it gradually; and their poſition in the point of contact is that to which their poſitions on both ſides of it gradually approximate.

But all this is deſtitute of the preciſion requiſite in philoſophical diſcuſſion. We are indebted to Sir Iſaac Newton for a theorem which aſcertains the direction of the tranſverſe force with all exactneſs, in the caſes in which we moſt of all wiſh to attain mathematical accuracy, and which not only opened the acceſs to thoſe diſcoveries which have immortaliſed his name, but alſo pointed out to him the path he was to follow, and even marked his firſt ſteps. It therefore merits a very particular treatment.

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Newton's fundamen tal theore for the di rection of deflectin force.

If a body deſcribes a curve line ABC, DEF (fig. 21.) lying in one plane; and if there be a point S ſo ſituated in this plane that the line joining it with the body deſcribes areas ASB, ASC, ASD, &c. proportional to the times in which the body deſcribes the arches AB, AC, AD, &c. the force which deflects the body from rectilineal motion is continually directed to the fixed point S.

Let us firſt ſuppoſe that the body deſcribes the polygon ABCDEF, &c. formed of the chords AB, BC, CD, DE, EF, &c. of this curve: and (for greater ſimplicity of argument) let us conſider areas deſcribed in equal ſucceſſive times; that is, let us ſuppoſe that the triangles ASB, BSC, CSD, &c. are equal, and deſcribed in equal times. Make B *c* = AB, and draw *c* S.

Areas ÷ to he times ndicate entral orces. Had the motion AB ſuffered no change in the point B, the body would have deſcribed B*c* in the equal moment ſucceeding the firſt: but it deſcribes BC. The body has therefore been deflected by an external force; and BC is the diagonal of a parallelogram (n° 45, 46.), of which B *c* is one ſide, and *c* C is another. The deflecting force will be diſcovered, both in reſpect of direction and intenſity, by completing the parallelogram B *c* C *b*. B *b* is the ſpace which the deflecting force would have cauſed the body to deſcribe in the time that it deſcribes B *c* or BC. Becauſe B *c* is equal to BA, the triangles BS*c*, BSA are equal. But (by the nature of the motion) BSA is equal to BSC. Therefore the triangles BSC and BS*c* are equal. They are alſo on the ſame baſe BS; therefore they lie between the ſame parallels, and C*c* is parallel to SB. But *c* C is parallel to B *b*. Therefore B *b* coincides with BS, and the deflecting force at B is directed toward S. By the ſame argument, the deflecting force at the angles D, E, F, &c. is directed to S.

Now, let the ſides of the polygon be diminiſhed, and their number increaſed without end. The demonſtration remains the ſame; and continues, when the polygon finally coaleſces with the curve, and the deflection is continual.

When areas are deſcribed proportional to the times, equal areas are deſcribed in equal times; and therefore the deflection is always directed to S. Q. E. D.

entre of eflection. entre of orces. entral orces. The point S may, with great propriety of language, be called the CENTRE OF DEFLECTION, or THE CENTRE OF FORCES; and forces which are thus continually directed to one fixed point, may be diſtinguiſhed from other deflecting forces by the name CENTRAL FORCES.

adius vec- or. The line joining the centre of forces with the body, and which may be conceived as a ſtiff line, carrying the body round, is uſually named the RADIUS VECTOR.

115 entral for- es produce reas pro- ortional to ne times. The converſe of this propoſition, viz. that if the deflecting forces be always directed to S, the motion is performed in one plane, in which S is ſituated, and areas are deſcribed proportional to the times—is eaſily demonſtrated by reverſing the ſteps of this demonſtration. The motion will be in the plane of the lines SB and B *c*; becauſe the diagonal BC of the parallelogram of forces is in the plane of the ſides. Areas are deſcribed proportional to the times; for C *c* being parallel to SB, the triangles SCB and S *c* B are equal; and therefore SCB and SAB are equal, &c. &c.

116 elocity is nverſely a- ne perpen- icular om the entre. *Cor.* 1. When a body deſcribes areas round S proportional to the times, or when it is continually deflected toward S, or acted on by a tranſverſe force directed to S, the velocities in the different points A and E of the curve are inverſely proportional to the perpendiculars S*r* and S*t*, drawn from the centre of forces to the tangents in thoſe points; that is, to the perpendiculars from the centre on the momentary directions of the motion: For ſince the triangles ASB, ESF are equal, their baſes AB, EF are inverſely as their altitudes S*r*, S*t*. But theſe baſes, being deſcribed in equal times, are as the velocities; and they ultimately coincide with the tangents at A and E.

117. *Cor.* 2. If $B\alpha$ and $F\epsilon$ be drawn perpendicular to SA and SE, we have $SA \times B\alpha = SE \times F\epsilon$, and $SA : SE = F\epsilon : B\alpha$: For $SA \times B\alpha$ is double of the triangle BSA, and $SE \times F\epsilon$ is double of the equal triangle SFE.

118 Angular velocity is inverſely as the ſquare f the diſtance from the centre of forces. *Cor.* 3. The angular velocity round S, that is, the magnitude of the angle deſcribed in equal times by the radius vector, is inverſely proportional to the ſquare of the diſtance from S. For when the arches AB, EF are diminiſhed continually, the perpendiculars $B\alpha$ and $F\epsilon$ will ultimately coincide with arches deſcribed round S with the radii SB and SF. Now the magnitude of an angle is proportional to the length of the arch which meaſures it directly, and to the radius of the arch inverſely. In any circle, an arch of two inches long meaſures twice as many degrees as an arch one inch long; and an arch an inch long contains twice as many degrees of a circle whoſe radius is twice as ſhort. Therefore, ultimately, the angle ASB is to the angle ESF as $B\alpha$ to $F\epsilon$, and as SF to SB jointly; that is, as $B\alpha \times SF$ to $F\epsilon \times SB$. But $B\alpha : F\epsilon = SE : SA$ (*Cor.* 2.) Therefore $ASB : ESF = SE \times SF : SB \times SA$, $=$ ultimately $SE^2 : SB^2$.

This corollary gives us an oſtenſible mark, in many very important caſes, of the action of a deflecting force being always directed to a fixed point. We are often able to meaſure the angular motion when we cannot meaſure the real velocities.

Intimate connection of dynamics and the higher geometry. Having thus diſcovered the chief circumſtances which enable us to aſcertain the direction of the deflecting force, we proceed to inveſtigate the quantity of this deflective determination in the different points of a curvilineal motion. This is a more difficult taſk. The momentary effect of the deflecting force is a ſmall deviation from the tangent; and this deviation is made with an accelerated motion. The law of this acceleration regulates the curvature of the path, and is to be determined by it. We may be allowed to obſerve by the way, that it appears clearly from the form in which Newton has preſented all his dynamical theorems, that we are indebted to theſe problems for the immenſe improvement which he has made in geometry by his invention of fluxions. The purpoſes he had in view ſuggeſted to his penetrating mind the means for attaining them; and the connection between dynamics and geometry is ſo intimate, that the ſame theorems are in a manner common to both. This is particularly the caſe in all that relates to curvature. Or ſhall we ſay that the geometry of Dr Barrow ſuggeſted the dynamical theorems to Newton? We have ſeen how the curvature of a parabola is produced by a force acting uniformly. The *momentary* action of all finite forces may be conſidered as uniform; and therefore the curvature will be that of ſome portion of ſome parabola; but it will be difficult to determine the preciſe degree without ſome farther help. We are beſt acquainted with the properties of the circle, and will have the cleareſt notions of the curvature of other curves by comparing them with circles.

Meaſure of curvature. The curvature of a circular arch of given length is ſo much greater as its radius is ſhorter; for it will contain ſo many more degrees in the ſame length; and therefore the change of direction of its extremities is ſo much greater. Curvatures may always be meaſured by the length of the arch directly and the radius inverſely.

119 Evolution and involution of curves.

Suppoſe a thread made faſt at one end of a material curve ABCD (fig 22), and applied to it in its whole length. Taking hold of its extremity D, unfold it gradually from the curve DCBA; the extremity D will deſcribe another curve D *c b a*. This geometrical operation is called the Evolution of curves, and D *c b a* is called the Evolute of DCBA, which is called the Involute of D *c b a*. Perhaps this denomination has been given from the geneſis of the area or ſurface contained by the two lines, which is folded up and unfolded ſomewhat like a fan. When the deſcribing point is in *b*, the thread *b* B is, undoubtedly, the momentary radius of a circle *e b f*, whoſe centre is B, the point of the involute which it is juſt going to quit. The momentary motion of *b* is the ſame, whether it is deſcribing an arch of the evolute paſſing through *b*, or an arch of a circle round the centre B. The ſame line *b t*, perpendicular to the thread *b* B, touches the circle *e b f* and the curve D *b a* in the point *b*. This circle *e b f* muſt lie within the curve D *b a* on the ſide of *b* B toward *a*; becauſe on this ſide the momentary radius is continually increaſing. For ſimilar reaſons, the circle *e b f* lies without the curve on the other ſide of *b* B. Therefore the circle *e b f* both touches and cuts the curve D *b a* in the point *b*. Moreover, becauſe every portion of the curve between *b* and D is deſcribed with radii that are ſhorter than *b* B, it muſt be more incurvated than any portion of the circle *e b f*. For ſimilar reaſons, every portion of the curve between *b* and *a* muſt be leſs incurvated than this circle; therefore the circle has that preciſe degree of curvature that belongs to the curve in the point *b*; it is therefore called the

Circle of curvature. Equicurve circle.

Equicurve Circle, or the Circle of Curvature, and B is called the centre, and B *b* the Radius of Curvature. It is eaſy to perceive that no circle can be deſcribed which ſhall touch the curve in *b*, and come between it and the circle *e b f*; for its centre muſt be in ſome point *i* of the radius *b* B. If *i b* be leſs than B *b*, it muſt fall within the curve on both ſides of *b*, and if *i b* is greater than B *b*, the circle muſt fall without the curve on both ſides of B *b*. The circle *e b f* lies cloſer to the curve, has cloſer contact with it than any other, and has therefore got the whimſical name of Osculating Circle; and this ſort of contact was called Osculation.

This view of the geneſis of curve lines is of particular uſe in dynamical diſcuſſions. It exhibits to the eye the perfect ſameneſs of the momentary motion, and therefore of the momentary deflection, in the curve and in the equicurve circle, and leaves the mind without a doubt but that the forces which produce the one will produce the other. A great variety of curves may be deſcribed in this way. If perpendiculars be drawn to the curve D *b a* in every point, they will interſect each other, each its immediate neighbour, in the circumference of the curve DBA: and geometry teaches us how to find the curve DBA which ſhall produce the curve D *b a* by evolution. See Evolution and Involution, *Supplement*.

It is a matter worthy of remark, that the path of a body that is deflected from rectilineal motion by a *finite* force, varying according to any law whatever, may always be deſcribed by evolution. This includes almoſt every caſe of the action of deflecting forces; none being excepted but when, by the oppoſite action of different forces, the body is in equilibrio in one ſingle point of its path.

Our taſk is now brought within a very narrow compaſs, namely, to meaſure the deflection in the arch of a circle.

Had the motion repreſented in fig. 21. been polygonal, it is plain that the deflecting force in the point B is to that in the point E as the diagonal B *b* of the parallelogram ABC *b* to the diagonal E *i* of the parallelogram DEF *i*; therefore let ABCZY be a circle paſſing through the points A, B, and C, and let the radius vector BS cut the circumference in Z; draw AZ, CZ, and the diagonal AC, which neceſſarily biſects and is biſected by the diagonal B *b*. The triangles *b* BC and CBZ are ſimilar; for the angle C *b* B is equal to the alternate angle AB *b* or ABZ, which is equal to the ACZ, ſtanding on the ſame chord AZ. And the angle CB *b*, or CBZ, is equal to CAZ, ſtanding on the ſame chord CZ; therefore the remaining angle *b* CB is equal to the remaining angle AZC; therefore ZA is to AC as BC to B *b*, and B *b* $= \frac{AC \times BC}{AZ}$. In like manner E *i* $= \frac{DF \times EF}{Dz}$.

Now let the points A and C continually approach, and ultimately coaleſce with B; it is evident that the circle ABCZY is ulimately the equicurve or coinciding circle at the point B, and that AS ultimately coaleſces with, and is equal to, BS, and that AC × BC is ultimately $2\,BC^2$; therefore ultimately B *b* : E *i* $= \frac{2BC^2}{BZ} : \frac{2EF^2}{Ez}$, or $= \frac{BC^2}{\frac{1}{2}BZ} : \frac{EF^2}{\frac{1}{2}Ez}$.

Measure of deflecting forces.

Now BC and EF being deſcribed in equal times, are as the velocities: B *b* and E *i* are the meaſures of the velocities which the deflective forces at B and E would generate in the time that the body deſcribes BC or EF, and are therefore the meaſures of thoſe forces. *They are as the ſquares of the velocities directly, and inverſely as thoſe chords of the equicurve circles which have the directions of the deflection.*

Obſerve, that B *b* or E *i* is the third proportional to half of the chord and the arch deſcribed; for B *b* : BC $= BC : \frac{BZ}{2}$.

It is evident that as the arches AB, BC, continually diminiſh, AC is ultimately parallel to the tangent B *r*, and BO is equal to the actual deflection from the tangent. The triangles BOC and AOZ are ſimilar, and BO $= \frac{OC^2}{OZ}$, or ultimately $= \frac{BC^2}{BZ}$. We may meaſure the forces by the actual deflections, becauſe they are the halves of the meaſures of the generated velocities; and we may ſay that

120 Measure of deflection.

The actual momentary deflection from the tangent is a third proportional to the deflective chord of the equicurve circle and the arch deſcribed during the moment.

Caution.

Either of theſe meaſures may be taken, but we muſt take care not to confound them. The firſt is the moſt proper, becauſe the change produced on the body (which is the *immediate* effect and meaſure of the force) is the determination, left inherent in it, to move with a certain velocity. This is the meaſure alſo which we obtain by means of the differential or fluxionary calculus; but the other meaſure muſt be obtained when our immediate object is to mark the actual path of the body. What is now delivered coincides with what was more briefly ſtated in ASTRONOMY, *Suppl.* n° 16. and is repeated in this place, becauſe the ſteps of this demonſtration, which is Newton's, ſo naturally terminate in the equicurve circle, and give at once the immediate meaſure of the deflecting force: at the ſame time the reader muſt perceive that this meaſure does not depend on the force being always directed to one centre; it is enough that the two ſides of the polygon, in immediate ſucceſſion, are deſcribed in equal times. This is neceſſary in order that ABC *b* may be a parallelogram, and that the diagonals AC and B *b* may mutually biſect each other.

Thus have we obtained a meaſure of deflecting force, and, in the moſt important caſes, a method of diſcovering its direction. It only remains to point out the relation between the intenſity of the force, the curvature of the path, and the velocity of the motion. Theſe three circumſtances have a neceſſary connection; for we ſee that the intenſity is expreſſed by certain values of the other two in the formula $f \doteq \frac{\text{Arch}^2}{\frac{1}{2}\text{Chord}}$, or $f = \frac{2\,\text{BC}}{\text{BZ}}$. The deflective velocity B *b* is acquired in the time that the body deſcribes BC; therefore the deflective velocity is to the velocity in the curve as B *b* to BC. The velocity B *b* is acquired by an accelerated motion along BO; for while, by progreſſive motion, the body deſcribes BC, it deflects from the tangent through a ſpace equal to the half of B *b*, becauſe the momentary action of the deflecting force may be conſidered as uniform. The progreſſive velocity BC may be generated by the ſame force, uniformly acting through a ſpace greater than BC; call this ſpace x. The ſpaces along which a body muſt be uniformly impelled in order to acquire different velocities, are as the ſquares of thoſe velocities; therefore $\text{B}\,b^2 : \text{BC}^2 = \text{B}\,o : x$; but $\text{B}\,b : \text{BC} = \text{BC} : \frac{1}{2}\,\text{BZ}$; therefore $\text{B}\,b^2 : \text{BC}^2 = \text{B}\,b : \frac{1}{2}\,\text{BZ}$, and $\text{B}\,b : \frac{1}{2}\,\text{BZ} = \text{B}\,o : x$, and $\text{B}\,b : \text{B}\,o = \frac{1}{2}\,\text{BZ} : x$; but B *o* is ½ of B *b*; therefore x is ¼ of BZ; that is,

121. *The velocity in any point of a curvilineal path, is that which the deflecting forces in that point would generate in the body by impelling it uniformly along one fourth part of the deflective chord of the equicurve circle.* If the velocity increaſe, the chord of the equicurve circle muſt increaſe; that is, the path becomes leſs incurvated. If the force be increaſed, the curvature will alſo increaſe, for the chord of curvature will be leſs.

There is another general obſervation to be made on the velocity of a curvilineal motion, which greatly aſſiſts us in our inveſtigations.

122 Compariſon of orbital motion with direct approach to the centre.

If a body deſcribes a curve by the action of a force always directed to a fixed point, and varying according to any proportion whatever of the diſtances from that point, and if another body, acted on by the ſame centripetal force, move toward the centre in a ſtraight line, and if in any one caſe of equal diſtances from the centre of force the two bodies have equal velocities, they will have equal velocities in every other caſe of equal diſtances from the centre.

Let one body be impelled from A (fig. 23.) toward C along the ſtraight line AVDEC, and let another be deflected along the curve line VIK *k*. About the centre C deſcribe concentric arches ID, KE, very near to each other, and cutting the curve in I and K, and the line AC in D and E; draw IC, cutting KE in N, and draw NT perpendicular to the arch IK of the curve, and complete the parallelogram ITNO. Let the bodies be ſuppoſed to have equal velocities at I and at D.

Then, becauſe the centripetal forces are ſuppoſed to be the ſame for both bodies when they are at equal diſtances, the accelerating forces at D and I may be repreſented by the equal lines DE and IN; but the force IN is not wholly employed in accelerating the body along the arch IK, but, acting tranſverſely, it is partly employed in incurvating the path. It is equivalent to the two forces IO and IT, of which only IT accelerates the body. Now IKN is a right-angled triangle, as is alſo the triangle INT; and they are ſimilar; therefore IN : IT = IK : IN, or DE : IT = IK : DE; that is, the force which accelerates the body along DE is to the force which accelerates the body along IK as the ſpace IK is to the ſpace DE; therefore (n° 86.) the increment of the ſquare of the velocity acquired along DE is equal to the increment of the ſquare of the velocity acquired along IK. But the velocities at D and I were equal, and conſequently their ſquares were equal; and theſe having received equal increments, therefore the ſquares of the velocities at E and K are equal, and the velocities themſelves are equal. And ſince this is the caſe in all the correſponding points of the line AC and the curve VIK, the velocities at all equal diſtances from C will be equal.

It it evident that the concluſion will be the ſame, if the bodies, inſtead of being accelerated by approaching the centre in the ſtraight line AC, and in the curve VIK, are moving in the oppoſite directions from E to A, or from I to V, and are therefore retarded by the centripetal force.

123 Retarded curvilineal motion always accompanied by receſs from the centre.

Cor. Hence it follows, that if a body be projected from any point, ſuch as V, of the curve, in a line tending ſtraight from the centre, with the velocity which it had in that point of the curve, it would go to a diſtance VA, ſuch, that if it were impelled along AV by the centripetal force, it would acquire its former velocity in the point V; alſo in any point between V and A it will have the ſame velocity in its receſs from the centre that it has there in its approach to the centre.

The line BLFG, whoſe ordinates are as the intenſities of the centripetal force in A, V, D, E, or in A, V, I, K, may be called the SCALE or EXPONENT of force; the areas bounded by the ordinates AB, VL, DF, EG, &c. drawn from any two points of the axis, are as the ſquares of the velocity acquired by acceleration along the intercepted part of the axis, or in any curvilineal path, while the body approaches the centre, or which are loſt while the body retires from it. When we can compute theſe areas we obtain the velocities (ſee n° 102.).

We are now in a condition to ſolve the chief problem in the ſcience of dynamics, to which the whole of it is, in a great meaſure, ſubſervient. The problem is this,

Let a body be projected with a known velocity from a

124 Inverſe problem of centripetal forces.

a given point and in a given direction, and let it be under the influence of a mechanical force, whoſe direction, intenſity, and variation, are all known: it is required to determine its path, and its motion in this path, for any given time?

This problem is ſuſceptible of three diſtinct claſſes of conditions, which require different inveſtigation.

1. The force may act in one conſtant direction; that is, in parallel lines.

2. The force may be always directed to a fixed point.

3. It may be directed to a point which is continually changing its place.

1. When the force acts in parallel lines, the problem is ſolved by compounding the rectilineal accelerated motion which the force would produce in its own direction with the uniform motion which the projection alone would have produced. The motion muſt be curvilineal, when the accelerating force is tranſverſe, in any degree whatever, to the projectile motion; and the curvilineal path muſt be concave on that ſide to which the deflecting force tends; for the force is ſuppoſed to act inceſſantly. The place of the body will be had for any time, by finding where the body would have been at the end of that time by each force acting alone, and by completing the parallelogram. Thus, ſuppoſe a body projected along AB (fig. 20.) while it is continually acted on by a force whoſe direction is AD. Let D and B be the places where the body would be at the end of a given time. Then the body will at the end of that time be in F, the oppoſite angle of the parallelogram ABFD. But it has not deſcribed the diagonal AF; becauſe its motion has been curvilineal, as we ſhall find by determining its place at other inſtants of this time.

The velocity in any point F is found by firſt determining the velocity at D, and making DT to DF as the velocity at D to the velocity at B (that is, the velocity of projection, becauſe the motion along AB is uniform). Then draw TF. Then AB is to TF as the conſtant velocity of projection to the velocity at F. We have ſeen already (n° 112—119.) that TF is a tangent to the curve in F. Hence we may determine the velocity at F in another way. Having determined the form of the path in the way already deſcribed, by finding its different points, draw the tangent F *d*, cutting the line DA in *d*. Then the velocity at A is to that at F as AB to *d* F. Hence alſo we ſee, that the velocities in every point of the curve are proportional to the portion of the tangents at thoſe points which are intercepted between *any* two lines parallel to AD.

Either of theſe methods for aſcertaining the velocity, in this caſe of parallel deflections, will in general be eaſier than the general method in n° 121. by the equicurve circle.

It was thus that Galileo diſcovered the parabolic motion of heavy bodies.

Inverſe problem of centripetal forces.

2 We muſt conſider the motions of bodies affected by centripetal or centrifugal forces, always tending to one fixed point. This is the celebrated *inverſe problem of centripetal forces*, and is the 42d propoſition of the firſt book of Newton's *Principia*. We ſhall give the ſolution after the manner of its illuſtrious author; becauſe it is elementary, in the pureſt ſenſe of the word, keeping in view the two leading circumſtances, and theſe only, namely, the motion of approach and receſs from the centre, and the motion of revolution. By this judicious proceſs, it becomes a pattern by which more refined, and, in ſome reſpects, better ſolutions ſhould be modelled. At the ſame time we ſhall ſupply ſome ſteps of the inveſtigation which his elegant conciſeneſs has made him omit.

125. Let a body, which tends to C (fig. 24.) with a force proportional to the ordinates of the exponent BLFG, having the axis CA, be projected from V in the direction VQ, with the velocity which the centripetal force would generate in it by accelerating it along AV. It is required to determine the path or orbit VIKI of the body, and its place I in this orbit, at the end of the aſſigned time T?

Suppoſe the thing done, and that I is the place of the body. About the centre C, with the diſtances CV and CI, deſcribe the circles YV and ID. Draw CIX to the circumference, and draw the ordinate DF of the exponent of forces, producing it toward *x*, and produce the ordinate VL toward *a*. Let V *t* be the diſtance to which the body would go along the tangent VQ in the time T, and join *t* C. Let this be ſuppoſed done for every point of the curve. Let *a i k* and *a x y* be two curves ſo related to the curve VIK, that the ordinate DF cuts off an area V *a i* D equal to the orbital ſector VCI, and an area V *a x* D equal to the circular ſector VCX.

Then, becauſe the velocity of projection is given, the diſtance V *t* is known, and the area of the triangle VC *t*. But this is equal to the area VCI, by the laws of central forces (n° 115.). Therefore the area V *a i* D is given. Alſo, becauſe the area VCI increaſes in the proportion of the time, the area V *a i* D increaſes at the ſame rate. Therefore having theſe ſubſidiary curves *a i k*, *a x y*, the problem is ſolved as follows:

Draw an ordinate D *i*, cutting off an area V *a i* D proportional to the time, and deſcribe a circle DIR. Then draw a line CX, cutting off a ſector VCX, equal to the area V *a x* D cut off by the ordinate D *i x*. This line will cut the circle DR in the point I, which is the point of the orbit that was demanded.

But the chief difficulty of the problem conſiſts in the deſcription of the two ſubſidiary curves *a i k* and *a x y*, into which the lines VIK and VXY are tranſformed. We attain this conſtruction by reſolving the motion in the arch of the orbit into two motions, one of which is in the direction of the tranſverſe force, or of the radius vector, and the other is in the direction of revolution, or perpendicular to the radius.

Let V *k* and IK be two very ſmall arches deſcribed in equal moments, and therefore ultimately in the ratio of the velocities in V and I (n° 73.). Deſcribe the circle KE, cutting IC in N. Draw KC and *k* C, and *k n* perpendicular to VC.

The element ICK of the orbit is $= \frac{\text{IC} \times \text{KN}}{2}$, or to $\frac{1}{2}$ IC × KN. This is equal to the element D *i k* E of the area V *a i* D, or to D *i* × DE, or to D *i* × IN. Therefore IN : KN = $\frac{1}{2}$ IC : D *i*, or 2 IN : KN = IC : D *i*, and D *i* $= \frac{\text{IC} \times \text{KN}}{2\ \text{IN}}$.

Now let A *l ſ g h* be the exponent of the velocities, that

that is (n° 86.), let $V l^2$ be to $D f^2$ as ABLV to ABFD, or $V l : D f = \sqrt{ABLV} : \sqrt{ABFD}$. Make $V v$ and $I i$ in the tangents reſpectively equal to $V l$ and $D f$. Draw $v u$ and $i o$ perpendicular to VC and IC, and $v m$ perpendicular to LV produced. Let $m r z$ be an equilateral hyperbola, having VC, ZC, for its aſſymptotes, and cutting FD produced in r. Then the ordinates $V m$, $D r$, are inverſely proportional to CV, CD, or $V m : D r = CD : CV, = CI : CV$. But becauſe the momentary ſectors $VC k$ and ICK are equal, $k n : KN = CI : CV$. Therefore,

$V m : D r = k n : KN$

but $V v : V m = V k : k n$

and $I i \text{ (or } D f) : V v = IK : V k$

therefore $I i : D r = IK : KN$

but $I i : i o = IK : KN$, by ſim. triang.

Therefore $D r = i o$, and $i o : V m = VC : CI$.

Alſo, by ſimilarity of triangles, $I o : i o = IN : KN$, and $2 I o : i o = 2 IN : KN$.

Now it was ſhewn, that in order that the ſpace $D i k E$ may be equal to the ſpace ICK, we muſt have

$2 IN : KN = IC : D i$

or $2 I o : i o = IC : D i$

but $i o : V m = VC : IC$

therefore $2 I o : V m = VC : D i$

and $D i = \frac{VC \times V m}{2 I o}$.

Having obtained $D i$, we eaſily get $D x$; for the ultimate ratio of ICK to XCY is that of IC^2 to VC^2. Therefore make

$IC^2 : VC^2 = D i : D x$.

Thus are the points of the two ſubſidiary curves $a i k$, $a x y$, determined.

The rectangle $VC \times V m$ is a conſtant magnitude; and is given, becauſe VC is given, and $V m$ is the given velocity $V l$, diminiſhed in the ratio of radius to the ſine of the given angle CVQ.

But the line $2 I o$ is of variable magnitude, but it is alſo given, by means of known quantities. $I o^2$ is $= I i^2 - i o^2 = D f^2 - D r^2$, and $I o = \sqrt{D f^2 - D r^2}$. Moreover, $D f^2 = ABFD$, and $D r^2 = \frac{VC^2 \times V m^2}{IC^2}$. Therefore $2 I o = 2 \sqrt{ABFD - \frac{VC^2 \times V m^2}{IC^2}}$, expreſſed in known quantities, becauſe ABFD is known from the nature of the centripetel force.

Let the indeterminate diſtance CI or CD be $= x$, and let the ordinate DF, expreſſing the force, be y. Let VC be a, and $V m$ be c, and let $a b$ be a rectangle equal to the whole area of the exponent of force lying between the ordinate AB and the ordinate CZ, ſo that $a b - \int y \dot{x}$ may repreſent the indeterminate area ABFD.

We have $D i = \frac{a c}{2 \sqrt{a b - \int y \dot{x} - \frac{a^2 c^2}{x^2}}}$

and $D x = \frac{a^3 c}{2 x^2 \sqrt{a b - \int y \dot{x} - \frac{a^2 c^2}{x^2}}}$.

Remark. We have hitherto ſuppoſed that the velocity of projection is acquired by acceleration along AV. But this was merely for greater ſimplicity of argument, and that the final values of $D i$ and $D x$ might be eaſier conceived. In whatever way the velocity is acquired, it will ſtill be true, that when in any point V we make $V l$ to $V m$ as the momentary increment $V k$ of the arch is to the perpendicular $k n$ on the radius vector, we ſhall have in every other point, ſuch as I, the line $D f$ to the line $D r$ as the increment IK of the arch to KN. And in the final equation $D f$ will ſtill be expreſſed by $\sqrt{a b - \int y \dot{x}}$.

126. *Cor.* 1. The angle which the path of the projectile makes with the radius vector is determined by this ſolution; for $I i$ is to $i o$ as radius to the ſine of this angle; which ſine is therefore $= \frac{a c}{x \sqrt{a b - \int y \dot{x}}}$.

127 Apſides determined; *Cor.* 2. When the magnitude $\frac{a c}{x}$ is equal to $\sqrt{a b - \int y x}$, the path is perpendicular to the radius vector, and the body is a tone of the apſides of its orbit, and begins to recede from the centre after having approached to it, or begins to approach after having receded.

128 And curvature. *Cor.* 3. The curvature of the orbit VIK is alſo determined in every point; for the curvature of any line is inverſely as the radius of the equicurve circle, and this is to the chord which paſſes through C as radius to the ſine of the angle $CI i$. Becauſe the velocity in any point I is $= \sqrt{ABFD}$, and is equal to what the centripetal force at I would produce, by impelling the body along ¼th of the deflective chord of the equicurve circle, we have this chord $= 4 \frac{ABFD}{DF}$. Or we obtain it by taking a third proportional to the momentary deflection and the momentary arch of the curve, or by other proceſſes of the higher geometry, all proceeding on the quantities furniſhed in this inveſtigation.

129 Newton the inventor. Such is the ſolution of this celebrated problem given by Sir Iſaac Newton, who may juſtly be called the inventor of the ſcience of which it is the chief reſult, as well as of the geometry, by help of which it is proſecuted. For we cannot give this glory to Galileo; for his ſimple problem of the motion of bodies affected by uniform and parallel gravity, however juſt and elegant his ſolution may be, was peculiar; and the ſame muſt be ſaid of Mr Huyghens's doctrine of centrifugal forces. Beſides, theſe theorems had been inveſtigated by Newton ſeveral years before, *ſua matheſi facem preferente*, as corollaries which he could not paſs unnoticed, from his general method. This is proved by letters from Huyghens. Newton's inveſtigation is extremely, but elegantly, conciſe, and is one of the beſt exertions of his ſagacious mind.

130 Hiſtory of this problem. Whether we conſider this problem as a piece of mere mathematical ſpeculation, or attend to its conſequences, which include the whole of the celeſtial motions in all their extent and complication, we muſt allow it to be highly intereſting, and likely to engage much attention in the period of ardent inquiry which cloſed the laſt century. Accordingly, it was no ſooner known, by the publication of the *Mathematical Principles of Natural Philoſophy* in 1686, than it occupied the talents of the moſt eminent mathematicians; and many ſolutions were publiſhed, ſome of which differ conſiderably from Newton's; ſome are more expeditious, and better fitted for computation. Of theſe, the moſt remarkable

for originality and ingenuity are thoſe of de Moivre, Hermann, Keill, and Stewart. The laſt differs moſt from the methods purſued by others. M'Laurin's propoſitions on this ſubject, and in that part of his fluxions which treats of curvature, are highly valuable, claſſing the chief affections of curvilineal motions geometrically, as they are ſuggeſted by the fluxionary method; and then ſhewing, in a very inſtructive manner, the connection between theſe mathematical affections of motion and the powers of nature which produce them. This part of his excellent work is a fine example of the real nature of all inquiries in dynamics; ſhewing that it differs from geometry little more than in the language, in which the word *force* is ſubſtituted for *acceleration*, *retardation*, or *deflection*. We recommend the careful peruſal of theſe propoſitions to all who wiſh to have clear conceptions of the ſubject. Dr John Keill and Dr Horſeley (biſhop of Rocheſter) have given particular treatiſes on the motions of bodies deflected by centripetal forces inverſely proportional to the cubes of the diſtances; induced by the ſingular motions which reſult from this law of action, and the multitude of beautiful propoſitions which they ſuggeſt to the mathematician. Newton, indeed, firſt perceived both of theſe peculiarities, and has begun this branch of the general problem. He firſt demonſtrated the deſcription of the logarithmic and hyperbolic ſpirals, and indicated a variety of curious recurring elliptical ſpirals, which would be deſcribed by means of this force, and ſhewing that they are all ſuſceptible of accurate quadrature. Several of thoſe authors affect to conſider their ſolutions as more perfect than Newton's, and as more immediately indicating the remarkable properties of ſuch motions; and alſo affect to have deduced them from different and original principles. But we cannot help ſaying, that their claims to ſuperiority are very ill founded; there is not a principle made uſe of in their ſolutions which was not pointed out by Newton, and employed by him. The appearance of originality ariſes from their having taken a more particular concern in ſome general property of curvilineal motions; ſuch as the curvature, the centrifugal force, &c. and the making that the leading ſtep of their proceſs. But Newton's is ſtill the beſt; becauſe it is ſtrictly elementary, aiming at the two leading circumſtances, the motion to or from the centre, and the motion of revolution round that centre. To theſe two purpoſes he adapted his two ſubſidiary curves. This procedure became Newton, *pater, et rerum inventor*, who was teaching the world, and who might ſay,

Avia Pieridum peragro loca, nullius ante
Trita pede——

Singular boaſt of John Bernoulli.

Is it not ſurpriſing, that 25 years after the publication of Newton's *Principia*, a mathematician on the continent ſhould publiſh a ſolution in the Memoirs of the French academy, and boaſt that he had given the firſt demonſtration of it? Yet John Bernoulli did this in 1710. Is it not more remarkable that this ſhould be preciſely the ſolution given by Newton, beginning from the ſame theorem, the 40th I. Prin. following Newton in every ſtep, and uſing the ſame ſubſidiary lines? Yet ſo it is. Bernoulli actually reduces the whole to two functions; namely, $\frac{a\,c}{\sqrt{a\,b-\int\varphi\,\dot{x}-\frac{a^2\,c^2}{x^2}}}$ and $\frac{a^2\,c}{\sqrt{a\,b\,x^4-\int\varphi\,x^4-a^2\,c^2\,x^2}}$; which laſt is plainly the ſame with Newton's $\frac{Q\times CX^2}{A^2\sqrt{ABDF-Z^2}}$; becauſe Newton's $\frac{Q}{A}$ is the ſame with $\frac{a\,c}{x}$, and Newton's $A^2\sqrt{ABFD-Z^2}$ is the ſame with $x^2\sqrt{a\,b-\int\varphi\,\dot{x}-\frac{a^2\,c^2}{x^2}}$, which Bernoulli has changed (apparently to hide the borrowing) into $\sqrt{a\,b\,x^4-\int\varphi\,x^4\,\dot{x}-a^2\,c^2\,x^2}$. This publication of Bernoulli is perhaps the moſt impudent piece of literary *robbery*, for theft is too mild a term, that has ever appeared; and is the more deſerving of ſevere reprehenſion, becauſe it is full of reflections on the ſimple and ſupremely elegant method of Newton. It is hardly conceivable that a perſon of Bernoulli's conſummate mathematical knowlege was ſo much blinded by the mechanical procedure of the ſymbolical calculus (which indeed is rarely accompanied by any ideas of the ſubject in hand) as not to perceive the perfect ſameneſs of his ſolution. No; he ſhews, from time to time, that the phyſical ideas of motion and force were preſent to his mind; for he affects to ſhew, that all Newton's brighteſt diſcoveries, ſuch as the proportionality of the areas and times, &c. flow as corollaries from his procedure.

Bernoulli's chief boaſt in this diſſertation is, that *now* philoſophers may be aſſured that the planets will always deſcribe conic ſections; a truth of which they had not as yet received any proof: becauſe, ſays he, Newton's argument for it in the corollary of the 13th propoſition is inconcluſive, and becauſe he had not been able to accommodate his demonſtration of the 41ſt and 42d propoſition to the particular caſe of the planetary gravitation. Two aſſertions that border on inſolence. Newton's demonſtration in the corollary of the 13th propoſition is juſt, founded on the principle on which the very demonſtration of the 42d, adopted by Bernoulli, proceeds, and without which that demonſtration is of no force; namely, that a body in given circumſtances of ſituation, velocity, direction, and centripetal force, can deſcribe no other figure than what it really deſcribes. Newton did not accommodate the demonſtration of the 42d propoſition to the planetary motions, becauſe he had already demonſtrated the nature of their orbits; but mentions the caſe of a force proportional to the reciprocal of the cubes of the diſtance; not as a deduction from the 42d, but becauſe it *was not* a deduction from it, and admitted a very ſingular and beautiful inveſtigation by methods totally and eſſentially different.

Bernoulli alſo ſays, that Newton's ſolution does not give us the notion of a continuous path, as his own does, but only informs us how to aſcertain points of this path. This is the boldeſt of all his aſſertions. Bernoulli uſes the differential calculus. It is the *eſſential* character of this calculus that it exhibits, and *can* exhibit, nothing but detached points. This is undeniable. And this has been objected to Newton's firſt propoſition. But Newton's fluxionary *geometry*, of which the calculus exhibits only elements (being the ſame with the differential), ſuppoſes oncluſion. ſuppoſes the continuity of all magnitudes; and when applied to dynamics, is no ſubſtitution whatever, but the *ipſa corpora*. This geometry offered itſelf to the mind of Newton, the accompliſhed and darling ſcholar of Barrow, whoſe geometry flaſhed on Newton's mind as the torch which was to ſhew him the ſteps of this yet untrodden path.

We truſt that our readers will not be diſpleaſed with our repeated endeavours to defend our great philoſopher from the injurious attacks that have been made on him. During his own illuſtrious life, while he was diffuſing light and knowledge around him, and never contended for fame, happy in being the inſtructor of mankind, he was injured by thoſe who envied his reputation, while they derived their chief honours from being his beſt commentators. Now, ſince he has left this world, he has been more groſsly injured by thoſe who avail themſelves of that very reputation: and who, by crude and contemptible inferences from his doctrine of elaſtic undulations, and groſs miſrepreſentations of his notions of an etherial fluid, have pretended to ſupport a ſyſtem of materialiſm; and thus have ſet Newton at the head of the atheiſtical ſect, which he held in abhorrence. For our part, we always think with pleaſure on the wonderful energy of that great mind; becauſe it gives us a foretaſte of thoſe pleaſures that await the wiſe and good, when the ſorrows flowing from the infirmities, the vices, and the arrogant vanity of man, are paſt;

Utque in hoc infelici campo,
Ubi luctus regnat, et pavor,
Mortalibus prorſus non abſit ſolatium.
Hujus enim ſcripta evolvas,
Mentemque tantarum rerum capacem
Corpori caduco ſuperſtitem credas.

132 ncluſion. It cannot be expected that, in the narrow limits preſcribed to a work like ours, we can proceed to conſider the various departments of this celebrated problem. We are only giving the outlines of the general doctrines of dynamics; and we have beſtowed more time on thoſe which are purely elementary than ſome readers may think they deſerve. We were anxious to give juſt conceptions of the fundamental principles of dynamics; becauſe we know that nothing elſe can intitle it to the name of a demonſtrative ſcience, and becauſe we ſee much indiſtinctneſs and uncertainty, and a general vagueneſs or want of preciſion, in ſeveral elementary works which are put into the hands of perſons entering on the ſtudy. This leads to errors of more conſequence than a perſon is apt to think; becauſe they affect our leading thoughts of mechaniſm itſelf, and our notions of the intimate nature of the viſible univerſe.

133 ſons for ſſions. But we muſt conclude the article with this great problem. Many very general doctrines of dynamics remain untouched; all, namely, that relate to the rotative motion of rigid bodies, and all that relate to the mutual action of bodies on each other in the way of impulſe.

The rotative motions, with the doctrine of mechanic momenta, have been conſidered at large in the article Rotation of the *Encycl. Britan.*; and we propoſe to offer ſome important conſiderations on the ſame ſubject in our ſupplement to the articles Machine and Mechanics. In the article Impulsion will be conſidered ſuch doctrines as are truly general, and independent of the ſpecific differences of the bodies. Dynamics profeſſes to involve no notions but thoſe of force, and its Concluſion. marks and meaſures.

Notwithſtanding theſe great omiſſions, we muſt obſerve that no new principle remains to be conſidered. We have given all that are neceſſary; and there is no queſtion that occurs in the caſes omitted, which cannot be completely anſwered by means of the propoſitions already eſtabliſhed. We have taught how to diſcover the exiſtence and agency of a mechanical force, to meaſure and characteriſe it, and then to ſtate what will be its various effects, according to the circumſtances of the caſe.

134 Univerſal reaction is a law of the material world. Proceeding by theſe principles, men have diſcovered an univerſal fact, that every action of one body on another is accompanied by an equal reaction of that other on the firſt, in the oppoſite direction; that is, to expreſs it in the language of dynamics, "all the phenomena which make us infer that the body A poſſeſſes a force by which it changes the motion of the body B, ſhew, at the ſame time, that B poſſeſſes a force by which it makes an equal and oppoſite alteration in the motion of A." This, however, is not a doctrine of abſtract dynamics: it does not flow from our idea of force; therefore it was not included in our liſt of the Laws of Motion. It is a part of the mechanical hiſtory of nature, juſt as the law of univerſal gravitation is; and it might be called the law of Universal Reaction. Sir Iſaac Newton has, in our humble apprehenſion, deviated from his accuſtomed logical accuracy, when he admits, as a third *axiom* or law of motion, that reaction is always equal and contrary to action. It is a phyſical law, in as far as it is *obſerved* to obtain through the whole extent of the ſolar ſyſtem. But Newton himſelf did not, in the ſubſequent part of his noble work, treat it as a logical axiom; that is, as a law of human thought with reſpect to motion: for he labours with much ſolicitude, and with equal ſagacity, to prove, by *fact and obſervation*, that it really obtains through the whole extent of the ſolar ſyſtem; and it is in this diſcovery that his chief claim to unequalled penetration and diſcernment appears.

135 Impulſion explained by it; Availing ourſelves of this fact, we, with very little trouble, ſtate all the laws of impulſion. The body A, for example, moving to the weſtward at the rate of eight feet per minute, overtakes the double body B, moving at the rate of four feet per minute. What muſt be the conſequence of their mutual impenetrability, and of the equality and contrariety of action and reaction? Their motions muſt be ſuch that both ſuſtain equal and oppoſite changes. They muſt give, in ſome way or other, *this* indication of poſſeſſing equal and oppoſite forces. This will be the caſe if, when the changes are completed, A and B move on in contact at the rate of four feet per minute: for here A has produced in each half of B a change of motion two; and therefore a totality of change equal to four. This is the effect, the mark, the meaſure, of the *impulſive* force of A; for it is the whole *impulſion*. B has produced in A a change of motion four, equal to the former, and in the oppoſite direction. This is the effect, mark, and meaſure, of the *repulſive* force of A; for it is the whole *repulſion*. And this is all that we obſerve in the colliſion of two lumps of clay; and the obſervation is one of the facts on which the reality of the phyſical law of equal action and reaction is founded: and we can make no farther inference from *this* fact.

But the event might have been very different. A and B may be two magnets floating on corks on water, with their north poles fronting each other. We know, by other means, that they really poſſeſs forces by which they equally repel each other. The dynamical principles already eſtabliſhed tell us alſo what muſt happen in this caſe. That both conditions of equal reaction and ſenſible repulſion may be fulfilled, A muſt come to reſt, and B muſt move forward at the rate of four feet per minute. The ſame thing muſt happen in the meeting of perfectly elaſtic bodies, ſuch as billiard balls. If elaſticities are known to be imperfect in any degree, our dynamical principles will ſtill ſtate the effect of their colliſion, in conformity to the law of equal reaction.

136 And rotation. In like manner, all the motions of rotation are explained or predicted by means of the ſame principles of dynamics applied to the force of coheſion. This is conſidered as a moving force, becauſe, when the attraction of a magnet acts on a bit of iron attached to one end of a long lath floating on water, the whole lath is moved, although the magnet does not act on it at all: ſome other force acts on it; it is its coheſion; which is therefore a moving force, and the ſubject of dynamical diſcuſſion.

137. And thus it appears that theſe ſubjects do not come neceſſarily, nor, perhaps, with ſcientific propriety, under the category of dynamics, but are parts of the mechanical hiſtory of nature. Yet, did a work like ours give room in this place, the ſtudy of mechanical nature might be conſiderably improved by giving a ſyſtem of ſuch *general* doctrines as involve no other notions but thoſe of force and its meaſures, and the hypotheſis of equal reaction. Some very general, nay univerſal, conſequences of this combination might be eſtabliſhed, which would greatly aſſiſt the mechanician in the ſolution of difficult and complicated problems. Such is the propoſition, that *the mutual actions of bodies depend on their relative motions only, and require no knowledge of their real motions.* This principle ſimplifies in a wonderful manner the moſt difficult and the moſt frequent caſes of action which nature preſents to our view; but at the ſame time gives a ſevere blow to human vanity, by forcing us to acknowledge that we know nothing of the real motion of any thing in the univerſe, and never ſhall know any thing of it till our intellectual conſtitution, or our opportunities of obſervation, are completely changed.

138. Mr D'Alembert has made this principle ſtill more ſerviceable for extricating ourſelves from the immenſe complication of actions that occurs in all the ſpontaneous phenomena of nature, by preſenting it to us in a different form, which more diſtinctly expreſſes what may be called the *elements* of the actions of bodies on each other. His propoſition is as follows (*ſee his Dynamique*, page 73.):

D'Alembert's general principle of dynamics. "In whatever manner a number of bodies change their motions, if we ſuppoſe that the motion which each body would have in the following moment, if it were perfectly free, is decompoſed into two others, one of which is the motion which it really takes in conſequence of their mutual actions, the other will be ſuch, that if each body were impreſſed by this force alone (that is, by the force which would produce this motion) the whole ſyſtem of bodies would be in equilibrio."

This is almoſt ſelf-evident; for if theſe ſecond conſtituent forces be not ſuch as would put the ſyſtem in equilibrio, the other conſtituent motions could not be thoſe which the bodies really take by the mutual action, but would be changed by the firſt.

For example, let there be three bodies P, Q, R, and let the forces A, B, C, act on them, ſuch as would give them the velocities p, q, r, in any directions whatever, producing the momenta, or quantities of motion, $P\times p$, $Q\times q$, $R\times r$, which we may call A, B, C, becauſe they are the proper meaſures of the moving force. Let us moreover ſuppoſe, that, by ſtriking each other, or by being any how connected with each other, they cannot take theſe motions A, B, and C, but really take the motions a, b, and c. It is plain that we may conceive the motion A impreſſed on the body P, to be compoſed of the motion a, which it really takes, and of another motion α. In like manner, B may be reſolved into b, which it takes, and another β; and C into c and κ. The motions will be the ſame, whether we act on P with the force A, or with the two forces a and α; whether we act on Q with the force B, or with b and β; and on R with the force C, or with c and κ. Now by the ſuppoſition, the bodies actually take the motions a, b, and c; therefore the motions α, β, and κ, muſt be ſuch as will not derange the motions a, b, and c; that is to ſay, that if the bodies had only the motions α, β, and κ, impreſſed on them, they would deſtroy each other, and the ſyſtem would remain at reſt.

Mr D'Alembert has applied this propoſition with great addreſs and ſucceſs to the very difficult queſtions that occur in the motions and actions of fluids, and many other moſt difficult problems, ſuch as the preceſſion of the equinoxes, &c. The cauſe of its utility is, that in moſt caſes it is not difficult to find what forces will put a ſyſtem in equilibrio; and, combining theſe with the known extraneous forces whoſe effects we are intereſted to diſcover, we obtain the motions which really follow the mutual action of the bodies.

This is not, properly ſpeaking, a principle: it is a form in which a general fact may be conceived. In the ſame way the celebrated mathematician De la Grange obſerved, that a ſyſtem of bodies acting on each other in any way, is in equilibrio, if there be impreſſed on its parts forces in the inverſe proportion of the velocities which each body takes in conſequence of their action or connection; and he expreſſes this univerſal fact by a very ſimple formula; and calling this alſo a principle, he ſolves every queſtion with eaſe and neatneſs, by reducing it to the inveſtigation of thoſe velocities. In this way he has written a complete ſyſtem of dynamics, to which he gives the title of *Mechanique Analytique*, full of the moſt ingenious and elegant ſolutions of very intereſting and difficult problems; and all this without drawing a line or figure, but accompliſhing the whole by algebraic operations.

139. But this is not teaching mechanical philoſophy; it is merely employing the reader in algebraic operations, each of which he perfectly underſtands in its quality of an algebraic or arithmetical operation, and where he may have the fulleſt conviction of the juſtneſs of his procedure. But all this may be (and, in the hands of an expert algebraiſt, it generally is), without any notions, diſtinct or indiſtinct, of the things, or the proceſſes of reaſoning that are repreſented by the ſymbols made uſe of. It is preciſely like the occupation of a banker's clerk when he carries his eye up and down the columns of pounds ſhillings and pence, calculates the compound intereſt, reverſionary values, &c.

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It were well if this were all, although it greatly diminiſhes the pleaſure which an accompliſhed mathematician might receive; but this total abſence of ideas expoſes even the moſt eminent analyſt to frequent riſks of paralogiſm and phyſical abſurdity. Euler, who was perhaps the moſt expert algebraiſt of the laſt century, making uſe of the Newtonian theorem for aſcertaining the motion of a body impelled along a ſtraight line AC (fig. 24) by a centripetal force, by comparing it with the motion in an ellipſe, of which the ſhorter axis was diminiſhed till it vaniſhed altogether, expreſſes his ſurpriſe at finding, that when he computes the place of the body for a time ſubſequent to that of its arrival at C, the body is back again, and in ſome place between C and A; in ſhort, that the body comes back again to A, and plays backward and forward. He ſays that this is ſomewhat wonderful, and ſeems inconſiſtent with ſound reaſon: "*ſed analyſi magis fidendum.*" It muſt be ſo. And he goes on to another problem.

In like manner Mr Maupertuis, an accompliſhed man and good philoſopher and geometer, finding the ſymbol MVS, or the quantity of matter, multiplied by the velocity and by the diſtance run over during the action, always preſent itſelf to him as a mathematical *minimum* in the actions of bodies on each other; he was amuſed by the obſervation, and preſumed that there was ſome reaſon for it in the nature of things. Finding that it gave him very neat ſolutions of many elementary problems in dynamics, he thought of trying whether it would aſſiſt him in accounting for the conſtant ratio of the ſines of incidence and refraction; he found that it gave an immediate and very neat ſolution. This problem had, before his time, occupied the minds of Des Cartes and Fermat. Each of theſe gentlemen ſolved the problem by ſaying, that the light did not take the *ſhorteſt* way from a point in the air to a point under water, but the *eaſieſt* way, in conformity with the acknowledged economy of nature and conſummate wiſdom of its adorable Author. But how was this the eaſieſt way, the courſe that economiſed the labour of nature? One of theſe gentlemen proved it to be ſo, if light move faſter in air than in water; the other proved it to be ſo, if light move faſter in water than in air. Both could not be right. Maupertuis was convinced that he had diſcovered what it was that nature was ſo chary of, and grudged to waſte—it was MVS! Therefore MVS can mean nothing but labour; nothing but natural exertion, mechanical action; therefore MVS is the proper meaſure of action. He kept this great diſcovery a profound ſecret; and, being Preſident of the Royal Academy of Berlin, he propoſed for the annual prize queſtion, "Are the laws of motion neceſſary or contingent truths?" He could not compete for the prize, by the laws of the Academy; but before the time of deciſion, he publiſhed at Paris his *Diſſertation on the Principle of the leaſt Action;* in which he pointed out the ſingular fact of MVS being always a minimum; and therefore, in fact, the object of nature's economical care. He ſolved a number of problems by making the minimum ſtate of $\frac{f v \dot{s}}{m}$ a condition of the problems; and, to crown the whole, ſhewed that the laws of motion which obtain in the univerſe could not be but what they are, becauſe this economy was worthy of infinite wiſdom; and *therefore* any other laws were impoſſible. The reputation of Maupertuis was already eſtabliſhed as a good mathematician and a worthy and amiable man, and he was a favourite of Frederic. The principle of leaſt action became a mode; and it drew attention for ſome time, till it went out of faſhion. It is no mechanical principle, but a neceſſary mathematical truth, as any perſon muſt ſee who recollects that v is the ſame with $\dot{s}$, and that f is the ſame with $m \dot{v}$.

Concluſion.

Great advantages of the geometrical method.

To avoid ſuch paralogiſms and ſuch whims, we are convinced that it is prudent to deviate as little as poſſible in our diſcuſſions from the *geometrical* method. This has ſurely the advantage of keeping the real ſubject of diſcuſſion cloſe in view; for motion includes the notion of lines, with all their qualities of magnitude and poſition. It is needleſs to take a repreſentative when the original itſelf is in our hands, and affords a much more comprehenſible object than one of its abſtract qualities, mere magnitude. Let any perſon candidly compare the lunar theory by Mayer or Euler with that by its illuſtrious inventor Sir Iſaac Newton, and ſay which of the two is moſt luminous and moſt pleaſing to the mind. No perſon will deny that theſe later performances are incomparably more adapted to all practical purpoſes, and lead to corrections which it would be extremely difficult and tedious to inveſtigate geometrically; but it muſt be acknowledged, at the ſame time, that *till this be done*, we have no idea whatever of the deviation of the track which this correction aſcertains from the path which the moon would follow, independent of the diſturbance expreſſed by the correction. In like manner, Dan. Bernoulli, by mixing as much as poſſible the linear method with the algebraic, in his diſſertations on muſical chords, made the beautiful diſcovery of the ſecondary trochoids, and demonſtrated the co-exiſtence of the harmonic ſounds in a full muſical note. Let the accompliſhed mathematician puſh forward our knowledge of dynamics by the employment of the ſymbolical analyſis; but let him be followed as cloſe as poſſible by the geometer, that we may not be robbed of ideas, and that the ſtudent may have light to direct his ſteps. But,—*manum e tabula.*

nano-eter.

Dynamometer.

DYNANOMETER, an inſtrument for aſcertaining the relative muſcular ſtrength of men and other animals. That it would be deſirable to know our relative ſtrengths at the different periods of life, and in different ſtates of health, will hardly be denied; and there can be no doubt but that it would be highly uſeful to have a portable inſtrument by which we could aſcertain the relative ſtrength of horſes or oxen intended for the plough or the waggon. Such an inſtrument was invented, many years ago, by Graham, and improved by Deſaguliers; but being conſtructed of wooden work it was too bulky to be portable, and therefore it was limited in its uſe.

M. Leroy of the Academy of Sciences at Paris conſtructed a much more convenient Dynanometer than Graham's, conſiſting of a metal tube, 10 or 12 inches in length, placed vertically on a foot like that of a candleſtick, and containing in the inſide a ſpiral ſpring, having above it a graduated ſhank terminating in a globe. This ſhank, together with the ſpring, ſunk into the tube in proportion to the weight acting upon it, and thus pointed in degrees the ſtrength of the perſon who preſſed on the ball with his hand.

This was a very ſimple conſtruction, and, we think, a good one; but it did not ſatisfy Buffon and Gueneau. Theſe two philoſophers wiſhed not merely to aſcertain the muſcular force of a finger or a hand, but to eſtimate that of each limb ſeparately, and of all the parts of the body. They therefore employed M. Regnier to contrive a new *dynamometer;* and the account which he gives * of his attempts to fulfil their wiſhes is calculated to enhance the difficulty of the enterprize. The inſtrument, however, which he conſtructed, is not ſuch as appears to us to have required any uncommon ſkill in mechanics, or any very great ſtretch of thought. It conſiſts chiefly of an elliptical ſpring, 12 inches in length, rather narrow, and covered with leather that it may not hurt the fingers when compreſſed by the hands. This ſpring is compoſed of the beſt ſteel well welded and tempered, and afterwards ſubjected to a ſtronger effort than is likely to be ever applied to it either by men or animals, that it may not loſe any of its elaſticity by uſe.

The effects of this machine are eaſily explained. If a perſon compreſſes the ſpring with his hands, or draws it out lengthwiſe by pulling the two extremities in contrary directions, the ſides of the ſpring approach towards each other; and it has an apparatus (we do not think a very ſimple one) appended to it, conſiſting of an index and ſemicircular plate, by which the degree of approach, and conſequently of effort, employed, is aſcertained with great accuracy. The author gives a tedious deſcription of other appendages, by means of which horſes or oxen may be employed to compreſs the ſpring. But as any mechanic may deviſe means for this purpoſe, we do not think it worth while to tranſcribe that deſcription. The Engliſh reader will find a full account of the whole apparatus in the 4th number of the very valuable miſcellany intitled *The Philoſophical Magazine.* The principle of the contrivance conſiſts in the elliptical ſpring, of which we confeſs ourſelves unable to perceive the ſuperiority to the ſpiral ſpring of M. Leroy, though the author ſees it very clearly.

DYSENTERY. See Medicine-*Index*, Encycl.—For the cure of this diſeaſe we have the following ſimple preſcription by Dr Perkins and Dr B. Lynde Oliver, of the State of Maſſachuſetts in North America.

Saturate any quantity of the beſt vinegar with common marine ſalt; to one large table-ſpoonful of this ſolution add four times the quantity of boiling water; let the patient take of this preparation, as hot as it can be ſwallowed, one ſpoonful once in half a minute until the whole is drank: this for an adult. The quantity may be varied according to the age, ſize, and conſtitution of the patient. If neceſſary, repeat the doſe once in ſix or eight hours. Conſiderable evacuations I conceive (ſays Dr Parkins) to be not only unneceſſary, but injurious, as they ſerve to debilitate and prolong the diſeaſe. A tea of plantain, or ſome other cooling ſimple drink, may be uſeful; and if a thirſt for cyder be diſcovered, it may be gratified. Carefully avoid keeping this preparation in veſſels partaking of the qualities of lead or copper, as the poiſon produced by that means may prove dangerous. The ſucceſs of the remedy depends much on preparing and giving the doſe as above directed.—The ſimplicity of this treatment renders it the more valuable, as all perſons have it in their power to avail themſelves of its uſe.

Dr Perkins ſays, that he has found it uſeful in agues, diarrhœas, and the yellow fever.

E.

EARTH, in chemiſtry. See Chemistry-*Index* in this Supplement.

Earth, in aſtronomy and geography. See *Encyclopædia.*

Earth, in ancient philoſophy, one of the elements, the ſubſtance of which this globe is compoſed. To aſcertain the denſity of that ſubſtance, many experiments have been made; but perhaps none more ingenious than thoſe of Mr Cavendiſh, which are detailed at full length in Part II. of the Tranſactions of the Royal Society of London for 1798. They were projected by the late Rev. John Michell, F. R. S. but he did not live to carry them into effect. After his death, the apparatus came to the Rev. F. J. H. Wollaſton, Jackſonian Profeſſor at Cambridge, who transferred them to Mr Cavendiſh. The apparatus contrived for making ſenſible the attraction of ſmall quantities of matter, and which has been improved by Mr Cavendiſh, is very ſimple: it conſiſts of a wooden arm 6 feet long, ſuſpended by the middle in an horizontal poſition by a ſlender wire 40 inches long; to each extremity is hung a leaden ball about two inches in diameter; and the whole is incloſed in a wooden caſe to defend it from the wind.

As no more force is required to turn this balance on its centre than is neceſſary to twiſt the ſlender ſuſpending wire, the ſmalleſt degree of attraction of a leaden weight or weights, a few (eight) inches in diameter, brought near to the ſmall ſuſpended ball or balls of the balance, will be ſufficient to move it ſenſibly aſide.

To determine from hence the denſity of the earth, all that is neceſſary is, to aſcertain what force is required to draw the arm aſide through a given ſpace, and then to have recourſe to calculation.

To prevent any diſturbance from currents that might be produced within the box that contained the balance, by even the difference of temperature that might be occaſioned

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* Journal de l'Ecole Polytechnique, v. 2.

Fig.1.

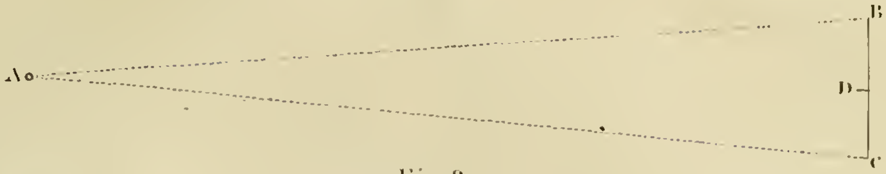


Fig.2.

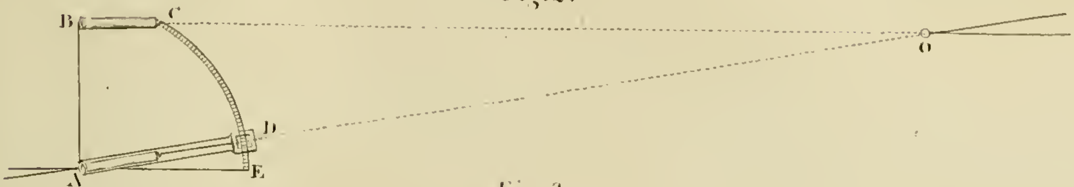
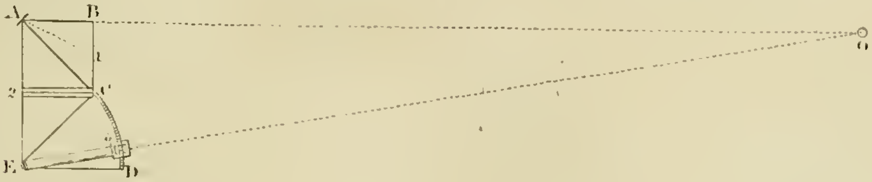


Fig.3.



DYNAMICS

Fig.1.

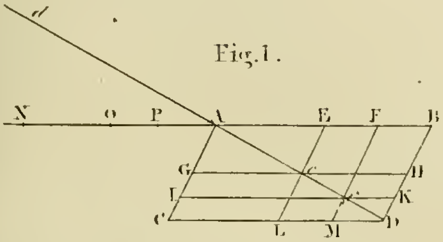


Fig.A

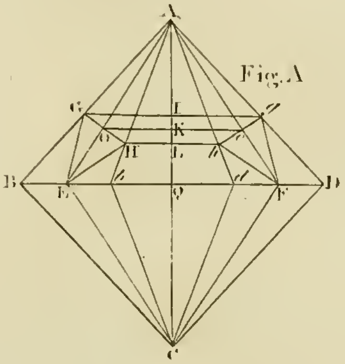


Fig. 2.

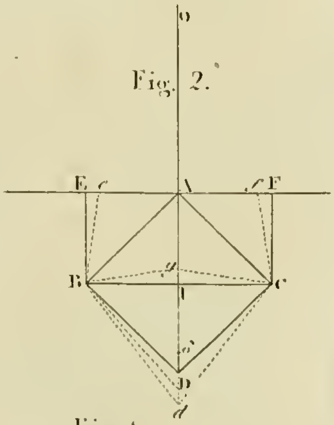


Fig.3.

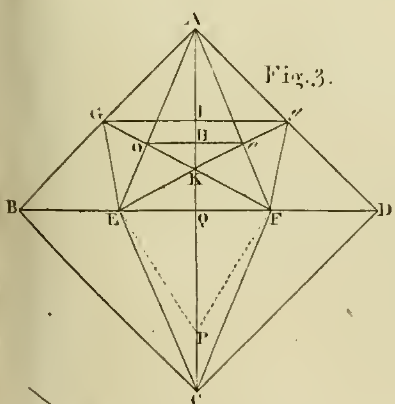


Fig.5.

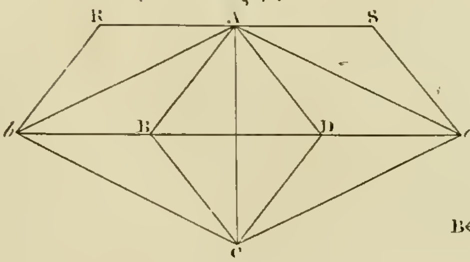
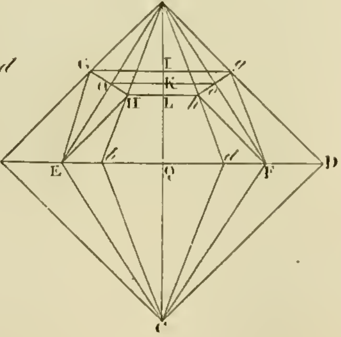


Fig.4.



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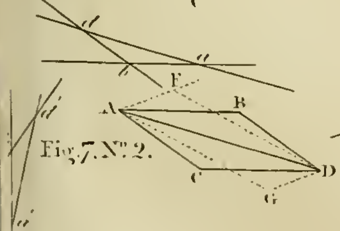


Fig.6.

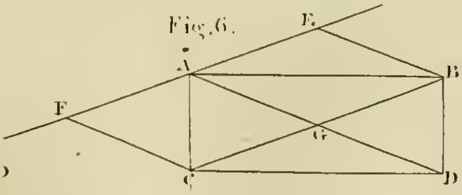
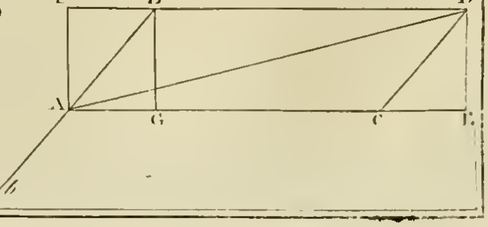


Fig.7.



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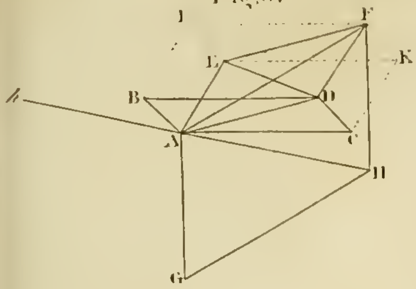

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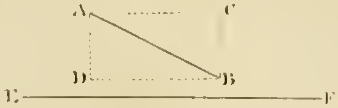

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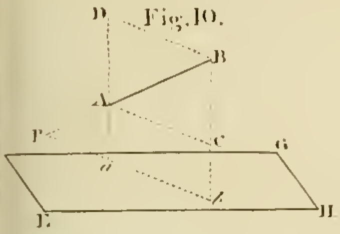

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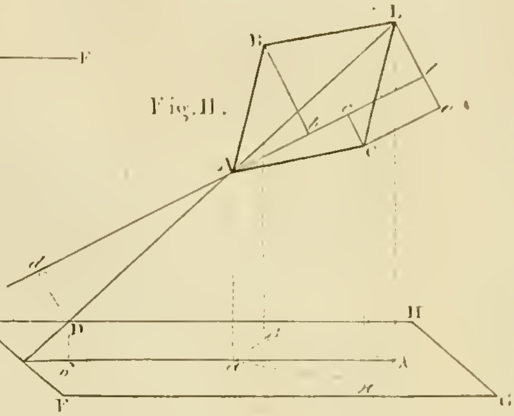

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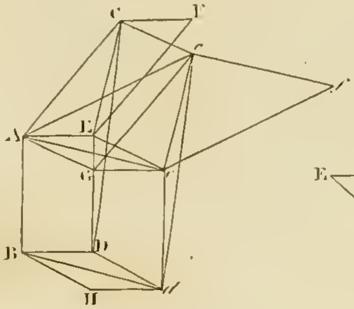

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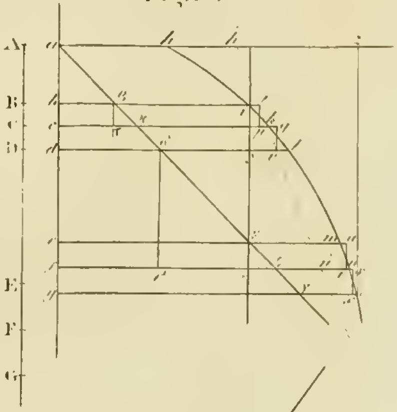

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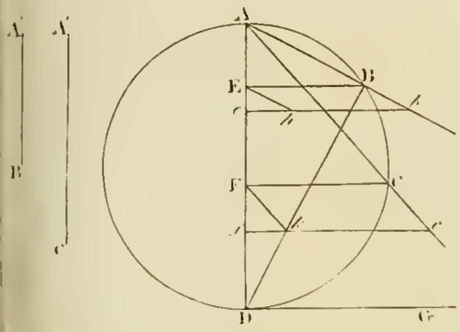

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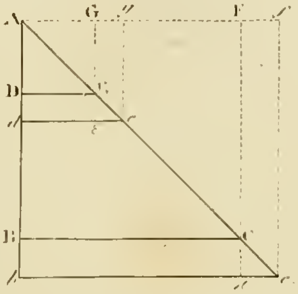

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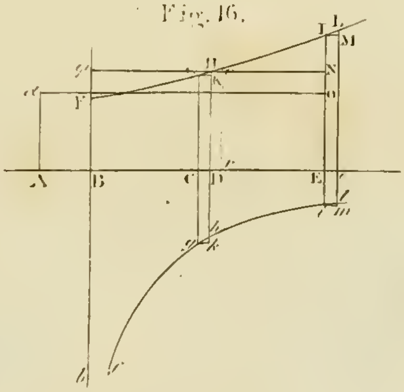

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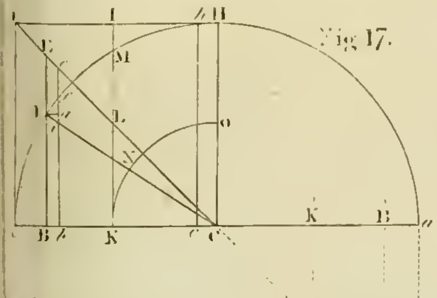

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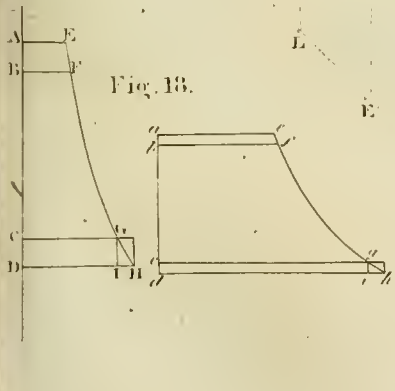

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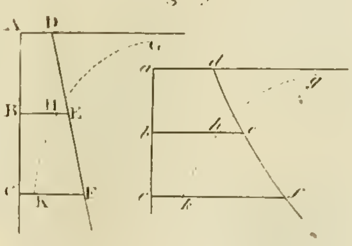

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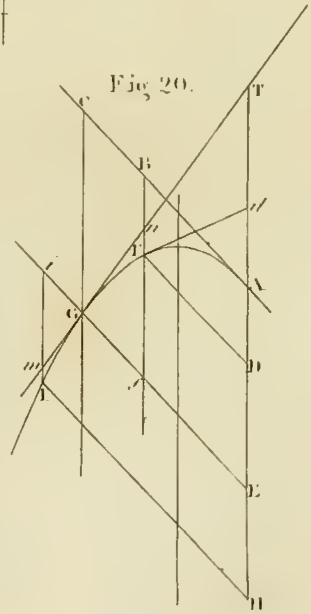

DYNAMICS PLATE XXIII

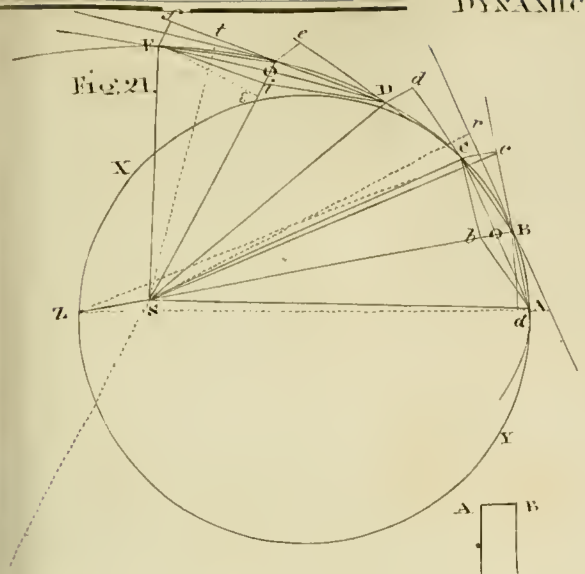
Fig. 21.

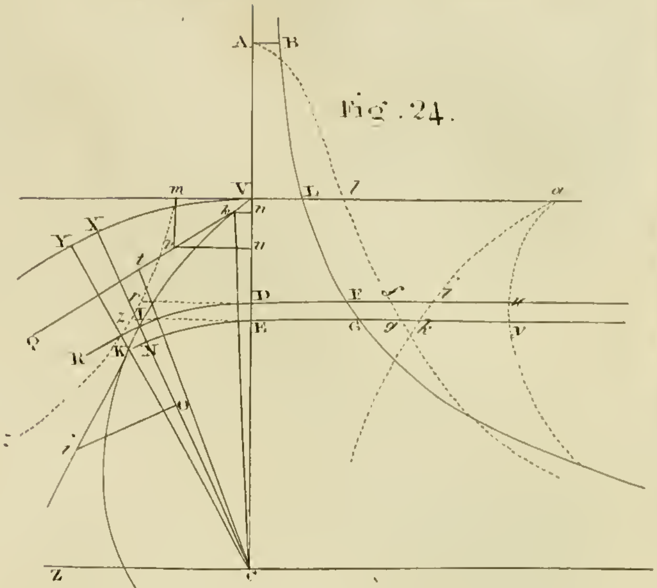
Fig. 24.

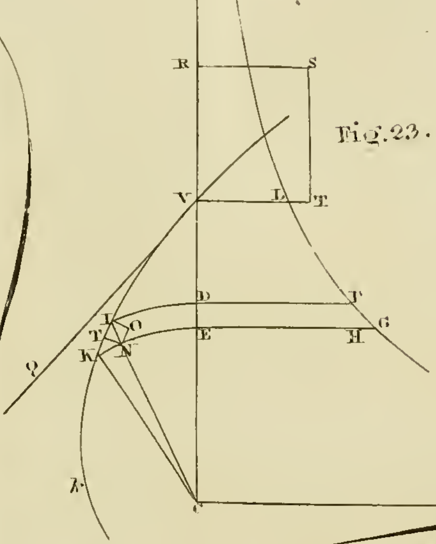
Fig. 23.

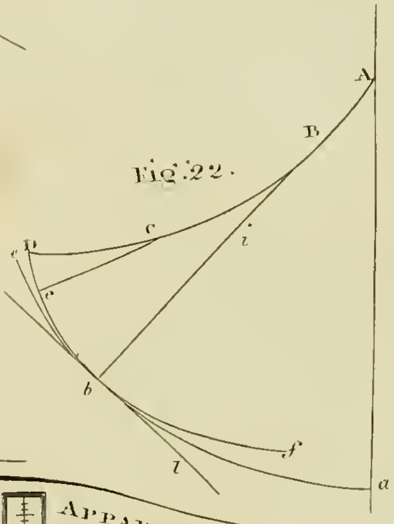
Fig. 22.

COLLIER'S APPARATUS.

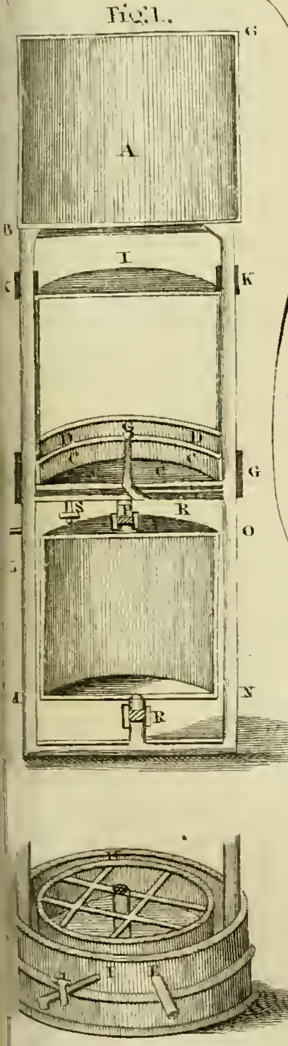
Fig. 1.

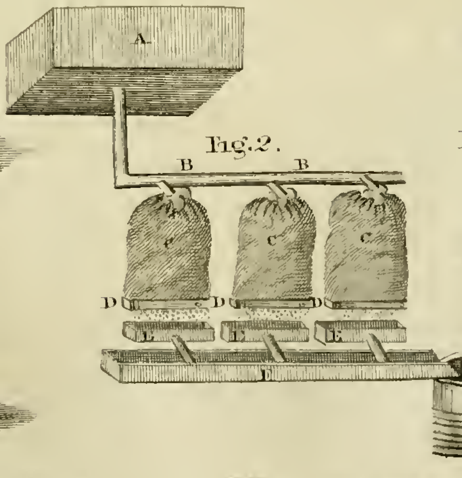
Fig. 2.

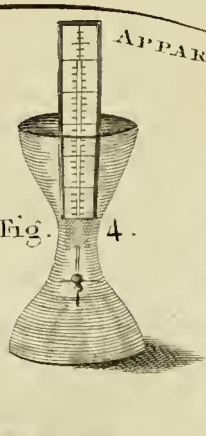
Fig. 4.

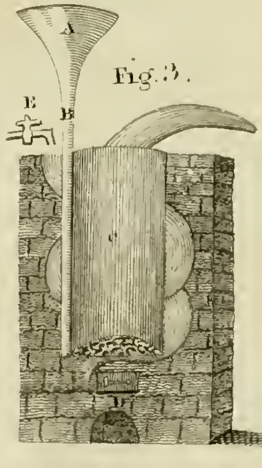
Fig. 3.

D. Lizars Sculpt.

caſioned by heat being communicated by the bodies of the experimenters to one ſide of it more than another, it was ſupported in the middle of a cloſe room; the operators, from adjoining apartments, viewed the operation through holes in the wall by means of teleſcopes; and the apparatus had a ſtrong light thrown upon its two ends (an opening being left at each end of the box for the purpoſe) by means of two lamps, alſo in the adjoining apartments, the rays from which were likewiſe made to paſs through the holes formed in the wall.

The two large balls were ſuſpended from a beam near the cieling, which could be moved in an horizontal direction, by means of a ſtring and pulley, ſo as to be brought near to the ſmall balls of the balance, or made to recede again, without requiring any perſon to be in the room.

From this deſcription it will be eaſily ſeen, that on the two large balls being brought near to the two ſmall ones, but on oppoſite ſides of each, that their forces may not counteract each other—the ſmall ſuſpending wire of the balance muſt be twiſted by the movements of the arms, occaſioned by attraction, which carries the ſmall towards the large balls; and that the wire, endeavouring to untwiſt itſelf, will again in its turn carry the ſmall balls away from the large ones. Vibrations are thus occaſioned, which would continue a long time before the ſmall balls would ſettle between the firſt point of reſt and the large balls: but it is not neceſſary to wait for this; an ivory ſcale at each end of the balance enables the experimenters, by means of their teleſcopes, to ſee the two extreme diviſions to which the ſmall balls move in their vibrations, and thus to determine the middle point. The time neceſſary for each vibration is alſo noticed.

A full account of theſe experiments, and of the calculations founded on them, would be little intereſting to the great majority of our readers. We ſhall therefore only mention the reſult. By a mean of the experiments the denſity of the earth comes out 5·48 times greater than that of water.

By the experiments made by Dr Maſkelyne on the attraction of the hill Schehallien, the denſity of the earth was computed to be only 4½ times that of water. The difference of reſult, therefore, is almoſt one-fifth, which no doubt muſt leſſen our confidence in either ſet of experiments, or in the principle on which they were deviſed.

Earth-Worm (ſee Lumbricus, *Encycl.*), is an animal which occaſions ſuch deſtruction in gardens, by gnawing the tender roots of ſhrubs and plants, that various methods have been propoſed for remedying this evil. One of the lateſt, and that which promiſes to prove the moſt ſucceſsful, is given by M. Socoloff in the fifth volume of the New Tranſactions of the Imperial Academy of Sciences at Peterſburgh. As the deſtructive power of quick lime, heightened by a fixed alkali, which corrodes or diſſolves all the tender parts of animals, has been long known, it occurred to our author that this mixture would be the beſt means for accompliſhing the object which he had in view. He therefore took three parts of quicklime, newly made, and two parts of a ſaturated ſolution of fixed alkali in water, and thence obtained a ſomewhat milky liquor ſufficiently cauſtic, highly hoſtile and poiſonous to earthworms and other ſmall animals; for as ſoon as it touched any part of their bodies, it occaſioned in them violent ſymptoms of great uneaſineſs. If this liquor be poured into thoſe holes in which the earth-worms reſide under ground, they immediately throw themſelves out as if driven by ſome force; and, after various contortions, either languiſh or die. If the leaves of plants or fruit trees frequented by the voracious caterpillars, which are ſo deſtructive to them, be ſprinkled over with this liquor, theſe inſects ſuddenly contract their bodies and drop to the ground. For though Nature has defended them tolerably well by their hairy ſkins from any thing that might injure their delicate bodies, yet as ſoon as they touch with their feet or mouths leaves which have been moiſtened by this liquor, they become as if it were ſtupified, inſtantly contract themſelves, and fall down.

With regard to plants or corn, theſe ſuſtain no injury from the liquor, becauſe it has no power over the productions of the vegetable kingdom, as our author has fully learned from experience; or if any hurt is to be ſuſpected, all the danger will be removed by the firſt ſhower that falls. This liquor may be procured in abundance in every place where lime is burnt. If the lime be freſh, one part of it infuſed into about ſeventy parts of common water will produce real lime-water. The want of the fixed alkali may be ſupplied by boiling wood-aſhes in water, and thickening the ley by evaporation.

This liquor might be employed alſo to kill bugs and other domeſtic inſects; but on account of its ſtrong lixivious ſmell, M. Socoloff thinks it could not be uſed with ſafety in houſes that are inhabited. Nothing, however, more ſpeedily or more effectually deſtroys bugs, as our author ſays he has repeatedly experienced, than the oily pickle that remains in caſks in which ſalted herrings have been packed.

EAU de Luce, a fragrant alkaline liquor which was ſome years ago in great repute, eſpecially among the fair ſex, and of which the leading perfection is, that it ſhall poſſeſs and retain a milky opacity.

Mr Nicholſon, in the ſecond number of his valuable journal, tells us, that being informed by a philoſophical friend, that the uſual recipes for making this compound (ſee Chemistry, *Encycl.* n° 1037.) do not ſucceed, and that the uſe of maſtic in it has hitherto been kept a ſecret, he made the following trials to procure a good eau de luce.

One dram of the rectified oil of amber was diſſolved in four ounces of the ſtrongeſt ardent ſpirit of the ſhops; its ſpecific gravity being .840 at 60 degrees of Fahrenheit. A portion of the clear ſpirit was poured upon a larger quantity of fine powdered maſtic than it was judged could be taken up. This was occaſionally agitated without heat; by which means the gum reſin was for the moſt part gradually diſſolved. One part of the oily ſolution was poured into a phial, and to this was added one part of the ſolution of maſtic. No opacity or other change appeared. Four parts of ſtrong cauſtic volatile alkali were then poured in, and immediately ſhaken. The fluid was of a denſe opake white colour, affording a ſlight ruddy tinge when the light was ſeen through a thin portion of it. In a ſecond mixture, four parts of the alkali were added to one of the ſolution of maſtic; it appeared of a leſs denſe and more yellowiſh white than the former mixture. More of the gum reſinous ſolution was then poured in; but it ſtill appeared leſs opaque than that mixture. It was ruddy by tranſmitted light. The laſt experiment was repeated with the oily ſolution inſtead of that of maſtic. The white was much leſs denſe than either of the foregoing compounds, and the requiſite opacity was not given by augmenting the doſe of the oily ſolution. No ruddineſs nor other remarkable appearance was ſeen by tranſmitted light. Theſe mixtures were left at repoſe for two days; no ſeparation appeared in either of the compounds containing maſtic; the compound conſiſting of the oily ſolution and alkali became paler by the ſeparation of a cream at the top.

It appears, therefore, that the firſt of theſe three mixtures, ſubject to variation of the quantity of its ingredients, and the odorant additions which may be made, is a good eau de luce.

In a ſubſequent number of the ſame Journal, we have the following recipe by one of the author's correſpondents, who had often proved its value by experience. "Digeſt ten or twelve grains of the whiteſt pieces of maſtic, ſelected for this purpoſe and powdered, in two ounces of alcohol; and, when nearly diſſolved, add twenty grains of elemi (See Amyris, *Encycl.*). When both the reſins are diſſolved, add ten or fifteen drops of rectified oil of amber, and fifteen or twenty of eſſence of bergamot: ſhake the whole well together, and let the fæces ſubſide. The ſolution will be of a pale amber colour. It is to be added in very ſmall portions to the beſt aqua ammoniæ puræ, until it aſſumes a milky whiteneſs, ſhaking the phial well after each addition, as directed by Macquer. The ſtrength and cauſticity of the ammoniac are of moſt eſſential conſequence. If, upon the addition of the firſt drop or two of the tincture, a denſe opaque coagulated precipitate is formed, not much unlike that which appears on dropping a ſolution of ſilver into water ſlightly impregnated with common ſalt, it is too ſtrong, and muſt be diluted with alcohol. A conſiderable proportion of the tincture, perhaps one to four, ought to be requiſite to give the liquor the proper degree of opacity."

EAVES Board, or Eaves-Lath, a thick feather-edged board, uſually nailed round the eaves of a houſe for the lowermoſt tiles, ſlate, or ſhingles, to reſt upon.

ECLIPSAREON, an inſtrument invented by Mr Ferguſon for ſhewing the phenomena of eclipſes; as their time, quantity, duration, progreſs, &c.

ECLIPTIC. See *Encycl.* both under Ecliptic and in Astronomy-*Index*. It was obſerved in Astronomy, *Encycl.* n° 407. that the obliquity of the ecliptic has been found gradually to decreaſe. This was obſerved, among others, by *La Lande*, who, in the third edition of his aſtronomy, reckoned the ſecular diminution of this obliquity at 50 ſeconds. From a new examination, however, of ancient obſervations, he has ſince found reaſon to eſtimate it at only 36 ſeconds; but whether this be perfectly accurate, is very doubtful. The mean obliquity was determined for the 1ſt of January 1793, with circular inſtruments, by *Mechain* at Barcelona, and *Piazzi* at Palermo, to be 23° 27′ 53″.3. Yet the obſervation of the ſummer ſolſtice of 1796, by *Mechain* and *Le Français*, gave 11 ſeconds more; which was juſtly conſidered as a perplexing circumſtance. But, as one of the ableſt of our literary journaliſts obſerves, might not this difference ariſe from the uncertainty of our tables of refraction, as affected by the hygroſcopic variations of the atmoſphere?

Ecliptic Bounds, or *Limits*, are the greateſt diſtances from the nodes at which the ſun or moon can be eclipſed, namely, near 18 degrees for the ſun, and 12 degrees for the moon.

Smeaton's Account of the Edyſtone Light-houſe.

EDYSTONE Rocks, ſo remarkable for the light-houſe built on them, obtained their name from the great variety of contrary ſets of the tide or current in their vicinity. They are ſituated nearly S. S. W. from the middle of Plymouth Sound, according to the true meridian. The diſtance from the port of Plymouth is nearly 14 miles, and from the promontory called *Ram-head* about 10 miles. They are almoſt in the line, but ſomewhat within it, which joins the Start and the Lizard points; and as they lie nearly in the direction of veſſels coaſting up and down the channel, they were neceſſarily, before the eſtabliſhment of a light houſe, very dangerous, and often fatal to ſhips under ſuch circumſtances. Their ſituation, likewiſe, with regard to the Bay of Biſcay and Atlantic ocean, is ſuch, that they lie open to the ſwells of the Bay and ocean from all the ſouth-weſtern points of the compaſs: which ſwells are generally allowed by mariners to be very great and heavy in thoſe ſeas, and particularly in the Bay of Biſcay. It is to be obſerved, that the ſoundings of the ſea from the ſouth-weſtward toward the Edyſtone are from 80 fathoms to 40, and everywhere till you come near the Edyſtone the ſea is full 30 fathoms in depth; ſo that all the heavy ſeas from the ſouth-weſt come uncontrouled upon the Edyſtone rocks, and break on them with the utmoſt fury.

The force and height of theſe ſeas is increaſed by the circumſtance of the rocks ſtretching acroſs the Channel, in a north and ſouth direction, to the length of above 100 fathoms, and by their lying in a ſloping manner toward the ſouth-weſt quarter. This *ſliving* of the rock, as it is technically called, does not ceaſe at low water, but ſtill goes on progreſſively; ſo that, at 50 fathoms weſtward, there are 12 fathoms water; nor do they terminate altogether at the diſtance of a mile. From this configuration it happens, that the ſeas are ſwelled to ſuch a degree in ſtorms and hard gales of wind, as to break on the rocks with the utmoſt violence.

The effect of this ſlope is likewiſe ſenſibly felt in moderate, and even in calm weather; for the libration of the water, cauſed in the Bay of Biſcay in hard gales at ſouth-weſt, continues in thoſe deep waters for many days, though ſucceeded by a calm; inſomuch, that when the ſea is to all appearance ſmooth and even, and its ſurface unruffled by the ſlighteſt breeze, yet thoſe librations ſtill continuing, which are called the *ground-ſwell*, and meeting the ſlope of the rocks, the ſea breaks upon them in a frightful manner, ſo as not only to obſtruct any work being done on the rock, but even the landing upon it, when, figuratively ſpeaking, you might go to ſea in a walnut ſhell. A circumſtance which ſtill farther increaſes the difficulty of working on the rock is, there being a ſudden drop of the ſurface of the rock, forming a ſtep of about four and a half, or five feet high; ſo that the ſeas, which in moderate weather come ſwelling to this part, meet ſo ſudden a check that they frequently fly to the height of 30 or 40 feet.

Notwithſtanding theſe difficulties, it is not ſurpriſing that the dangers to which navigators were expoſed by the Edyſtone rocks ſhould make a commercial nation deſirous of having a light-houſe on them. The wonder is, that any one ſhould be found hardy enough to undertake the building. Such a man was firſt found in in the perſon of *Henry Winſtanley* of Littlebury in Eſſex, Gent. who, in the year 1696, was furniſhed by the maſter, wardens, and aſſiſtants, of the Trinity-houſe of Deptford-ſtrond with the neceſſary powers to carry the deſign into execution.

Mr Winſtanley had diſtinguiſhed himſelf in a certain branch of mechanics, the tendency of which is to raiſe wonder and ſurpriſe. He had at his houſe at Littlebury a ſet of contrivances, ſuch as the following: Being taken into one particular room of his houſe, and there obſerving an old ſlipper careleſsly lying on the floor; if, as was natural, you gave it a kick with your foot, up ſtarted a *ghoſt* before you. If you ſat down in a certain chair, a couple of arms would immediately claſp you in, ſo as to render it impoſſible to diſentangle yourſelf till your attendant ſet you at liberty. And if you ſat down in a certain arbour by the ſide of a canal, you were forthwith ſent out *afloat* to the middle of the canal, from whence it was impoſſible for you to eſcape till the manager returned you to your former place.—Whether thoſe things were ſhewn to ſtrangers at his houſe for money, or were done by way of amuſement to thoſe that came to viſit the place, is uncertain, as Mr Winſtanley is ſaid to have been a man of ſome property; but it is at leaſt certain, that he eſtabliſhed a place of public exhibition at Hyde Park-corner, called *Winſtanley's water-works*, which were ſhewn at ſtated times at one ſhilling each perſon. The particulars of thoſe water-works are not now known; but, according to the taſte of the times, we muſt naturally ſuppoſe a great variety of *jets d'eau*, &c.

Theſe particulars are at preſent of no other importance than that they ſerve to give a ſketch of the talents and turn of mind of the original undertaker, and to account for the whimſical kind of buildings which he erected on the Edyſtone; from the deſign of which, it ſeems as if it were not ſufficient for his enterpriſing genius to erect a building on the ſpot, where, of all others, it was leaſt likely to ſtand unhurt; but that he would alſo give it an elevation, in appearance the moſt liable to ſubject it to damage from the violence of the wind and waves.

This ingenious man entered upon his great undertaking in 1696, and completed it in ſomething more than four years. The firſt ſummer was occupied with making 12 holes in the rock, and in faſtening 12 great irons, which were to hold the work that was afterward to be done. The next ſummer was ſpent in making a ſolid body, or round pillar, 12 feet high and 14 feet in diameter. In the third year, the aforeſaid pillar or work was made good at the foundation, from the rock, to 16 feet in diameter; and all the work was raiſed, which, to the vane, was 80 feet high. Being all finiſhed, with the lantern, and all the rooms that were in it, we "ventured (ſays Mr Winſtanley) to lodge there ſoon after midſummer, for the greater diſpatch of this work: but the firſt night the weather came bad, and ſo continued, that it was eleven days before any boats could come near us again; and not being acquainted with the height of the ſeas riſing, we were almoſt all the time drowned with wet, and our proviſions in as bad a condition, though we worked night and day, as much as poſſible, to make ſhelter for ourſelves."

Mr Winſtanley, however, ſucceeded in ſetting up the light on the 14th of November in that year (1698); but he was detained till within three days of Chriſtmas before he could return to ſhore, being almoſt at the laſt extremity for want of proviſions.

In the fourth year, obſerving the effects that the ſea produced on the houſe, burying the lantern at times, although more than 60 feet high, Mr Winſtanley encompaſſed the aforeſaid building early in the ſpring with a new work of four feet thickneſs from the foundation, making all ſolid for near 20 feet high; and taking down the upper part of the firſt building, and enlarging every part in its proportion, he raiſed it 40 feet higher than it was at firſt: Yet, he obſerves, "the ſea, in times of ſtorms, flies in appearance *one hundred feet above the vane*, and at times doth cover half the ſide of the houſe and the lantern as if it were under water."

No material occurrences concerning this building happened till November 1703, when the fabric, needing ſome repairs, Mr Winſtanley went down to Plymouth to ſuperintend the work. And "we muſt not wonder (ſays Mr Smeaton), if, from the preceding accounts of the violence of the ſeas, and the ſtructure of the light-houſe, the common ſenſe of the public led them to ſuppoſe this building would not be of long duration. The following is an anecdote which I received to the ſame effect from ſo many perſons that I can have no doubt of the truth of it: Mr Winſtanley being among his friends previous to his going off with his workmen on account of thoſe reparations, the danger being intimated to him, and that one day or other the light-houſe would certainly be overſet; he replied, "He was ſo very well aſſured of the ſtrength of his building, he ſhould only wiſh to be there in the greateſt ſtorm that ever blew under the face of the heavens, that he might ſee what effect it would have on the ſtructure."—It happened that Mr Winſtanley was but too amply gratified in this wiſh; for while he was there with his workmen and light-keepers, that dreadful ſtorm began which raged moſt violently on the 26th of November 1703, in the night; and of all the accounts of the kind which hiſtory furniſhes us with, we have none that has exceeded this in Great Britain, or was more injurious or extenſive in its devaſtation. The next morning, November 27th, when the violence of the ſtorm was ſo much abated that it could be ſeen whether the light-houſe had ſuffered by it, nothing appeared ſtanding, but, upon a nearer inſpection, ſome of the large irons by which the work was fixed upon the rock; nor were any of the people, or any of the materials of the building, ever found afterwards, ſave only part of an iron chain, which had got ſo faſt jambed into a chink of the rock, that it could never afterwards be diſengaged till it was cut out in the year 1756."

Thus periſhed Mr Winſtanley, together with his building: but ſo great was the utility of that building while it ſtood, that the public could not fail to be deſirous of having another in its place. Accordingly, in 1706, an act of parliament of the 4th of Queen Anne was paſſed, for the better enabling the maſter, &c. of the Trinity-houſe of Deptford-ſtrond to rebuild the ſame. By this act, the duties payable by ſhipping paſſing the light-houſe were veſted in the corporation of the Trinity-houſe, who were empowered to grant a leaſe to ſuch undertaker or undertakers as they ſhould approve. In conſequence, they agreed with a Captain *Lovel* or *Lovet* for a term of 99 years, commencing from the day on which a light ſhould be exhibited, and continuing ſo long as that exhibition ſhould laſt during the ſaid term. On this foundation Captain Lovet engaged Mr John Rudyerd to be his engineer or architect and ſurveyor.

It does not appear that Mr Rudyerd was bred to any mechanical buſineſs or ſcientific profeſſion, being at that time a ſilk mercer on Ludgate-hill; nor is it known that, in any other inſtance, he had diſtinguiſhed himſelf by any mechanical performance before or after. His want of perſonal experience, however, was in a degree aſſiſted by Mr Smith and Mr Norcutt, both ſhipwrights in the King's yard at Woolwich.

It is not, as Mr Smeaton obſerves, very material in what way this gentleman became qualified for the execution of his work; it is ſufficient that he directed the performance in a maſterly manner, and ſo as perfectly to anſwer the end for which it was intended. He ſaw the errors in the former building, and avoided them; inſtead of a polygon he choſe a circle for the outline of his building, and carried up the elevation in that form. His principal aim appears to have been *uſe* and *ſimplicity;* and indeed, in a building ſo ſituated, the former could hardly be acquired in its full extent without the latter. He ſeems to have adopted ideas the very reverſe of his predeceſſor; for all the unwieldy ornaments at top, the open gallery, the projecting cranes, and other contrivances, more for ornament and pleaſure than uſe, Mr Rudyerd laid totally aſide. He ſaw, that how beautiful ſoever ornaments might be in themſelves, yet when they are improperly applied and out of place, by affecting to ſhew a taſte, they betray ignorance of its firſt principle, *judgment;* for whatever deviates from propriety is erroneous, and at beſt inſipid.

It is impoſſible for us to give an accurate account of the conſtruction of Mr Rudyerd's light-houſe. We can only ſay, in general terms, that it was altogether built of wood; for the courſes of moorſtone, which Mr Rudyerd, adverting to the maxim, that *weight* is beſt reſiſted by *weight*, introduced into the ſolid part of his building, muſt be conſidered as being of the nature of ballaſt; the weight of theſe amounted to above 270 tons. The main column of the building conſiſted of one ſimple figure, being an elegant fruſtum of a cone, unbroken by any projecting ornament, or any thing on which the violence of the ſtorms could lay hold; meaſuring, excluſively of its ſloping foundation, 22 feet and eight inches on its largeſt circular baſe; 61 feet high above that circular baſe; and 14 feet and three inches in diameter at the top: ſo that the circular baſe was ſomewhat greater than one-third of the total height, and the diameter at the top was leſs than two-thirds of the baſe at the greateſt circle. On the flat roof of this main column, as a platform, Mr Rudyerd fixed his lantern, which was an octagon of ten feet and ſix inches diameter externally The mean height of the window-frames of the lantern above the balcony floor was nearly nine feet; ſo that the elevation of the centre of the light above the higheſt ſide of the baſe was 70 feet; that is, lower than the centre of Mr Winſtanley's ſecond lantern by ſeven feet, but higher than that of his firſt by 24 feet. The width of Mr Rudyerd's lantern was, however, nearly the ſame as that of Mr Winſtanley's ſecond: but inſtead of the towering ornaments of iron-work, and a vane that roſe above the top of the cupola no leſs than 21 feet, Mr Rudyerd judiciouſly contented himſelf with finiſhing his building with a round ball of two feet and three inches diameter, which terminated at three feet above the top of his cupola. The whole height of Mr Rudyerd's light-houſe, from the loweſt ſide to the top of the ball, was 92 feet, on a baſe of 23 feet and four inches, taken at a medium between the higheſt and loweſt part of the rock that it covered. The whole building was completed in the year 1709, three years from its commencement.

This great work, after having braved the elements for forty-ſix years, was burnt to the ground in 1755. On the 2d of December of that year, when the light-keeper, then on the watch, went, about two o'clock in the morning, into the lantern, to ſnuff the candles according to cuſtom, he found it in a ſmoke; and in ſpite of all that he and his companions could do, the whole edifice was on fire in the compaſs of little more than eight hours, and in a few days was burnt to its foundation. The three light-men were with much difficulty got on ſhore, when one of them immediately ran off, and has never ſince been heard of. Another, who had been dreadfully burned by melted lead, of which, according to his own account, he had ſwallowed a quantity, lingered in agony for twelve days, and then expired. His ſtomach being opened, there was found in it a ſolid piece of lead of a flat oval form, which weighed ſeven ounces and five drachms; and thus was verified an aſſertion which, to the ſurgeon and others who attended him, appeared altogether incredible, *viz.* that any human being could live after receiving melted lead into the ſtomach.

On the deſtruction of Mr Rudyerd's light-houſe, Mr Smeaton (ſee SMEATON in this Supplement) was recommended by Lord Macclesfield, then preſident of the Royal Society, as the fitteſt perſon in England to build another. It was with ſome difficulty that he was able to perſuade the proprietors that a ſtone building, properly conſtructed, would in all reſpects be preferable to one of wood; but having at laſt convinced them, he turned his thoughts to the ſhape which was moſt ſuitable to a building ſo critically ſituated. Reflecting on the ſtructure of the former buildings, it ſeemed a material improvement to procure, if poſſible, an enlargement of the baſe, without increaſing the ſize of the *waiſt*, or that part of the building which is between the top of the rock and the top of the ſolid work. Hence he thought a greater degree of ſtrength and ſtiffneſs would be gained, accompanied with leſs reſiſtance to the acting power. On this occaſion, the natural figure of the waiſt or bole of a large ſpreading oak occurred to Mr Smeaton.

" Let us (ſays he) conſider its particular figure.—Connected with its roots, which lie hid below ground, it riſes from the ſurface with a large ſwelling baſe, which at the height of one diameter is generally reduced by an elegant curve, concave to the eye, to a diameter leſs by at leaſt one third, and ſometimes to half its original baſe. From thence, its taper diminiſhing more ſlowly, its ſides by degrees come into a perpendicular, and for ſome height form a cylinder. After that, a preparation of more circumference becomes neceſſary, for the ſtrong inſertion and eſtabliſhment of the principal boughs, which produces a ſwelling of its diameter.—Now we can hardly doubt but that every ſection of the tree is nearly of an equal ſtrength in proportion to what it has to reſiſt; and were we to lop off its principal boughs, and expoſe it in that ſtate to a rapid current of water, we ſhould find it as capable of reſiſting the action of the heavier fluid, when diveſted of the greater part of its clothing, as it was that of the lighter, when all its ſpreading ornaments were expoſed to the fury of the wind: and hence we may derive an idea of what the proper ſhape of a column of the greateſt ſtability ought to be, to reſiſt the action of external violence, when the quantity of matter is given of which it is to be compoſed."

The next thing to be conſidered was, how the blocks of ſtone could be bonded to the rock, and to one another, in ſo firm a manner as that not only the whole together, but every individual piece, when connected with what preceded, ſhould be proof againſt the greateſt violence of the ſea. For this purpoſe, cramping was the firſt idea, but was rejected on account of the great quantity of iron which was neceſſary, and from the trouble and loſs of time which would attend that operation. In its place was ſubſtituted the method of dovetailing. From ſome ſpecimens which Mr Smeaton had ſeen in Belidor's deſcription of the ſtone floor of the great ſluice at Cherburgh, (where the tails of the upright headers are cut into dovetails for their inſertion into the maſs of rough maſonry below,) he was led to think, that if the blocks themſelves were, both inſide and outſide, formed into large dovetails, they might be managed ſo as to lock one another together, being primarily engrafted into the rock; and in the round or entire courſes above the top of the rock, they might all proceed from, and be locked to, one large centre ſtone. Theſe particulars being digeſted in his own mind, he explained his deſign by the help of drawings; with which, after mature deliberation, the proprietors were perfectly ſatisfied; and declared, that the ſcheme was not only in itſelf practicable, but, as appeared to them, the only means of doing the buſineſs effectually.

During this time Mr Smeaton had never viſited the rock on which he was to be employed: he therefore reſolved to go to Plymouth early in the ſpring of 1756, that he might loſe no opportunity of viewing it. At Plymouth he met Mr Joſias Jeſſop, to whom he was referred for information and aſſiſtance, and who afterwards proved of great ſervice: he was not only an approved workman in his branch as a ſhipwright, but a competent draughtſman and an excellent modeller; 'in which laſt (ſays the author) he was accurate to a great degree: he therefore appeared to be a very fit perſon to overlook the exact execution of a deſign given.' Mr Jeſſop, like others, expreſſed his doubts that a ſtone building could ſtand on the Edyſtone: but they were removed by the propoſed mode of its conſtruction.—As Mr Smeaton was impatient to go to the rock, he ſeized the firſt opportunity that ſeemed to promiſe any chance of landing on it. On the 2d of April he got within a ſtone's throw of it, but could not land: on the 5th he was more fortunate; he now landed, and ſtaid on the rock for two hours and a half. This time was employed in taking a general view of the whole. No remains of the houſe could be perceived either on the rock, or about it, except the greateſt part of the iron branches that had been fixed by Mr Rudyerd; and ſome of the moorſtones were diſcerned lying in the bottom of the gut. Such traces were alſo obſerved of the ſituation of the irons fixed by Mr Winſtanley, as to render it no very difficult taſk to make out his plan, and the poſition of the edifice; whence it appeared very probable, that Mr Winſtanley's building was overſet altogether, and that it had torn up a portion of the rock itſelf, as far as the irons had been faſtened in it. With regard to the ſteps, which were ſaid to have been cut in the rock by Mr Rudyerd, the traces of only five were remaining; theſe were faintly cut, and without much regularity. It was next tried in what degree the rock was workable; and Mr Smeaton had the ſatisfaction of finding every thing ſucceed to his wiſhes.

Having thus determined that there was no impracticability in fixing a ſtone building, it became of the greateſt importance to ſecure a more ſafe and certain landing on the rock; as it would frequently happen, while the veſſels were lying off the rock, waiting for a favourable time to enter the gut, that tides might change, ground ſwells come on, winds ſhift, and ſtorms ariſe, which would of courſe make it deſirable to return to Plymouth, if poſſible, though the purpoſe of the voyage was unperformed. In addition to this, when veſſels had got with ſome facility into the gut, they frequently could not get out again without extreme danger: for as the larger ſort had not room to turn in it, they were in reality obliged to go out ſtern forward; the Sugar-loaf rock being ſo critically placed, with ſhallow water on both ſides of it, that it prohibits a thorough paſſage. It was true, indeed, that by the ſkill and expertneſs of thoſe ſeamen who had frequently attended the ſervice of the Edyſtone, not only row boats, but the attendant veſſels, after having delivered their cargoes, had been carried quite through, at the top of an high tide, with a fair wind and ſmooth water: but this was not an experiment to be commonly repeated. The two voyages which Mr Smeaton had made were in a ſmall ſailing veſſel of about ten or twelve tons burden, which was built for the ſervice, and called the Edyſtone Boat. It occurred to him, that while the light houſe was ſtanding, if the boat had been ſtaved on the rocks while lying in the gut, there was a poſſibility of the men being ſaved by getting into the houſe, as the light-keepers would have been ready to throw out a rope to their aſſiſtance: but that if any accident of the kind were to happen now that the houſe was down, and no protection nor ſhelter to be had, there was little chance of their eſcape;—and theſe conſiderations being likely to caſt a damp on every exertion to land, he determined to go out no more without another ſailing boat to attend.

The weather being unfavourable for viſiting the rock, all exertions were uſed to forward the work on ſhore; and, firſt, a work-yard was choſen in a field adjacent to Mill Bay, about a mile weſt from Plymouth. The next object was to procure moor ſtone, or granite; and with this view the author viſited Hingſtone Downs, and obſerved the manner of working the ſtone, which is curious. He next went to Lanlivery, near Fowey harbour, from which place the ſtone-work for the late light-houſe had been furniſhed.

During this time he had made five voyages to the rock with little ſucceſs: the event of the laſt had ſtrongly pointed out, that the much greater tonnage of the ſtone which muſt be neceſſary to be carried out and fixed, in caſe of a ſtone building, than was requiſite in the compoſitions of his predeceſſors, would make the uncertainty and delay which they had deſcribed as being attendant on their voyages, in order to fix their work, bear far heavier on the ſcheme; and would thus occaſion the whole time of the performance to be lengthened. It appeared, therefore, that had a veſſel been fixed within a quarter of a mile, or ſome ſuch competent diſtance from the rocks, and which ſhould be capable of lodging the workmen, all their tools and looſe materials, the ſeveral pieces of wrought ſtone only excepted, that then the workmen might, by means of ſmall row-boats or yawls, have effected a landing both of themſelves and of their materials, and have been at work on the rock during the greateſt part of thoſe days which otherwiſe, as voyagers, they would have loſt in fruitleſs endeavours to get to the place of action. Agreeably to this opinion, it was propoſed to build a ſtrong and very well found ſloop of about fifty tons, with iron chains for mooring her on the rocky ground near the Edyſtone. A veſſel was in fact afterward moored in this ſituation: but it was one not built for the ſervice, but originally intended to have been ſtationed as a temporary floating light during the rebuilding of the light-houſe.

Mr Smeaton now made a ſixth voyage to the rock, on which he employed himſelf for nineteen hours in taking ſuch dimenſions as would enable him to make an accurate model of its ſurface. He likewiſe attempted a ſeventh voyage: but being unable to reach the Edyſtone, he bore away for Falmouth, in order to examine the moor-ſtone works at Conſtantine in that neighbourhood. From the difficulties which occurred here, as well as at other places, he was convinced that a ſufficient quantity of moor-ſtone could not be readily and expeditiouſly procured, in order to complete the whole building; and that he muſt therefore confine the moorſtone to the outſide, as being more durable, and content himſelf with the uſe of Portland, or ſome other free-working ſtone, for the inſide work. In conſequence, after making three more voyages to the rock, and completing all the obſervations which he was deſirous of taking there, he viſited the iſle of Portland in his return to London, and made the neceſſary agreements for carrying on his work.

On his arrival in London, Mr Smeaton again met the proprietors, from whom he experienced the greateſt liberality and confidence: they declared, that as he was now apprized of what was to be done, they left both the time and the means of its accompliſhment to him.

‘ On this occaſion (he obſerves), I found myſelf totally unfettered; and perhaps no reſolution of the proprietors ever more conduced to the ultimate ſucceſs of the work than this, which ſet me ſo much at liberty. Had they been of the ſame temper and diſpoſition of by far the greateſt part of thoſe who have employed me, both before and ſince, their language would have been, Get on, Get on, for God's ſake get on! the public is in expectation; get us ſomething ſpeedily to ſhew, by which we may gain credit with the public!—This, however, was not their tone, which I looked upon as a happy earneſt from the proprietors in the outſet.’

During his ſtay in London, he reſolved, as an abſolutely neceſſary preliminary ſtep, to form models of the rock, both in its preſent ſtate and as cut to the intended ſhape for receiving the building. Connected with the laſt was a model of the building itſelf, ſhewing diſtinctly how the work was to be adapted to each ſeparate ſtep in the aſcent of the rock, and particularly exhibiting the conſtruction of the firſt entire courſe after riſing to the level of the upper ſurface of the rock: to this a ſolid being fitted, the model ſhewed the external form of the whole building, including the lantern; while, by a ſection on paper, the whole inſide work was repreſented. Theſe models, as well, indeed, as moſt of the material parts of the buſineſs, were the entire work of Mr Smeaton's own hands. After exhibiting theſe to the Lords of the Admiralty, who expreſſed their warmeſt approbation, he returned to Plymouth on the 23d of July 1756.

On his arrival at Plymouth, he found that Mr Jeſſop had completely fitted up, for preſent ſervice, the ſloop, which had before been uſed as an attendant; as well as the Edyſtone boat, and a large yawl, with ſails and oars. Another ſeaman was now taken into the ſervice, which made the number of the crew ſix. The Neptune Buſs, which had been built for the purpoſe of exhibiting a temporary light, but which was afterward moored near to the rock, was arrived: but as her deſtination was not known, all orders for mooring-chains were ſuſpended, and Mr Smeaton was obliged to content himſelf with preparing cables in the beſt manner that he could for mooring the ſloop in that ſituation. As the weather was unfavourable, he had but one opportunity of viſiting the rock; he therefore applied vigorouſly to prepare every thing on ſhore. The firſt buſineſs was to eſtabliſh the working companies, which were to conſiſt of two complete ſets of hands, to relieve each other by turns; ſo that, whenever winds and tides would permit, the work might be purſued by day and night. In his diſtribution and management of theſe people he appears to have acted with great judgment. He made choice of, and agreed with, Mr Thomas Richardſon, a maſter maſon of Plymouth, to act as foreman of one of the companies; and alſo with William Hill, who had been ſome time foreman to another maſter maſon of the ſame place, to act as the other foreman. He likewiſe entered three maſons, and nine tinners (Corniſh miners), as a company, to go out with Mr Richardſon to take the firſt turn, or week, commencing from Saturday the 31ſt of July. Mr Jeſſop was appointed general aſſiſtant. The wages of the foremen, while at ſea, were to be 5 s. per day certain; and for every hour ſpent on the rock, the farther premium of 1 s.—but when employed in the work-yard or otherwiſe on ſhore, their wages were to be 3 s. 6 d. per day. The wages of the maſons were to be 2 s. 6 d. per day certain at ſea, with a premium of 9 d. per hour; and the tinners were to have 2 s. per day certain at ſea, and 8 d. per hour. In the work-yard, or at ſhore, the maſons were to have 20d. and the tinners 18d. per day, and to be paid for over-time when required to work;—and that the ſeamen might not want inducement to do their utmoſt in landing the workmen at the Edyſtone as early as poſſible at every opportunity, and in ſupplying them with what was neceſſary for keeping them at work, over and above their weekly wages, which were ſettled at 8 s. per week, they were all to receive a premium for every landing on the rock; the maſter ſeamen having 2s. 6 d. and the ordinary men 2s. to make their advantage equivalent to that of the other workmen, in whatever ſervice the ſeamen, who were conſtantly on duty, were employed. Mr Jeſſop, as general aſſiſtant, was to have 10s. 6d. per day at ſea, and 5 s. per day on land; and every one was to ſupply himſelf with victuals.—Mr Smeaton likewiſe agreed for half an acre of ground on the weſt ſide of Mill-bay for

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a work-yard, as before mentioned, which he marked out, and ordered to be fenced with boards. At this time arrived Mr John Harriſon, who was to act as clerk to the Edyſtone works, with whom a plan was digeſted for keeping the accounts and correſpondence; and for the diſtinct noting of ſo great a variety of articles, it was found expedient to open fourteen different books.

Matters being thus ſettled on ſhore, and the weather having become more promiſing, Mr Richardſon and his company embarked in the ſloop, with her ground tackle on board, attended by the author and Mr Jeſſop, and having the yawl alſo properly manned. Having landed on the rock, Mr Smeaton proceeded to fix the centre, and to lay down the lines of the intended work on its ſurface; and being followed by Mr Richardſon, he, with ſharp picks, left indelible traces of thoſe lines, ſo as that the workmen might proceed on them whenever they ſhould be able to land. The roughneſs of the ſea, however, ſoon rendered it adviſable to return to the ſloop; and from the ſame cauſe it was thought unſafe to attempt to moor her that evening. On the next day, the wind continued to blow very freſh; but on the following they were able to moor the ſloop: and every one being anxious to make a beginning, the whole company landed on the rock, and immediately began the work, which was purſued for about four hours, when they were driven off by the ſea. On the following day, all hands landed before ſun-riſe, and worked, during that tide, for ſix hours; and in the afternoon's tide they again landed, and continued the work, by the help of links, till ten o'clock at night. They purſued this courſe for ſome time with very little interruption, working, at an average, for about five hours in each tide.

The weather had now been fair from Auguſt 27th to the 14th of September; and in this ſpace they had worked for 177 hours on the rock. During this interval, alſo, Mr Jeſſop had prevented a weſt Indiaman homeward bound, and a man of war's tender, from driving on the rocks, to which they were approaching, though they themſelves were not aware of it. On the 16th, the work on the rock was in the following ſituation: The loweſt new ſtep (the moſt difficult to work, becauſe the loweſt), with its dovetails, was quite completed.—The ſecond ſtep was rough bedded, and all its dovetails ſcapelled out.—The third ſtep (being the loweſt in Mr Rudyerd's work) was ſmooth bedded, and all the dovetails roughed out.—The fourth was in the like ſtate.—The fifth was rough bedded, and its dovetails were ſcapelled out; and the ſixth was ſmooth bedded, and all the dovetails roughed out.—Laſtly, the top of the rock, the greateſt part of the bulk whereof had been previouſly taken down as low as it could be done with propriety, was now to be reduced to a level with the upper ſurface of the ſixth ſtep; the top of that ſtep being neceſſarily to form a part of the bed for the ſeventh or firſt regular courſe: ſo that what now remained, was to bring the top of the rock to a regular floor by picks; and from what now appeared (as all the upper parts that had been damaged by the fire were cut off) the new building was likely to reſt on a baſis even more ſolid than the former lighthouſes had done.

The equinoctial winds that were now reigning, afforded little proſpect of doing much more work on the rock for this ſeaſon: for though a more moderate interval of weather might be expected, yet that muſt be employed in weighing the Buſs's moorings. To prevent the neceſſity of this, however, it was an object of conſideration, whether they could not diſpenſe with that operation, and thereby have a little more time for work on the rock. Mr Smeaton's contrivance for this purpoſe was admirable; but it was rendered vain by the bad ſailing of the buſs. After overcoming many difficulties, the buſs with Mr Smeaton on board was driven at a great rate towards the bay of Biſcay, in danger every hour of being ſwallowed up by the waves or daſhed in pieces on the rocks of Scilly. At laſt, on Friday morning the 26th of November, they reached Plymouth Sound, and relinquiſhed all thoughts of returning to their work on the rock that ſeaſon.

The winter therefore of 1756, and the following ſpring, were employed in preparing materials for the outwork: the maſonry particularly required great attention. It was a deſirable object to uſe large and heavy pieces of ſtone in the building; yet their ſize muſt neceſſarily be limited by the practicability of landing them with ſafety. Now ſmall veſſels only could deliver their cargoes alongſide of this hazardous rock; and theſe could not deliver very large ſtones, becauſe the ſudden riſing and falling of the veſſels in the gut amounted frequently to the difference of three or four feet, even in moderate weather; ſo that in caſe after a ſtone was raiſed from the floor of the veſſel, her gunwale ſhould take a ſwing, ſo as to hitch under the ſtone, one of a very large magnitude muſt, on the veſſel's riſing, infallibly ſink her. From this conſideration, it was determined that ſuch ſtones ſhould be uſed as did not much exceed a ton weight; though occaſionally particular pieces might amount to two tons. That they might attain a certainty in putting the work together on the rock, the ſtones of each courſe were tried together in their real ſituation with reſpect to each other; and they were ſo exactly marked, that every ſtone, after the courſe was taken aſunder, could be replaced in the identical poſition in which it lay on the platform, within the fortieth part of an inch:—nor was this judged ſufficient; for every courſe was not only tried ſingly together on the platform and marked, but the courſe above it was put on it, and marked in the ſame way; ſo that every two contiguous courſes might fit each other on the outſide, and prevent an irregularity in the outline. This degree of accuracy might ſeem ſuperfluous: but as the nature of the building required the workmen to be in a condition to reſiſt a ſtorm at every ſtep, it became neceſſary to fix the centre ſtone firſt, as being leaſt expoſed to the ſtroke of the ſea; and in order to have ſure means of attaching all the reſt to this, and to one another, it was indiſpenſable that the whole of the two courſes ſhould be tried together; in order that, if any defect appeared at the outſide, by an accumulation of errors from the centre, it might be rectified on the platform.

Another circumſtance, to which Mr Smeaton was particularly attentive, and concerning which his remarks are very valuable, was to aſcertain the moſt proper compoſition for water cements. In making mortar for buildings expoſed to water, *tarras* had been moſt eſteemed: but ſtill there were objections to its uſe. Mr Smeaton was therefore induced to try the *terra puzzolana*, found in Italy, as a ſubſtitute for *tarras*. Fortunately there was a quantity of it in the hands of a merchant at Plymouth, which had been imported as a venture from Civita Vecchia, when Weſtminſter-bridge was building; and which he expected to have ſold for that work to a good advantage, but failed in his ſpeculation: for having found that *tarras* anſwered their purpoſe, neither commiſſioners, engineers, nor contractors, would trouble themſelves to make a trial of the other material. This was found in every reſpect equal to *tarras*, as far as concerned the hardening of water-mortar, if not preferable to it; and if made into a mortar with lime produced from a ſtone found at Aberthaw, on the coaſt of Glamorganſhire, it exceeded, in hardneſs, any of the compoſitions commonly uſed in dry work; and in wet and dry, or wholly wet, was far ſuperior to any which Mr Smeaton had ſeen, inſomuch that he did not doubt its making a cement that would equal the beſt merchantable Portland ſtone in ſolidity and durability.

Theſe preliminary arrangements being ſettled, they proceeded, on the 3d of June 1757, to carry out the Neptune buſs, and to begin the work. After getting up the moorings (a work of no ſmall difficulty and ſome danger), and after fixing the fender-piles, the ſhears, windlaſs, &c. the firſt ſtone was landed, got to its place, and fixed, on Sunday the 12th of June; and on the next day the firſt courſe was completed. On the 14th, the ſecond courſe was begun: but, in conſequence of a freſh gale, the workmen were obliged to quit the rock, after ſecuring every thing as well as poſſible. Such was the violence of the gale, that it was impracticable for the boats to get out of the gut, otherwiſe than by paſſing the Sugar-loaf rock, in which they providentially ſucceeded. On the 18th, they were again as ſuddenly driven from their work, and ſeveral pieces of ſtone were waſhed away by the violence of the ſea. In the night of the 6th of July, the watch on the deck of the buſs eſpied a ſail on the rocks, and one of the yawls was ſent to her relief, which brought back the whole crew, ſeveral of whom were in their ſhirts, and in great diſtreſs. It was a ſnow of about 130 tons burthen, which was returning in ballaſt from Dartmouth; but not knowing exactly where they were, they had miſtaken the rocks for ſo many fiſhing-boats, till it was too late to clear them; and on the veſſel's ſtriking, ſhe filled ſo quickly, that the boat floated on deck before they could get into it.

During this time the building went on, though its progreſs was retarded by various interruptions and accidents; till, at the latter end of Auguſt, when the ſeventh courſe was nearly finiſhed, a violent ſtorm aroſe, which carried away the ſhears and triangles, together with two of the largeſt ſtones which had been left chained on the rock! yet notwithſtanding theſe and various other difficulties, the ninth courſe was completed by the end of September.

"Being now arrived at the eve of October (ſays Mr Smeaton), I maturely conſidered our ſituation; and finding that we had been 18 days in completing the laſt courſe, whereas the former one was begun and finiſhed in five, though the weather, both on ſhore and above head, had remained to all appearance much the ſame; I from thence concluded it to be very probable, we might not get another courſe completed in the compaſs of the month of October: So that when I reflected on the many diſaſters that we had ſuffered laſt year by continuing out to the month of November, and how little work we in reality did after this time, it appeared to me very problematical whether we might be able, with every poſſible exertion, to get another courſe finiſhed this ſeaſon; and conſidering how very ineligible it was to have a courſe lie open during the winter in this ſtage of the work, and that we had now got three complete courſes eſtabliſhed above the top of the rock, the ſum of whoſe height was four feet ſix inches; and that we could not leave the work in a more defenſible ſtate, whether as relative to the natural violence of the ſea, or the poſſibility of external injuries—from theſe conſiderations, it appeared to me highly proper to put a period to the outwork of the preſent ſeaſon."

At the commencement of the following year, 1758, the weather proved very tempeſtuous till March; and on viſiting the rock, they diſcovered that the great buoy on the moorings had been carried away; nor were the mooring chains, though ſought with the greateſt perſeverance, recovered till the middle of May. In conſequence of this delay, and from other accidents, the tenth courſe of the building was not completed till the 5th of July. From this time, the progreſs was without any very material interruption; ſo that on the 26th of September the 25th courſe, being the firſt of the ſuperſtructure, was finiſhed. The work was now ſo far advanced, that Mr Smeaton made a propoſal to the Trinity Board and to the proprietors, of exhibiting a light during the enſuing winter; and for this purpoſe he continued his operations longer than he otherwiſe would have done, in order to complete the firſt room, and make it habitable; but foul weather coming on, he was obliged to quit the rock, and returned to Plymouth. A ſtorm enſued; and, on the next morning, looking out with his teleſcope, he could diſcern the houſe with the ſea breaking over it, but nothing of the buſs. On the following day, the air being more clear, he had a diſtinct view of the building; but the buſs was really gone. This was a day of double regret, as it likewiſe brought a negative on his propoſal for exhibiting a light from the houſe during the winter. The buſs had run into Dartmouth harbour; ſhe was brought home; and the work on the rock being ſecured againſt the winter, the operations of the third ſeaſon were cloſed.

During the early part of 1759, Mr Smeaton was employed in London in forming and making out the neceſſary deſigns for the iron rails of the balcony, the caſt iron, the wrought iron, and the copper works for the lantern, together with the plate glaſs work. It was not till the 22d of June that he arrived at Plymouth. As the moorings had been again loſt, new chains were provided, and the buſs was once more fixed in her ſituation. On the 5th of July he landed on the rock, and found every thing perfectly ſound and firm, without the leaſt perceptible alteration, excepting that the cement, uſed in the firſt year, now in appearance approached the hardneſs of the moorſtone; and that uſed in the laſt year had the full hardneſs of Portland; but on hauling up the ſtones for the next circle from the ſtore-room, where they had been depoſited, he had the mortification to find only ſeven inſtead of eight. It was imagined that a body of falling water, making its way through the open ribs of the centre, had waſhed this ſtone out of the ſtore-room door, though it weighed between four and five hundred weight.

The progreſs of the work, however, was now ſuch, that

that a whole room, with its vaulted cover, was built complete in ſeven days.

On the 17th of Auguſt the main column was completed.

On the 27th Mr Richardſon and his company left the Edyſtone, and gave an account that they had lived in it ſince the 23d, having found it much more warm than the buſs's hold and cabin.

They had now finiſhed every thing belonging to the maſonry. The work of the cupola was going on briſkly in the yard at Mill-bay, though it was retarded by the ſucceſſive illneſſes of the two principal copperſmiths. However, by the exertions of Mr Smeaton, who was himſelf ready to work at every buſineſs, all matters were put in ſuch forwardneſs, that by the 8th of September there was nothing to prevent the frame of the lantern from being fixed in its place but bad weather. It was not till the 15th that the weather permitted the boats to deliver their cargoes. The 16th was remarkably fine; ſo that by the evening the whole frame of the lantern was ſcrewed together, and fixed in its place. On the 17th, which was alſo exceedingly fine, the cupola was brought out, and the ſhears and tackle were ſet up for hoiſting it.

“ This (ſays Mr Smeaton) perhaps may be accounted one of the moſt difficult and hazardous operations of the whole undertaking; not ſo much on account of its weight, being only about 11 cwt. as on account of the great height to which it was to be hoiſted clear of the building, and ſo as, if poſſible, to avoid ſuch blows as might bruiſe it. It was alſo required to be hoiſted a conſiderable height above the balcony floor; which, though the largeſt baſe that we had for the ſhears to ſtand on, was yet but 14 feet within the rails, and therefore narrow in proportion to their height. About noon the whole of our tackle was in readineſs; and in the afternoon the Weſton (boat) was brought into the gut, and in leſs than half an hour her troubleſome cargo was placed on the top of the lantern without the leaſt damage. During the whole of this operation it pleaſed God that not a breath of wind diſcompoſed the ſurface of the water, and there was the leaſt ſwell about the rocks I had obſerved during the ſeaſon.

“ Tueſday, September 18th, in the morning, I had the ſatisfaction to perceive the Edyſtone boat, on board of which I expected the ball to be; and which being double gilt, I had ordered the carriage of it to be carefully attended to. The wind and tide were both unfavourable to the veſſel's getting ſoon near us; therefore, being deſirous to get the ball ſcrewed on before the ſhears and tackle were taken down, one of the yawls was diſpatched to bring it away. This being done, and the ball fixed, the ſhears and tackle were taken down, which took up nearly as much time as was employed in ſetting them up; that is, near 12 hours each, in the whole, to do the work of an hour.—I muſt obſerve, that by choice I ſcrewed on the ball with mine own hands, that in caſe any of the ſcrews had not held quite tight and firm, the circumſtance might not have been ſlipped over without my knowledge; being well aware, that even this part would at times come to a conſiderable ſtreſs of wind and ſea, and which could not be replaced without ſome difficulty in caſe any thing ſhould fail.—It may not be amiſs to intimate to thoſe who may in future have to perform the ſame operation, that the ſcaffold on which this was done conſiſted of four boards only, well nailed together, at ſuch diſtances as to permit it to be lifted over the ball when done with. It reſted on the cupola, encompaſſing its neck; and Roger Cornthwaite, one of the maſons, placed himſelf on the oppoſite ſide upon it, to balance me while I moved round to fix the ſcrews.”

Reſpecting the diſpoſition of the internal part of the edifice, Mr Smeaton fixed the beds in the uppermoſt room, and the fire-place, which conſtituted the kitchen, in the room below it; whereas, in the late houſe, the upper room was the kitchen, and the beds were placed in one of the rooms below: the conſequence of which was, that the beds and bedding were generally in a very damp and diſagreeable ſtate. The preſent diſpoſition has perfectly anſwered the end propoſed, as nothing can be more completely dry than the two habitable rooms.

On the 1ſt of October, every thing being finiſhed, and the chandeliers hung, there was nothing to hinder a trial by lighting the candles in the day-time. Accordingly 24 candles were put into their proper places, and were continued burning for three hours, during which time it blew a hard gale; and a fire being kept at the ſame time in the kitchen, they both operated without any interference; not any degree of ſmoke appearing in the lantern nor in any of the rooms: and by opening the vent-holes, which had been made in the bottom of the lantern for occaſional uſe, it could be kept quite cool; whereas, in the late light-houſe, it uſed to be ſo hot, eſpecially in the ſummer, as to give much trouble by the running of the candles.

All being thus in readineſs, and a conductor, in caſe of lightning, being adapted to the building, notice was given to the Trinity-houſe that the light would be exhibited on the 16th of October 1759. The ſeaſon of the year being now advanced to that which was always very precarious, the Neptune buſs was unmoored, and on the 9th of October ſhe came to an anchor in Plymouth harbour.—“ And thus (ſays Mr Smeaton), after innumerable difficulties and dangers, was a happy period put to this undertaking, without the loſs of life or limb to any one concerned in it, or accident, by which the work could be ſaid to be materially retarded.”

With regard to ſubſequent occurrences, it is truly obſerved, that the beſt account is, that after a trial of 40 years, which have elapſed ſince the finiſhing of the building, it ſtill remains in its original good condition. A few particulars are however intereſting. On the 19th of October Mr Smeaton, with Mr Jeſſop, &c. viſited the houſe, and, landing, found all well. Henry Edwards, one of the light-keepers, gave an account that they lighted the houſe as they were directed, and found the lights to burn ſteadily, notwithſtanding it blew very hard; that they had the greateſt ſeas on the days immediately preceding the lighting; and that then the waves broke up ſo high, that had they not been thrown off by the cove courſe, they would have endangered breaking the glaſs in the lantern; that when the ſeas broke the higheſt, they had experienced a ſenſible motion; but that, as it was barely perceptible, it had occaſioned them neither fear nor ſurpriſe.

During his ſtay at Plymouth, in the times of ſtormy weather, Mr Smeaton took ſeveral opportunities of viewing the light-houſe with his teleſcope from the Hoa, and alſo from the garriſon; both which places were ſufficiently elevated to ſee the baſe of the building, and the whole of the rock at low water in clear weather;

ther; and though he had many occaſions of viewing the unfiniſhed building when buried in the waves in a ſtorm at ſouth-weſt, yet having never before had a view of it under this circumſtance in its finiſhed ſtate, he was aſtoniſhed to find that the account given by Mr Winſtanley did not appear to be at all exaggerated. At intervals of a minute, and ſometimes of two or three, when a combination happened to produce one overgrown wave, it would ſtrike the rock and the building conjointly, and fly up in a white column, enwrapping it like a ſheet, riſing at leaſt to double the height of the houſe, and totally intercepting it from the ſight; and this appearance being momentary, both as to its riſing and falling, he was enabled to judge of the comparative height very nearly by the comparative ſpaces, alternately occupied by the houſe and by the column of water in the field of the teleſcope.

The year 1759 concluded with ſome very ſtormy weather; and in January 1760, Mr Jeſſop viſited the houſe, but could not land. He got a letter, however, from Henry Edwards, acquainting him that there had been ſuch very bad weather that the ſea frequently ran over the houſe; ſo that for 12 days together they could not open the door of the lantern nor any other. He ſaid, "the houſe did ſhake as if a man had been up in a great tree. The old men were almoſt frighted out of their lives, wiſhing they had never ſeen the place, and curſing thoſe that firſt perſuaded them to go there. The fear ſeized them in the back; but rubbing them with oil of turpentine gave them relief." He farther mentioned, that on the 5th of December, at night, they had a very great ſtorm; ſo that the ladder, which was laſhed below the entry door, broke looſe, and was waſhed away. Alſo, on the 13th, there was ſo violent a ſtorm of wind that he thought the houſe would overſet; and at midnight the ſea broke one pane of glaſs in the lantern. They had a very melancholy time of it, having alſo had a great deal of thunder and lightning.—"The ſtorms (obſerves Mr Smeaton) which the building has now ſuſtained without material damage, convince us, and every one, of the ſtability of the ſtone light-houſe, except thoſe (who are not a few) who had taken a notion that nothing but *wood* could reſiſt the ſea upon the Edyſtone rocks; who ſaid, that though they allowed it was built very ſtrong, yet if ſuch a ſtorm as had deſtroyed Winſtanley's light-houſe was again to happen, they doubted not but it muſt ſhare the ſame fate. The year 1762 was uſhered in with ſtormy weather, and indeed produced a tempeſt of the firſt magnitude; the rage of which was ſo great, that one of thoſe who had been uſed to predict its downfal was heard to ſay, If the Edyſtone light-houſe is ſtanding now, it will ſtand till the day of judgment. And, in reality, from this time, its exiſtence has been ſo entirely laid out of mens minds, that whatever ſtorms have happened ſince, no inquiry has ever been made concerning it."

For the length of this detail we cannot bring ourſelves to make any apology. If there be a few of our readers to whom it may appear tedious, we are perſuaded that there are many more to whom it will be in a high degree intereſting; while ſuch of them as are engineers will derive inſtruction even from this very abridged hiſtory of the Edyſtone light-houſe.

EFFECTION, denotes the geometrical conſtruction of a propoſition. The term is alſo uſed in reference to problems and practices, which, when they are deducible from, or founded upon, ſome general propoſitions, are called the *geometrical effection* of them.

ELASTICITY. In addition to the article in the *Encyclopædia*, ſee, in this *Supplement*, the view of Boscovich's theory of natural philoſophy, n° 26.

ELECTIONS, or Choice, ſignify the ſeveral different ways of taking any number of things propoſed, either ſeparately, or as combined in pairs, in threes, in fours, &c.; not as to the order, but only as to the number and variety of them. Thus, of the things a, b, c, d, e, &c. the elections of

one thing are (a,) $1 = 2^1 - 1$,
two things are (a, b, ab,) $3 = 2^2 - 1$,
three things are (a, b, c, ab, ac, bc, abc,) $7 = 2^3 - 1$,
&c.; and of any number n, all the elections are $2^n - 1$; that is, one leſs than the power of 2 whoſe exponent is n, the number of ſingle things to be choſen, either ſeparately or in combination.

ELECTRICITY.

We cannot but be ſomewhat ſurpriſed that, among the many attempts which have been made by the philoſophers of Britain to explain the wonderful phenomena which are claſſed under this name, no author of eminence, beſides the Hon. Mr Cavendiſh and Lord Mahon, have availed themſelves of their ſuſceptibility of mathematical diſcuſſion; and our wonder is the greater, becauſe it was by a mathematical view of the ſubject, in the phenomena of attraction and repulſion, that the celebrated philoſopher Franklin was led to the only knowledge of electricity that deſerves the name of ſcience; for we had ſcarcely any leading facts, by which we could claſs the phenomena, till he publiſhed his theory of *poſitive* and *negative*, or *plus* and *minus*, electricity. This is founded entirely on the phenomena of attraction and repulſion. Theſe furniſh us with all the indications of the preſence of the mighty agent, and the marks of its kind, and the meaſures of its force. Mechanical force accompanies every other appearance; and this accompaniment is regulated in a determinate manner. Many of the effects of electricity are ſtrictly mechanical, producing local motion in the ſame manner as magnetiſm or gravitation produce it. One ſhould have expected that the countrymen of Newton, prompted by his ſucceſs and his fame, would take to this mode of examination, and would have endeavoured to deduce, from the laws obſerved in the action of this motive force, an explanation of other wonderful phenomena, which are inſeparably connected with thoſe of attraction and repulſion.

But this has not been the caſe, if we except the labours of the two philoſophers above mentioned, and a few very obvious poſitions, which muſt occur to all the inventors and improvers of electrometers, batteries, and other things of meaſurable nature.

This view has, however, been taken of the ſubject by a philoſopher of unqueſtioned merit, Mr Æpinus of the Imperial Academy of St Peterſburgh. This gentleman,

gentleman, ſtruck with the reſemblance of the electrical properties of the tourmalin to the properties of a magnet, which have always been conſidered as the ſubject of mathematical diſcuſſion, fortunately remarked a wonderful ſimilarity in the whole ſeries of electrical and magnetical attractions and repulſions, and ſet himſelf ſeriouſly to the claſſification of them. Having done this with great ſucceſs, and having maturely reflected on Dr Franklin's happy thought of plus and minus electricity, and his conſequent theory of the Leyden phial, he at laſt hit on a mode of conceiving the whole ſubject of magnetiſm and electricity, that bids fair for leading us to a full explanation of all the phenomena; in as far, at leaſt, as it enables us to claſs them with preciſion, and to predict what will be the reſult of any propoſed treatment. He candidly gives it the modeſt name of a hypotheſis.

This was publiſhed at St Peterſburg in 1759, under the title of *Theoria Electritatis et Magnetiſmi*, and is unqueſtionably one of the moſt ingenious and brilliant performances of the eighteenth century. It is indeed moſt ſurpriſing that it is ſo little known in this country. This, we imagine, has been chiefly owing to the very ſlight and almoſt unintelligible account which Dr Prieſtley has given of it in his hiſtory of electricity; a work which profeſſes to comprehend every thing that has been done by the philoſophers of Europe and America for the advancement of this part of natural ſcience, and which indeed contains a great deal of inſtructive information, and, at the ſame time, ſo many looſe conjectures and inſignificant obſervations, that the reader (eſpecially if acquainted with the Doctor's character as an unwearied bookmaker) reaſonably believes that he has let nothing ſlip that was worthy of notice. We do not pretend to account for the manner in which Dr Prieſtley has mentioned this work, ſo much, and ſo deſervedly celebrated on the continent. We cannot think that he has read it ſo as to comprehend it; and imagine, that ſeeing ſo much algebraic notation in every page, and being at that time a novice in mathematical learning, he contented himſelf with a few ſcattered paragraphs which were free of thoſe embaraſſments; and thus could only get a very imperfect notion of the ſyſtem. The Hon. Mr Cavendiſh has done it more juſtice in the 61ſt volume of the Philoſophical Tranſactions, and conſiders his own moſt excellent diſſertation only as an extenſion and more accurate application of Æpinus's theory. That we have not an account of this expoſition of the Franklinian theory of electricity in our language, is a material want in Britiſh literature; and we truſt, therefore, that our readers will be highly pleaſed with having the ingenious diſcoveries of the great American philoſopher put into a form ſo nearly approaching to a ſyſtem of demonſtrative ſcience.

We propoſe, therefore, in this place, to give ſuch a brief account of Æpinus's theory of electricity, as will enable the reader to reduce to a very ſimple and eaſily remembered law all the phenomena of electricity which have any cloſe dependence on the mechanical effects of this powerful agent of Nature; referring for a demonſtration of what is purely mathematical to Sir Iſaac Newton's Principia, and the Diſſertation by Mr Cavendiſh already mentioned, except in ſuch important articles as we think ourſelves able to preſent in a new, and, we hope, a more familiar form. We do not mean, in this place, to give a ſyſtem of philoſophical electricity, nor even to narrate and explain the more remarkable phenomena. Of theſe we have already given a vaſt collection in the article ELECTRICITY, *Encycl.* We confine ourſelves to the phenomena which may be called *mechanical*, producing meaſurable motion as their *immediate* effect; and thus giving us a principle for the mathematical examination of the cauſe of electrical phenomena. We ſhall conſider the reader as acquainted with the other phyſical effects of electricity, and ſhall frequently refer to them for proofs.

Moreover, as our intention is merely to give a ſynoptical view of this elaborate and copious performance of Mr Æpinus, hoping that it will excite our countrymen to a careful peruſal of ſo valuable a work, we ſhall omit moſt of the algebraic inveſtigations contained in it, and preſent the concluſions in a more familiar, and not leſs convincing form. At the ſame time we will inſert the valuable additions made by Mr Cavendiſh, and many important particulars not noticed by either of thoſe gentlemen.

HYPOTHESIS OF ÆPINUS.

1 Hypotheſis. THE phenomena of electricity are produced by a fluid of peculiar nature, and therefore called the ELECTRIC FLUID, having the following properties:

2 1. Its particles repel each other, with a force decreaſing as the diſtances increaſe.

3 2. Its particles attract the particles of ſome ingredient in all other bodies, with a force decreaſing, according to the ſame law, with an increaſe of diſtance; and this attraction is mutual.

4 3. The electric fluid is diſperſed in the pores of other bodies; and moves, with various degrees of facility, through the pores of different kinds of matter. In thoſe bodies which we call *non-electrics*, ſuch as water or metals, it moves without any perceivable obſtruction; but in glaſs, roſins, and all bodies called *electrics*, it moves with very great difficulty, or is altogether immoveable.

5 4. The phenomena of electricity are of two kinds; 1. Such as ariſe from the actual motion of the fluid from a body containing more into one containing leſs of it. 2. Such as do not immediately ariſe from this transference, but are inſtances of its attraction and repulſion.

Theſe things being ſuppoſed, certain conſequences neceſſarily reſult from them, which ought to be analogous to the obſerved phenomena of electricity, if this hypotheſis be complete, or ſome farther modification of the aſſumed properties is neceſſary, in order to make the analogy perfect.

6 Plate XXIV. Suppoſe the body A (fig. 1.) to contain a certain quantity of fluid. Its particles adjoining to the ſurface, ſuch as P, are attracted by the particles of common matter in the body, but repelled by the other particles of the fluid. The totality of the attractive forces acting on P may be equal to the totality of the repulſive forces, or may be unequal. If theſe two ſums are equal, P is in equilibrio, and has no tendency to change its place. But there may be ſuch a quantity of fluid in the body, that the repulſions of the fluid exceed the attractions of the common matter. In this caſe, P has a tendency to quit the body, or there is an expulſive force acting on it, and it *will* quit the body if it be moveable.

moveable. Becauſe the ſame muſt be admitted in reſpect of every other particle of moveable fluid, it is plain that there will be an efflux, till the attraction of the common matter for the particles of fluid is equal to the repulſion of the remaining fluid. On the other hand, if the primitive repulſion of the fluid acting on the particle P be leſs than the attractions of the common matter, there will be the ſame, or at leaſt a ſimilar, ſuperiority of attraction acting on the fluid reſiding in the circumambient bodies; and there will be an influx from all hands, till an equilibrium be reſtored.

7 Natural quantity, why ſo called.

Hence it follows, that there may always be aſſigned to any body ſuch a quantity of fluid that there ſhall be no tendency either to efflux or influx. But if the quantity be increaſed, and nothing prevent the motion, the redundant fluid will flow out; and if the proper quantity be diminiſhed, there will be an influx of the ſurrounding fluid, if not prevented by ſome external force. This may be called the body's NATURAL QUANTITY; becauſe the body, when left to itſelf, will always be reduced to this ſtate.

8. If two bodies A and B, contain each its natural quantity, they will not exert any ſenſible action on each other; for, becauſe the fluid contained in B is united by attraction to the common matter, and is alſo repelled by the fluid in A, it neceſſarily follows that the whole body B is repelled by the fluid in A. But, on the other hand, the matter in A attracts the fluid in B, and conſequently attracts the whole body B: Similar action is exerted by B on A. Theſe contrary forces are either equal, and deſtroy each other, or unequal, and one of them prevails. This equality or inequality evidently depends on the quantity of fluid contained in one or both of the bodies (n° 7.) Now it is known that bodies left entirely to themſelves neither attract nor repel; and it follows from the hypothetical properties of the fluid, that if there be either a redundancy or deficiency of fluid, there will be an efflux or influx, till the attractions and repulſions balance each other. Therefore the internal ſtate of two bodies which neither attract nor repel each other, is that where each contains its natural quantity of electric fluid.

9. In order, therefore, to conceive diſtinctly the ſtate of a body containing its natural quantity, and to have a diſtinct notion of this natural quantity, we muſt ſuppoſe that the quantity of fluid competent to a particle of matter in A repels the fluid competent to a particle of matter in B, juſt as much as it attracts that particle of matter; and alſo, that the fluid belonging to a particle of matter in A, repels the fluid belonging to a particle of matter in B, juſt as much as the particle of matter in A attracts it. Thus the whole fluid in the one repels the whole fluid in the other as much as it attracts the whole matter.

Since this muſt be conceived of every particle of common matter in a body, we muſt admit, that when a body is in its natural ſtate, the quantity of electric fluid in it is proportional to the quantity of matter, every particle being united with an equal quantity of fluid. This, however, does not neceſſarily require that different kinds of matter, in their natural or ſaturated ſtate, ſhall contain the ſame proportion of fluid. It is ſufficient that each contains ſuch a quantity, uniformly diſtributed among its particles, that its repulſion for the fluid in another body is equal to its attraction for the common matter in it. It is, however, more probable, for reaſons to be given afterwards, that the quantity of electric fluid attached, or competent, to a particle of all kinds of matter is the ſame.

We ſhall now conſider more particularly the immediate reſults of this hypotheſis, in the moſt ſimple caſes, from which we may derive ſome elementary propoſitions.

10 Electric phenomena ariſe from redundancy or deficiency in fluid total or partial.

Since our hypotheſis is accommodated to the fact, that bodies in their natural ſtate, having their natural quantity of electric fluid, are altogether inactive on each other, by making this natural quantity ſuch, that its mutual repulſion exactly balances its attraction for the common matter—it follows, that we muſt deduce all the electric phenomena from a redundancy or deficiency of electric fluid. This accordingly is the Franklinian doctrine. The redundant ſtate of a body is called by Dr Franklin POSITIVE OR PLUS ELECTRICITY, and the deficient ſtate is called NEGATIVE OR MINUS ELECTRICITY.

A body may contain more than its natural quantity, or leſs, in every part, or it may be redundant in one place and deficient in another. Theſe different conditions will exhibit different appearances, which muſt be conſidered firſt of all.

11 Action of the redundant fluid or matter how computed.

Let the body (fig. 1.) be ſuppoſed in its natural ſtate throughout, which we ſhall generally expreſs by ſaying that it is SATURATED; and let us expreſs the quantity of fluid required for its ſaturation by the ſymbol Q. Let P be a ſuperficial particle of the fluid. It is attracted by the common matter of the body (which we ſhall in future call ſimply the *matter*), and it is repelled equally by the fluid. Let us call the attraction a, and the repulſion r. Then the force with which the ſuperficial particle is attracted by the body, muſt be $= a - r$, and $a - r$ muſt be $= 0$, becauſe $a = r$. Let the quantity f of fluid be added to the body, and uniformly diſtributed through its ſubſtance. Then, becauſe we muſt admit that the action is in proportion to the quantity of acting fluid, and this is now $Q + f$, we have $Q : Q + f = r : \frac{\overline{Q + f} \times r}{Q}$; and therefore P is repelled by the whole fluid with the force $\frac{\overline{Q+f} \times r}{Q}$, or $\frac{Qr}{Q} + \frac{fr}{Q}$, or $r + \frac{fr}{Q}$. But it is attracted by the common matter in the ſame manner as before, that is, with a force $= a$. Therefore the whole action on P is $= a - r - \frac{fr}{Q}$. But $a - r = 0$. Therefore the whole action on P is $= -\frac{fr}{Q}$; that is, P is repelled with the force $\frac{fr}{Q}$.

This will perhaps be as diſtinctly conceived by recollecting, that as much of the fluid as was neceſſary for ſaturation, that is, the quantity Q, puts the particle P in equilibrio; and therefore we need only conſider the action of the redundant fluid f. To find the repulſive force of this, ſay $Q : f = r : \frac{fr}{Q}$, and prefix the ſign —; becauſe we are to conſider attractions as poſitive, and repulſions as negative, quantities.

Unleſs, therefore, the particle P be withheld by ſome other

12 tes of a ly cau- r efflux influx.

ther force, it will quit the body, being expelled by a force $\frac{fr}{Q}$. And as every ſuperficial particle is in a ſimilar ſituation, we ſee that there will be an efflux from an overcharged body, till all the redundant fluid has quitted it. This efflux will indeed gradually diminiſh as the expelling force $\frac{fr}{Q}$ diminiſhes; that is, as f diminiſhes, but will never ceaſe till f be reduced to nothing. But if there be either an external force acting on the ſuperficial fluid in the oppoſite direction, or ſome internal obſtruction to its motion, the efflux will ſtop when the remaining expelling force is juſt in equilibrio with this external force, or this obſtruction.

13. On the other hand, if the body contains leſs than its natural quantity of fluid, there will be an influx from without; for if there be a deficiency of fluid $= f$, the particle P will be repelled with the force $\frac{\overline{Q-f}\times r,}{Q}$ $= r - \frac{fr}{Q}$. It is attracted with the force a; and therefore the whole action is $= a - r + \frac{fr}{Q}, = + \frac{fr}{Q}$ (becauſe $a - r = 0$); that is, P is attracted with the force $\frac{fr}{Q}$. Fluid will therefore enter from all quarters, as long as there is any deficiency of the quantity neceſſary for ſaturation, unleſs it be oppoſed by ſome external force, or hindered by ſome internal obſtruction.

When there is a deficiency of fluid, there is a redundancy of matter, ſuch that its attraction for external fluid is equal to the repulſion of a quantity f of fluid. This confirms the aſſumption in nº 10, that *the action of a body on the electric fluid depends entirely on the redundant fluid, or the redundant matter of the body.*

14 w bodies ideo- trics or -elec- s.

The efflux or influx may be prevented, either by ſurrounding the body with ſubſtances, through the pores of which the fluid cannot move at all, or by the body itſelf being of this conſtitution. And thus we ſee, that the very circumſtance of being impervious to the fluid, or completely permeable, renders the body capable or incapable of permanently exhibiting electrical phenomena, if ſurrounded by permeable bodies. This circumſtance alone, therefore, is ſufficient to conſtitute the difference between *electrics per ſe*, and *non-electrics*.—Here, then, is a numerous claſs of phenomena, which receive an explanation by this hypothetical conſtitution of the electric fluid. All electrics *per ſe* are bodies fit for confining electricity in bodies which are rendered capable (by whatever means) of producing electrical phenomena; and no conductor, or ſubſtance which allows the electricity to paſs through it, can be made electric by any of the means which produce that effect in *inſulators*. And it is well known that the electricity of electrics is vaſtly more durable than that of non-electrics in ſimilar ſituations. It is true, indeed, that an electric, which has been excited ſo as to exhibit electric phenomena with great vivacity, loſes this power very quickly if plunged into water, or any other conducting body. But this is owing to the redundancy or deficiency being quite ſuperficial, ſo that the parts which are diſpoſed to give out or to take in the fluid are in immediate contact with the conducting matter. That the redundancy or deficiency is ſuperficial, follows from this hypotheſis; for when the ſurface is overcharged by the means employed for exciting, the impermeability of the electric *per ſe* prevents this redundant fluid from penetrating to any depth; and when the ſurface has been rendered deficient in fluid, the ſame impermeability prevents the fluid from expanding from the interior parts, ſo as to contribute to the repleniſhing the ſuperficial ſtratum with fluid. If, indeed, we could fall on any way of overcharging the interior parts of a glaſs ball, or of abſtracting the natural quantity from them, it is highly probable, that it would continue to attract or repel even after it had been plunged in water. Although the ſurrounding water would inſtantly take off the fluid redundant contained in the very ſurface, the repulſion of the fluid in the internal parts would ſtill be ſenſible; nay, if a very ſmall permeability be ſuppoſed, the body would again become overcharged at the ſurface; juſt as we ſee, that when we plunge a red-hot ball of iron into water, and take it out again immediately, it is black on the ſurface, and may be touched with the finger; but in half a minute after, it again becomes red hot. Perhaps this may be accompliſhed with a globe of ſealing wax, which is permeable while liquid, by electrifying it in a particular way while in that ſtate, and allowing it to freeze. But the reader is not far enough advanced in the hypotheſis to underſtand the proceſs which muſt be followed. He cannot but recollect, however, many examples in coated glaſs, &c. where the electricity is moſt pertinaciouſly retained by a ſurface in very cloſe contact with conductors.

15 Conſequences of unequable diſtribution of fluid. 1. Action on external fluid.

Let us now ſuppoſe a body NS (fig. 2.) containing in the half NA a quantity f of redundant fluid, and in the half AS let there be a deficiency g of fluid; that is, let there be a quantity of matter unſaturated, and ſuch as will attract fluid as much as the quantity g of fluid would repel it. Let the fluid neceſſary for the ſaturation of each half of NS be Q, as before. Let the attraction of the whole matter of NA for a particle of fluid at N be a; and let r be the repulſion exerted on the ſame particle N by the whole uniformly diſtributed fluid in NA, and let r' be the repulſion exerted by the *ſame quantity* of fluid in the remote part SA. Then the force with which the particle N or S is attracted by the merely ſaturated body NS muſt be $= a - r - r'$. This is evidently nothing, if the body be in its natural ſtate. But as NA contains the redundant fluid f, and SA is deficient by the quantity g, the whole action muſt be $a - \frac{\overline{Q+f}\times r}{Q}$ $- \frac{\overline{Q-g}\times r'.}{Q}$ But becauſe $a - r - r' = o$, the action becomes $= \frac{gr' - fr}{Q}$, or becauſe r is greater than r', the particle N is repelled with the force $\frac{fr - gr'.}{Q}$ In like manner the particle S is attracted with the force $\frac{gr - fr'}{Q}$.

16 2. Action on the contained fluid.

In the mean time, a particle C, ſituated at the middle, muſt be in equilibrio, if the body be in its natural ſtate, being equally attracted, and alſo equally repelled, on both ſides. But as we ſuppoſe that NA is overcharged

ged with the quantity f, C muſt be repelled in the direction CS with the force $\frac{fr}{Q}$. And if we alſo ſuppoſe that AS is deficient by the quantity g, C is attracted in the direction CS with a force $\frac{gr}{Q}$. Therefore, on the whole, it is urged in the direction CS with the force $\frac{fr+gr}{Q}$, or $\frac{\overline{f+g}\times r}{Q}$.

17 It will be uniformly diffuſed, unleſs obſtructed.

Hence we learn, that as long as there is any redundancy in AN, and deficiency in AS, there is a tendency of the redundant fluid to move from N toward S; and, if the body be altogether permeable by the electric fluid, we cannot have a permanent ſtate till the fluid is ſimilarly diſtributed, and equally divided, between the two halves of NS. Therefore a ſtate like that aſſumed in this example cannot be permanent in a conducting body, unleſs an external force act on it; but it may ſubſiſt in a non-conductor, and in a leſſer degree, in all imperfect conductors.

18 Nature of the obſtruction.

It is neceſſary, in this place, to conſider a little the nature of that reſiſtance which muſt be aſſigned to the motion of the electric fluid through the pores of the body. If it reſemble the reſiſtance oppoſed by a perfect fluid, ariſing ſolely from the inertia of its particles, then there is no inequality of force ſo minute but that it will operate a uniform diſtribution of the fluid, or at leaſt a diſtribution which will make the exceſs of the mutual attractions and repulſions preciſely equal and oppoſite to the external force which keeps it in any ſtate of unequal diſtribution. But it may reſemble the reſiſtance to the deſcent of a parcel of ſmall ſhot diſſeminated among a quantity of grain, or the reſiſtance to motion through the pores of a plaſtic or ductile body, ſuch as clay or lead. Here, in order that a particle may change its place, it muſt overcome the tenacity of the adjoining particles of the body. Therefore, when an unequal diſtribution has been produced by an external force, the removal or alteration of that force will not be followed by an equable diſtribution of the fluid. In every part there will remain ſuch an inequality of diſtribution, that the want of equilibrium between the electric attractions or repulſions is balanced by the tenacity of the parts.

19. We learn farther from the foregoing propoſitions, that a particle at N is leſs repelled than if the part AS were overcharged as AN is: for in that caſe, it would be expelled by a force $\frac{f\times\overline{r+r'}}{Q}$, which is much greater than $\frac{fr-gr'}{Q}$. And, in like manner, the particle S is attracted with leſs force than it would be if NA were equally undercharged with SA.

20. The condition of the body now deſcribed may be changed by different methods. The redundant fluid in AN may flow into AS, where it is deficient, till the whole be uniformly diſtributed; or fluid may eſcape from AN, and fluid may enter into AS, till the body be in its natural ſtate. The firſt method will be ſo much the ſlower as the body is leſs permeable, or more remarkably *electric per ſe*; and the ſecond method will be ſlower than if the whole body were overcharged or undercharged.

21. What we have been now ſaying of a body NS that is overcharged at one end, and undercharged at the other, and capable of retaining this ſtate, is applicable, in every particular, to two conducting bodies NA and SA′, having a non-conducting body Z interpoſed between them, as in fig. 3. All the formulas, or expreſſions of the forces which tend to expel or to draw in fluid, are the ſame as before. Perhaps this is the beſt way of forming to ourſelves a diſtinct notion of the body that is redundant in fluid at one end, and deficient at the other. And we perceive, that the ſtate of the two bodies, ſeparated by the electric Z, will be more permanent when one is overcharged, and the other undercharged, than if both are either over or undercharged.

22 A body may be inactive, or neutral, where it i redundant or deficie

It muſt be remarked, that the quantities f and g were taken at random. They may be ſo taken, that the force with which the fluid tends to eſcape at N, or to enter at S, may be nothing, or may even be changed to their oppoſite. Thus, in order that there may be no tendency to eſcape from N, we have only to ſuppoſe $gr'-fr=0$, or $g:f=r:r'$, and $g=\frac{fr}{r'}$. In this caſe, the particle at N is as much attracted by the redundant matter in SA as it is repelled by the redundant fluid in NA.

23 Condition neceſſary for this.

When the extremity N is rendered inactive in this manner, the condition of the other extremity S is conſiderably changed. To diſcover this condition, put $\frac{fr}{r'}$ in place of g in the formula $\frac{gr-fr'}{Q}$, which expreſſes the attraction for a particle at S, and we obtain $\frac{f\times\overline{r^2-r'^2}}{Qr'}$.

24. On the other hand, we may have the redundancy and deficiency ſo balanced, that there ſhall be no tendency to influx at S. For this purpoſe, we muſt make $g=\frac{fr'}{r}$. When this obtains at S, the action at N will be had by putting $\frac{fr'}{r}$ in place of g in the formula $\frac{fr-gr'}{Q}$, and this will give us $\frac{f\times\overline{r'^2-r^2}}{Qr}$ for the force repelling a particle at N.

25. When the tendency to efflux or influx is induced in this manner, by a due proportion of the redundancy and deficiency of electric fluid, the part of the body where this obtains is by no means in its natural ſtate, and may contain either more or leſs than its natural quantity. But it neither acts like an overcharged nor like an undercharged body, and may therefore be called NEUTRAL. The reader, who is converſant with electrical experiments, will recollect numberleſs inſtances of this, and will alſo recollect that they are important ones. Such, for example, is the caſe with the plates and covers of the electrophorus. Theſe circumſtances, therefore, claim particular attention.

26. As the quantities f and g may be ſo choſen, that the appartus ſhall be *neutral*, either at S or at N; they may likewiſe be ſo, that either end ſhall exhibit either the appearance of *redundancy* or *deficiency*. Thus, inſtead of neutrality at N, we may have repulſion, as at the firſt, by making g leſs in any degree than $\frac{fr}{r'}$. If, on the contrary, g be greater than $\frac{fr}{r'}$, the extremity N, tho' overcharged, will attract fluid. In like manner, if g be

be leſs than $\frac{fr'}{r}$, the extremity S, although undercharged, will repel fluid.—We may make the following general remarks.

27 oth ends nnot be eutral at ıce.

1. Both extremities N and S cannot be neutral at the ſame time: for ſince the neutrality ariſes from the increaſed quantity of redundancy or deficiency at the other extremity, ſo as to compenſate for its greater diſtance, the activity of that extremity muſt be proportionably greater on the fluid adjoining to its ſurface, whether externally or internally. When an overcharged extremity is rendered neutral, the other extremity attracts fluid more ſtrongly; and when a deficient extremity is rendered neutral, the other repels fluid more ſtrongly. All theſe elementary corollaries will be fully verified afterwards, and give clear explanations of the moſt curious phenomena.

2. We have been ſuppoſing that the redundant fluid is uniformly ſpread, and that the body is divided into equal portions; but this was merely to ſimplify the procedure and the formulæ. The reader muſt ſee that the general concluſions are not affected by this, and that ſimilar formulæ will be obtained, whatever is the diſpoſition of the fluid. We cannot tell in what manner the redundant fluid is diſpoſed, even in a body of the ſimpleſt form, till we know what is the variation of its attraction and repulſion by a change of diſtance; and even when this has been diſcovered, we find it difficult in moſt caſes, and impoſſible in many, to aſcertain the mode of diſtribution. We ſhall learn it in ſome important caſes, by means of various phenomena judiciouſly ſelected.

28. A body may be conſidered in many diviſions, in ſome of which the fluid is redundant, and in others deficient. We may expreſs the repulſion of the whole of this body in the ſame way as we expreſs that of a body conſidered in two diviſions, uſing the letters f, g, h, &c. to expreſs the quantities of redundant or deficient fluid in each portion, while Q expreſſes the quantity neceſſary for ſaturating each of them; and the repulſion at different diſtances may be expreſſed by r, r', r'', r''', &c. as they are more and more remote; and we may expreſs their action as attractive or repulſive by prefixing the ſign + or —. Thus the attraction may be $\frac{(fr - gr' + hr'' - ir''')}{Q}$, &c.

29 nſible actions of ectrical dies.

Having obtained the expreſſions of the inviſible actions of electrified bodies on the fluid within them, or ſurrounding them, let us now conſider their ſenſible actions on other bodies, producing motion, or tendencies to motion.

Here it is obvious that the mechanical phenomena exhibited are what may be called *remote* EFFECTS of the acting forces. The immediate effects, or the mutual actions of the particles, are not obſerved, but hypothetically inferred. The tangible matter of the body is put in motion, in conſequence of its connection with the fluid reſiding in the body, which fluid is the only ſubject of the action of the other body.

In conſidering theſe phenomena, we ſhall content ourſelves with a more general view of the actions which take place between the fluid or tangible matter of the one body, and the fluid or matter of the other, ſo as to gain our purpoſe by more ſimple formulæ than thoſe hitherto employed. They were premiſed, however, becauſe we *muſt* have recourſe to them on many very important particular occaſions.

30. Let there be two bodies, A and B, in their natural ſtate. Let the tangible matter in A be called M, and let the fluid neceſſary for its ſaturation be called F, and let m and f be the tangible matter and the fluid in B. Let the mutual action between a ſingle particle of fluid and the matter neceſſary for its ſaturation be expreſſed by the indeterminate ſymbol z, becauſe it varies by a change of diſtance.

The actions are mutual and equal. Therefore when the motion of B by the action of A is determined, the motion of A is alſo aſcertained. We ſhall therefore only conſider how A is affected. 1. Every particle of fluid in A tends toward every particle of matter in B with the force z. The whole tendency of A toward B may therefore be expreſſed by z, multiplied by the product of F and m. 2. Every particle of fluid in A is repelled by every particle of fluid in B, with the ſame force z. 3. Every particle of matter in A is attracted by every particle of fluid in B, with the ſame force. We may expreſs this more purely and briefly thus:

1. F tends *toward m* with the force $+ Fmz$
2. F tends *from f* with the force $- Ffz$
3. M tends *toward f* with the force $+ Mfz$

Therefore the ſenſible tendency of A to or from B will be $= z \times \overline{Fm + Mf - Ff}$. But, by the hypotheſis, the attraction of a particle of the fluid in A for a particle of the matter in B, is equal to its repulſion for the particle or parcel of the fluid attached or competent to that particle of matter. Therefore the attraction Fmz is balanced by the repulſion Ffz. Therefore there remains the attraction of the matter in A for the fluid in B unbalanced, and the body A will tend toward the body B with the force Mfz, or B attracts A with the force Mfz. A muſt therefore move toward B. And, by the 3d law of motion, B muſt move toward A with equal force.

31 Completion of the hypotheſis of Æpinus.

But the fact is, that no tendency of any kind is obſerved between bodies in their natural ſtate. The hypotheſis, therefore, is not complete. If we abide by it, as far as it is already expreſſed, we muſt farther ſuppoſe, that there is ſome repulſive force exerted between the bodies to balance the attraction of M for f. Mr Æpinus, therefore, ſuppoſes, that every particle of tangible matter repels another particle as much as it attracts the fluid neceſſary for its ſaturation. The whole action of B on A will now be $= z \times \overline{Fm - Ff - Mm + Mf}$. Fmz is balanced by Ffz, and Mmz by Mfz, and no exceſs remains on either ſide.

32 Objections anſwered.

Æpinus acknowledges that this circumſtance appeared to himſelf to be hardly admiſſible; it ſeeming inconceivable that a particle in A ſhall repel a particle in B, or tend from it, electrically, while it attracts it, or tends toward it, by planetary gravitation. We cannot conceive this; but more attentive conſideration ſhewed him, that there is nothing in it contrary to the obſerved analogy of natural operations. We muſt acknowledge, that we ſee innumerable inſtances of inherent forces of attraction and repulſion; and nothing hinders us from referring this lately diſcovered power to the claſs of primitive and fundamental powers of nature. Nor is there any difficulty in reconciling this repulſion with univerſal gravitation; for while bodies are in their natural ſtate,

ſtate, the electric attractions and repulſions preciſely balance each other, and there is nothing to diſturb the phenomena of planetary gravitation; and when bodies are not in their natural electrical ſtate, it is a fact that their gravitation is diſturbed. Although we cannot conceive a body to have a tendency to another body, and at the ſame time a tendency from it, when we derive our notion of theſe tendencies entirely from our own conſciouſneſs of effort, endeavour, *conatus*, *niſus accedendi ſeu recedendi*, nothing is more certain than that bodies exhibit at once the appearances which we endeavour to expreſs by theſe words. We can bring the north poles of two magnets near each other, in which caſe they recede from each other; and if this be prevented by ſome obſtacle, they preſs on this obſtacle, and ſeem to endeavour to ſeparate. If, while they are in this ſtate, we electrify one of them, we find that they will now approach each other; and we have a diſtinct proof that both tendencies are in actual exertion by varying their diſtances, ſo that one or other force may prevail; or by placing a third body, which ſhall be affected by the one but not by the other, &c. We do not underſtand, nor can conceive in the leaſt, how either force, or how gravity, reſides in a body; but the effects are paſt contradiction. It muſt be granted, therefore, that this additional circumſtance of Æpinus's hypotheſis has nothing in it that is repugnant to the obſerved phenomena of Nature.

N. B. It is not neceſſary to ſuppoſe (although Mr Æpinus does ſuppoſe it), that every atom of tangible matter repels every other atom. It will equally explain all the phenomena, if we ſuppoſe that every particle contains an atom or ingredient having this property, and that it is this atom alone which attracts the particles of electrical fluid. The material atoms having this property, and their correſponding atoms of fluid, may be very few in compariſon with the number of atoms which compoſe the tangible matter. Their mutual ſpecific action being very great in compariſon with the attraction of gravitation (as we certainly obſerve in the action of light), all the phenomena of electricity will be produced without any ſenſible effect on the phenomena of gravitation, even although neither the electric fluid nor its ally, this ingredient of tangible matter, ſhould not gravitate. But this ſuppoſition is by no means neceſſary.

Since we call that the natural electrical ſtate of bodies in which they do not affect each other, and the hypothetical powers of the fluid are accommodated to this condition, we may conſider any body that has more than its natural quantity as conſiſting of a quantity of matter ſaturated with fluid, and a quantity of redundant fluid ſuperadded; and an undercharged body may be conſidered as conſiſting of a quantity of matter ſuperadded. The ſaturated matter of theſe two bodies will be totally inactive on another body in its natural ſtate, and will neither attract nor repel it, nor be attracted nor repelled by it; therefore the action of the overcharged body will depend entirely on the redundant fluid; and that of the undercharged body will depend entirely on the redundant matter; therefore we need only conſider them as conſiſting of this redundant fluid or matter, agreeably to what was ſaid in more vague terms in n° 10. and 13. This will free us from the complicated formulæ which would otherwiſe be neceſſary for expreſſing all the actions of the fluid and tangible matter of two bodies on each other. The reſults will be ſufficiently particular for diſtinguiſhing the ſenſible action of bodies in the chief general caſes: but in ſome particular and important caſes, it is abſolutely neceſſary to employ every term.

33 General e preſſion (ſymbolical) of the mutual action.

1. Suppoſe two bodies A and B, containing the quantities F and f' of redundant fluid, it is plain that their mutual action is expreſſed by $F' \times f' + z$, and that it is a repulſion; for ſince every particle of redundant fluid in A repels every particle of redundant fluid in B with the force z; and ſince F' and f' are the numbers of ſuch particles in each, the whole repulſion muſt be expreſſed by the product of theſe numbers.

2. In like manner, two bodies A and B, containing the redundant matter M' and m', will repel each other with the force $M' m' z$. 34.

3. And two bodies A and B, one of which A contains the redundant fluid F', and the other B contains the redundant matter m', will attract each other with the force $F m' z$. 35.

4. It follows from theſe premiſes, that if either of the bodies be in its natural ſtate, they will neither attract nor repel each other; for, in ſuch a caſe, one of the factors F', or f', or M', or m', which is neceſſary for making a product, is wanting. This may be perceived independent of the mathematical formula; for if A contain redundant fluid, and B be in its natural ſtate, every particle of the redundant fluid in A is as much repelled by the natural fluid in B as it is attracted by the tangible matter. 36.

37 Seeming paradox.

The three firſt propoſitions agree perfectly with the known phenomena of electricity; for bodies repel each other, whether both are poſitively or both are negatively electrified, and bodies always attract each other when the one is poſitively and the other negatively electrified. But the fourth caſe ſeems very inconſiſtent with the moſt familiar phenomena. Dr Franklin and all his followers aſſert, on the contrary, that electrified bodies, whether poſitive or negative, always attract, and are attracted, by all bodies which are in their natural ſtate of electricity. But it will be clearly ſhewn preſently, that they are miſtaken, and that Franklin's theory neceſſarily ſuppoſes the truth of the fourth propoſition, otherwiſe two bodies in their natural ſtate could not be neutral or inactive, as any one may perceive on a very ſlight examination by the Franklinian principles. It will preſently appear, with the fulleſt evidence; and, in the mean time, we proceed to explain the action of bodies which are overcharged in ſome part, and undercharged in another.

38 Action of a body having the fluid unequably diſpoſed.

Let the body B (fig. 4.) be overcharged in the part B *n*, and undercharged in the part B *s*, and let f' and m' be the redundant fluid and common matter in thoſe parts; let A be overcharged, and contain the redundant fluid F; let z and z' expreſs the intenſity of action correſponding with the diſtances of A from the overcharged and undercharged parts of B; the part B *n* repels A with the force $F' f' z$, while the part B *s* attracts it with the force $F' m' z$: A will therefore be attracted or repelled by B, according as $F' m' z'$ is greater or leſs than $F' f' z'$; that is, according as $m' z'$ is greater or leſs than $f' z$. This, again, depends on the proportion of f' to m', and on the proportion of z to z'. The firſt depends on many external circumſtances, which may occaſion a greater or leſs redundancy or deficiency of electrical fluid; the ſecond depends

pends entirely on the law of electric attraction and repulſion, or the change produced in its intenſity by a change of diſtance. As we are, at preſent, only aiming at very general notions, it is enough to recollect, that all the electric phenomena, and indeed the general analogy of nature, concur in ſhewing that the intenſity of both forces (attraction and repulſion) decreaſes by an increaſe of diſtance; and to combine this with that circumſtance of the hypotheſis which ſtates the repulſion to be equal to the attraction at the ſame diſtance; therefore both forces vary by the ſame law, and we have z always greater than z. The viſible action of B on A (which, by the 3d law of motion, is accompanied by a ſimilar action of A on B) may be various, even with one poſition of B, and will be changed by changing this poſition.

afes of
nſible re-
ulſion.

1. We may ſuppoſe that B contains, on the whole, its natural quantity, but that part of it is abſtracted from B *s*, and is crowded into B *n*. This is a very common caſe, as we ſhall ſee preſently, and it will be expreſſed in our formula by making $f' = m'$. In this caſe, therefore, we have $F' f z$ greater than $F m' z$, becauſe z is greater than z'. A will therefore be repelled by B, and will repel it; and the repulſion will be $F' f' \times \overline{z - z'}$.

f attrac-
on.

It is evident that if A be placed on the other ſide of B, the appearances will be reverſed, and the bodies will attract each other with the force $F' f' \times \overline{z - z'}$.

It is alſo plain, that if A be as much undercharged as we have ſuppoſed it overcharged, all the appearances will be reverſed; if on the undercharged ſide of B, it will be repelled; and if on the overcharged ſide of B, it will be attracted.

39
f neutra-
ty.

2. If the redundancy and deficiency in the two portions of B be inverſely proportional to the forces, ſo that $F' : m' = z' : z$, we ſhall have $f' z = m' z'$, and $m' = \frac{f' z}{z'}$. In this caſe theſe two actions balance each other, and A is neither attracted nor repelled when at this preciſe diſtance from the overcharged ſide of B. B may be ſaid to be NEUTRAL with reſpect to A, although A and the adjoining ſide of B are both overcharged.

40
odies neu-
ral at one
nd are
ore ac-
ve at the
ther.

But if A be placed at the ſame diſtance on the other ſide of B, the effect will be very different: For becauſe $m' = \frac{f' z}{z'}$, and $m' z'$ is now changed into $m' z$, and $f' z$ into $f z'$, we have the action on $A = F' \times \left(\frac{f' z}{z'} - f' z'\right), = F' f' \times \frac{z^2 - z'^2}{z'}$; that is, A is ſtrongly attracted.

In like manner, f' and m' may be ſo proportioned, that when A, containing redundant fluid, is placed near the undercharged end of *s* B, it ſhall neither be attracted nor repelled, B becoming neutral with regard to A at that preciſe diſtance. For this purpoſe m' muſt be $= \frac{f z'}{z}$. And if A be now placed at the ſame diſtance on the other ſide of B, it will be repelled with the force $F' f' \times \frac{z^2 - z'^2}{z}$.

Thus, when the overcharged end is rendered neutral to an overcharged body, the other end ſtrongly attracts it; and when the undercharged end is rendered neutral to the ſame body, the overcharged end ſtrongly repels it.

Similar appearances are exhibited when A is undercharged.

Theſe caſes are of frequent occurrence, and are important, as will appear afterwards.

41.

It is eaſy now to ſee what changes will be made on the action of B on A, by changing the proportion of f' and m'. If m' be made greater than $\frac{f'' z}{z}$, A will be attracted in the ſituation where it was formerly neutral; and if m' be made leſs, A will be repelled, &c. &c.

Therefore, when we obſerve B to be neutral, or attractive, or repulſive, we muſt conclude that m' is equal to $\frac{f z}{z'}$, or greater or leſs than it, &c.

We have been thus minute, that the reader may perceive the agreement between this action on a body containing redundant fluid, and the action on the ſuperficial fluid formerly conſidered in nº 21, 22, 23, 24. When theſe things are attended to, we ſhall explain, with great eaſe, all the curious phenomena of the electrophorus.

42
Neutrality
generally
limited to a
preciſe diſ-
tance. Im-
portant in-
formation
obtained
from this.

There is another circumſtance to be attended to here, which will alſo explain ſome electrical appearances that ſeem very puzzling. We limited the inactivity of B to a certain preciſe diſtance of the body A. This inactivity required that m' ſhould be $= \frac{f z}{z'}$. If A be brought nearer, both z and z' are increaſed. If they are both increaſed in the ſame proportion, the value of $\frac{z}{z'}$ will be the ſame as before, and the body A will neither be attracted nor repelled at this new diſtance. But if z increaſe faſter than z', we ſhall have $f' z$ greater than $m' z'$, and A will be repelled; and if z increaſes more ſlowly than z', A will be attracted by bringing it nearer. The contrary effects will be obſerved if A be removed farther from the overcharged end of B. This explains many curious phenomena; and thoſe phenomena become inſtructive, becauſe they enable us to diſcover the law of electric action, by ſhewing us the manner in which it diminiſhes by a change of diſtance. Electricians cannot but recollect many inſtances, in which the motion of the electrometer appeared very capricious. The general fact is, that when an overcharged pith ball is ſo ſituated near the overcharged ſide of the electrophorus as to be neutral, it is repelled when brought nearer, but attracted when removed to a greater diſtance. This ſhews that z increaſes faſter than z' when A is brought nearer to B. Now, ſince the bodies may be again rendered neutral at a greater diſtance than before, and the ſame appearances are ſtill obſerved, it follows, that the law of action is ſuch, that *every* diminution of diſtance cauſes z to increaſe faſter than z'. We ſhall find this to be valuable information.

43
Action
when the
fluid is un-
equably diſ-
poſed in
both bodies.

Let us, in the laſt place, inquire into the ſenſible effect on A when it alſo is partly overcharged and partly undercharged. This is a much more complicated caſe, and is ſuſceptible of great variety of external appearances, according to the degrees of redundancy and deficiency, and according to the kind of electricity (poſitive or negative) of the ends which front each other.

First,

Firſt, then, let the overcharged end of A (fig. 5.) fron the undercharged end of B, they being overcharged in N and *n*, but undercharged in S and *s*. Let F and *f* be the quantity of fluid natural to each; and let F′ and *f*′ be the redundancy in N and *n*, and M′ and *m*′ the deficiency in S and *s*. Moreover, let Z and Z′ repreſent the intenſity of actions of a particle in N on a particle in *n* and *s*; and let *z* and *z*′, repreſent the actions of a particle in S on a particle in *n* and in *s*; or, in other words, let Z, Z′, *z*, *z*′, repreſent the intenſity of action between particle and particle, correſponding to the diſtances N *s*, N *n*, S *s*, S *n*.

Proceeding in the ſame manner as in the former examples, we eaſily ſee, that the action of B on A is $= \frac{F' m' Z - F' f' Z' - M' m' z + M' f' z'}{F f}$; the attractions are conſidered as poſitive quantities, having the ſign + prefixed to them, and the repulſions are negative, having the ſign —.

This action will be either attractive or repulſive, according as the ſum of the firſt and laſt terms of the numerator exceeds or falls ſhort of the ſum of the ſecond and third: And the value of each term will be greater or leſs, according to the quantity of redundant fluid and matter, and alſo according to the intenſity of the electric action. It would require ſeveral pages to ſtate all thoſe poſſible varieties. We ſhall therefore content ourſelves at preſent with ſtating the ſimpleſt caſe; becauſe a clear conception of this will enable the reader to form a pretty diſtinct notion of the other poſſible caſes; and alſo, becauſe this caſe is very frequent, and is the moſt uſeful for the explanation of phenomena.

We ſhall ſuppoſe, that the redundant part of each body is juſt as much overcharged as the deficient part is undercharged; ſo that $F = M'$, and $f' = m'$. In this caſe, the formula becomes $\frac{F' f' (Z - Z' - z + z'}{F f}$.

Uſeful repreſentation of the mutual forces by ordinates to a curve.

Here we ſee that the ſenſible or external effect on A depends entirely on the law of electric action, or the variation of its intenſity by a change of diſtance. If the ſum of Z and *z*′ exceed the ſum of Z′ and *z*, A will be attracted; but if $Z + z'$ be leſs than $Z' + z$, A will be repelled. This circumſtance ſuggeſts to us a very perſpicuous method of expreſſing theſe actions between particle and particle, ſo that the imagination ſhall have a ready conception of the circumſtance which determines the external complicated effect of this internal action. This will be obtained by meaſuring off from a fixed point of a ſtraight line portions reſpectively equal to the diſtances N *s*, N *n*, S *s*, and S *n*, between the points of the two bodies A and B, where we ſuppoſe the forces of the redundant fluid and redundant matter to be concentrated, and erect ordinates having the proportion of thoſe forces. If the law of action be known, even though very imperfectly, we ſhall ſee, with one glance, of which kind the movements or tendencies of the bodies will be. Thus, in fig. 5. drawing the line C *z*, take $C p = N s$, $C q = N n$, $C r = S s$, and $C t = S n$, and erect the ordinates P *p*, Q *q*, R *r*, and T *t*. If the electric action be like all the other attractions and repulſions which we are familiarly acquainted with, decreaſing with an increaſe of diſtance, and decreaſing more ſlowly as the diſtances are greater, theſe ordinates will be bounded by a curve PQRTZ, which has its convexity turned toward the axis. We ſhall preſently get full proof that this is the caſe here; but we premiſe this general view of the ſubject, that we may avoid the more tedious, but more philoſophical, proceſs of deducing the nature of the curve from the phenomena now under conſideration.

45
General character of the ſcal of electric force.

This conſtruction evidently makes the pair of ordinates P *p*, Q *q*, equidiſtant with the pair R *r*, T *t*. Alſo, P *p*, R *r*, and Q *q*, T *t*, are equidiſtant pairs. It is no leſs clear, that the ſum of P *p* and T *t* exceeds the ſum of Q *q* and R *r*. For if C *z* be biſected in V, and V *v* be drawn perpendicular to it, cutting the ſtraight lines PT and QR in *x* and *y*, then *x v* is the half ſum of P *p* and T *t*, and *y v* is the half ſum of Q *q* and R *r*. Moreover, if Q *m* and T *n* are drawn parallel to the baſe, we ſee that P *m* exceeds R *r*; and, in general, that if any pair of equiſtant ordinates are brought nearer to C, their difference increaſes, and *vice verſa*. Alſo, if two pairs of equidiſtant ordinates be brought nearer to C, each pair by the ſame quantity, the difference of the neareſt pair will increaſe more than the difference of the more remote pair. And this will hold true, although the firſt of the remote pair ſhould ſtand between the two ordinates of the firſt pair. If the reader will take the trouble of conſidering theſe ſimple conſequences with a little attention, he will have a notion of all the effects that are to be expected in the mutual actions of the two bodies, ſufficiently preciſe for our preſent purpoſe. We ſhall give a much more accurate account of theſe mathematical truths in treating the article Magnetism, where preciſion is abſolutely neceſſary, and where it will be attended with the greateſt ſucceſs in the explanation of phenomena.

Now let us apply this to our preſent purpoſe. *Firſt*, then, When the overcharged end of A is turned toward the undercharged end of B, A muſt be attracted; for $P p + T t$ is greater than $Q q + R r$. 46.

Secondly, This attraction muſt increaſe by bringing the bodies nearer; for this will increaſe the difference between P *m* and R *n*. 47.

Thirdly, The attraction will increaſe by increaſing the length either of A or of B (the diſtance N *s* remaining the ſame); for by increaſing the length of A, which is repreſented by *pr* or *q t*, R *r* is more diminiſhed than T *t* is. In like manner, by increaſing B, whoſe length is repreſented by *p q* or *r t*, we diminiſh Q *q* more than T *t*. 48.

49
Uſe of this picture of the forces.

On the other hand, if the overcharged end of B front the overcharged end of A, their mutual action will be

$$\frac{F' f' (- P p + Q q + R r - T t),}{F f}$$

and A will be repelled, and the repulſion will increaſe or diminiſh, by change of diſtance or magnitude, preciſely in the ſame manner that the attractions did. It is hardly neceſſary to obſerve, that all theſe conſequences will reſult equally from bringing an apparatus ſimilar to that repreſented in fig. 3. near to another of the ſame kind; and that they will be various according to the poſition and the redundancy or deficiency of the two parts of each apparatus.

50
Curious phenomena which ſhould reſult from the hypotheſis reſembling magnetiſm.

If the body B of fig. 5. is not at liberty to approach toward A, nor to recede from it, and can only turn round its centre B, it will arrange itſelf in a certain determinate poſition with reſpect to that of A. For example, if the centre B (fig. 7.) be placed in the line paſſing through S and N of the body A, B will arrange itſelf in the ſame ſtraight line: for if we forcibly give it another poſition, ſuch as s B n, N will attract s and repel n, and theſe actions will concur in putting B into the poſition s' B n'. S, however, will repel s and attract n; and theſe forces tend to give the contrary poſition. But S being more remote than N, the former forces will prevail, and B will take the poſition s' B n'.

If the centre B be placed ſomewhere on the line AD, drawn through a certain point of the body NAS (which will be determined afterwards), at right angles to NAS, the body B will aſſume the poſition n' B s', parallel to NAS, but ſubcontrary. For if we forcibly give it any other poſition n B s, it is plain that N repels n and attracts s, while S attracts n and repels s. Theſe four forces evidently combine to turn the body round its centre, and cannot balance each other till B aſſume the poſition n' B s', where n' is next to S, and s' is next to N.

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If the centre of B have any other ſituation, ſuch as B′, the body will arrange itſelf in ſome ſuch poſition as n' B′ s'. It may be demonſtrated, that if B be infinitely ſmall, ſo that the action of the end of A on each of its extremities may be conſidered as equal, B will arrange itſelf in the tangent BT of a curve NB′S, ſuch that if we draw NB, SB, and from any point T of the tangent draw TE parallel to BN, and TF parallel to B′S, we ſhall have BE to BF, as the force of S to the force of N. This arrangement of B will be ſtill more remarkable and diſtinct if N be an overcharged ſphere, and S an undercharged one, and both be inſulated. We muſt leave it to the reader's reflection to ſee the changes which will ariſe from the inequality of the redundancy and deficiency in A or B, or both, and proceed to conſider the conſequences of the mobility of the electric fluid. Theſe will remove all the difficulty and paradox that appears in ſome of the foregoing propoſitions.

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Let the body A (fig. 4.) contain redundant fluid, and let B be in its natural ſtate, but let the fluid in A be fixed, and that in B perfectly moveable; it is evident that the redundant fluid in A will repel the moveable fluid in B, toward its remote extremity n, and leave it undercharged in s. The fluid will be rarefied in s, and conſtipated in n. We need only conſider the mutual actions of the redundant fluid and redundant matter. It is plain that things are now in the ſituation deſcribed in n° 15.: A muſt be attracted by B, becauſe $f' = m'$, and z is greater than z'. The attractive force is $F' f' \times (z - z')$.

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Thus we ſee that the hypotheſis is accommodated to the phenomena in the caſe in which it appeared to differ ſo widely from it. Had the fluid been immoveable, the mutual actions would have ſo balanced each other that no external effects would have appeared. But now the greater vicinity of the redundant matter prevails, A is attracted by B, and, the actions being all mutual, B is attracted by A, and approaches it.

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We have ſuppoſed that the fluid in A is immoveable; but this was for the ſake of greater ſimplicity. Suppoſe it moveable. Then, as ſoon as the uniform diſtribution of the fluid in B is changed, and B becomes undercharged at s, and overcharged at n, there are forces acting on the fluid in A, and tending to change its ſtate of diſtribution. The redundant matter in S attracts the redundant fluid in A more than the more remote redundant fluid in n repels it, becauſe z' is leſs than z. This tends to conſtipate the redundant fluid of A in the nearer parts, and render N more redundant, and S leſs redundant in fluid than before. It is plain that this muſt increaſe their mutual action, without changing its nature. It can be ſtrictly demonſtrated, that however ſmall the redundancy in A may be, it can never be rendered deficient in its remote extremity by the action of the unequally diſpoſed fluid in B, if the fluid in B be no more nor leſs than its natural quantity. It is alſo plain that this change in the diſpoſition of the fluid in A muſt increaſe the ſimilar change in B. It will be ſtill more rarefied in s, and condenſed in n; and this will go on in both till all is in equilibrio. When things are in this ſtate, a particle of fluid in B is in equilibrio by the combined action of ſeveral forces. The particle B is propelled toward n by the action of the redundant fluid in A. But it is urged toward S by the repulſion of the redundant fluid on the ſide of n, and alſo by the attraction of the redundant matter on the ſide of s; and the repulſion of the redundant fluid in A muſt be conceived as balancing the united action of thoſe two forces reſiding in B.

53
General notion of the forced diſpoſition of electric fluid in a body.

Hence we may conclude, that the denſity of the fluid in B will increaſe gradually from s to n. It will be extremely difficult to obtain any more preciſe idea of its denſity in the different parts of B, even although we knew the law of action between ſingle particles.

This muſt depend very much on the form and dimenſions of B; for any individual particle ſuſtains the ſenſible action of all the redundant fluid and redundant matter in it, ſince we ſuppoſe it affected by the more remote fluid in A. All that we can ſay of it in general is, that the denſity in the vicinity of s is leſs than the natural denſity; but in the vicinity of n it is greater; and therefore there muſt be ſome point between s and n where the fluid will have its natural denſity. This point may be called a NEUTRAL point. We do not mean by this that a particle of ſuperficial fluid will neither be attracted nor repelled in this place. This will not always be the caſe (although it will never be *greatly* otherwiſe); nor will the variation of the denſity in the different parts of B be proportional to the force of A on thoſe parts. Some eminent naturaliſts have been of this opinion; and, having made experiments in which it appeared to be otherwiſe, they have rejected the whole theory. But a little reflection will convince the mathematician, that the ſum of the internal forces which tend to urge a particle of fluid from its place, and which are balanced by the action of A, are *not* proportional to the variations of denſity, although they increaſe and decreaſe together. We ſhall take the proper opportunity of explaining thoſe experiments; and will alſo conſider ſome ſimple, but important caſes, where we think the law of diſtribution of the fluid aſcertained with tolerable preciſion.

Neutral point.

If we ſuppoſe, on the other hand, that A is undercharged, the redundant matter in A will attract the moveable fluid in B, and will abſtract it from the remote extremity, and crowd it into the adjacent extremity. Moreover, the fluid now becoming redundant in the nearer extremity of B, will act more ſtrongly on the moveable fluid in A than the more remote redundant matter of B; and thus fluid will be propelled toward the remote ſide of A, which will become now undercharged;

charged in its nearer ſide, and leſs undercharged in its remote ſide than if B were taken away. This muſt increaſe the inequability of diſtribution of the fluid in B, and both will be put farther from their natural ſtate; but A will never become overcharged in its remote extremity.

Things being in this ſtate, it is plain that A and B will mutually attract each other in the ſame manner, and with the ſame force, as when A was as much overcharged as it is now undercharged.

54
Electric atmoſphere is not adequate to the explanation of the phenomena.

Thus, then, we ſee how the attraction obtains, whether A be over or undercharged. A fact which Dr Franklin could never explain to his own ſatisfaction; nor will it ever be explained conſiſtently with the acknowledged principles and obſerved laws of mechanics by any perſon who employs elaſtic atmoſpheres for this purpoſe. It is indeed a ſufficient objection to the employment of ſuch electric or other atmoſpheres, that the ſame extent of attraction and repulſion between the particles of the atmoſphere is neceſſary, as is employed here between the particles of the fluid reſiding in the body; and therefore they ceaſe to give any explanation, even although their ſuppoſed actions were legitimately deduced from their conſtitution. This is by no means the caſe. Let any perſon examine ſeriouſly the *modus operandi* of the electric atmoſpheres employed by Lord Mahon (the only perſon who has written mathematically on the ſubject), and he will ſee that the whole is nothing but figurative language, without any diſtinct perception of what is meant by theſe atmoſpheres, as diſtinct from the fluid moveable in the conducting bodies, or any perception how the unequal denſity of theſe atmoſpheres protrudes the fluid along the conductor. Beſides, it is well known that a conducting wire becomes poſitive at one end, and negative at the other, by the mere vicinity of an overcharged or undercharged body, and this in an inſtant, although it be ſurrounded with ſealing-wax, or other non-conductors, to any thickneſs: in this caſe there can be no atmoſpheres to operate on the included fluid. To this we may add Dr Franklin's judicious experiment of whirling an electrified ball many times round his head, with great rapidity, by means of a ſilk line, without any ſenſible diminution of its electricity. It is not conceivable that an electric atmoſphere could remain attached to the ball; nor could it be inſtantaneouſly formed round the ball, in every point of its motion, ſo as to be operative the moment he ſtopped it and tried it; for this would have exhauſted or greatly diminiſhed the electricity of the ball); whereas that ſagacious philoſopher affirms (and any perſon will find it true), that when the air is dry, he did not obſerve the electricity more diminiſhed than that of another ball which remained all the while in the ſame place.

55
Induced electricity.

Let the overcharged body A (fig. 6.) be brought near the ends of two oblong conductors B and C in their natural ſtate, and lying parallel to each other; the fluid will be propelled toward their remote ends N, *n*, where it will be condenſed, while it will be rarefied in the ends S and *s*, adjacent to A. Both will be attracted by A, and will attract it. But the redundant fluid in NB will repel the redundant fluid in *n* C; and the redundant matter in SB will repel the redundant matter in *s* C. For this reaſon the bodies B and C will repel each other, and will ſeparate; but SB attracts *n* C, and NB attracts *s* C; and on this account the bodies ſhould approach: but the diſtances of the attracting parts being greater than thoſe of the repelling parts, the repulſions muſt prevail, and the bodies muſt really ſeparate.

It is equally clear that the very ſame *ſenſible* appearance will reſult from bringing an undercharged body near the ends of B and C, although the internal motions are juſt the oppoſite to the former.

If another body D, electrified in the ſame way with A, be brought near the oppoſite ends of B and C, it will prevent or diminiſh the internal motions, and it ſhould therefore prevent or diminiſh the external effects.

If another conducting body be brought near to the end *s* of C that fronts A, it will be affected as C is, and the end *f* will repel *s*; but if it be brought near the remote end, as is the caſe with the body F, it will attract this remote end. As the body A, containing more or leſs than its natural ſhare of electric fluid, affects every other body, while they do not (when out of its neighbourhood) affect each other, it is uſually ſaid to be the electrified body, and the others are ſaid to be electrified by it; and ſince theſe bodies, when perfect conductors, cannot retain their power of exhibiting electrical appearances (ſee nº 17.), it will be convenient to diſtinguiſh this laſt electrical ſtate by a particular name. We ſhall call it ELECTRICITY BY POSITION, OR INDUCED ELECTRICITY. It is induced by poſition with regard to the permanently electrical body.

56
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We have ſuppoſed, in theſe laſt propoſitions, that the fluid was perfectly moveable in B, and, at laſt, alſo, in A: but let us examine the conſequences of ſome obſtruction to this motion. Without entering into a minute enquiry on this head, we may ſtate the obſtruction as uniform, and ſuch that a certain ſmall force is neceſſary for cauſing a particle of fluid to get through between two particles of the common matter, juſt as we conceive to happen in tenacious bodies of uniform texture (ſee nº 18.).

It is evident, that when an overcharged body A (fig. 4. or 5.) is brought near ſuch an imperfect conductor B, the fluid cannot be ſo copiouſly propelled to the remote extremity *n*. We may conceive the ſtate of diſtribution by taking a conſtant quantity from the intenſities of the force of A at every point of B. This circumſtance alone ſhews us that there will not be ſo unequable a diſtribution of the fluid, and therefore *there will not be ſuch a ſtrong attraction between imperfect as between perfect conductors.* But beſides this, we ſee that an incomparably longer time muſt elapſe before things come to a ſtate of equilibrium. Each particle of fluid employs time to overcome the obſtacle to its motion, and it cannot advance till after the ſucceeding ones, each eſcaping in its turn, have again come up with the foremoſt. An important conſequence reſults from this. The neutral point, where the fluid is of the natural denſity, will not be ſo far from the other body as it would have been without theſe obſtructions; and this point will be a conſiderable while of advancing along the imperfect conductor. At the firſt approach of the overcharged electric, the near extremity of the imperfect conductor becomes a little undercharged, and the neutral point advances from the very extremity a ſmall way, the diſplaced fluid being crowded a little before it, and giving way by degrees

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as its foremoſt particles get paſt the obſtructions. The motion forward takes place over a conſiderable extent at the very firſt; namely, in that part of the conductor where the propelling power of the neighbouring electric is juſt able to puſh a particle over the obſtruction. As the propulſion goes on, the neutral point muſt gradually advance, and at laſt reach a certain diſtance, determined by the degree of the obſtruction. It is plain, that the final accumulation at the remote end of the imperfect conductor will be leſs than in a perfect conductor, and the neutral point will be nearer to the other end.

57 Irregular diſtribution. There is another remarkable conſequence of the obſtruction. It muſt always happen that, at the beginning of the action, the greateſt conſtipation will not be towards the remote extremity, but in a place much nearer to the diſturbing cauſe. Beyond this, the conſtipation will diminiſh. As time elapſes during this operation, this conſtipated fluid acts on the fluid beyond it by repulſion, and may do this with ſufficient force to diſplace ſome of it, and render a part of the imperfect conductor deficient, with a ſmall conſtipation beyond it. This may, in like manner, produce a rarefaction farther on, followed by another condenſation; and this may be frequently repeated when the obſtruction is very great, and the repulſion of the overcharged body very great alſo. This can be ſtrictly demonſtrated in ſome very ſimple caſes, but the demonſtration is very tedious: As the reſult, however, is of the firſt importance in the theory of electricity, and ſerves to explain ſome of the moſt abſtruſe phenomena, we wiſh the reader to have ſome ſtronger ground of confidence than the above bare aſſertion. He may obſerve ſimilar effects of cauſes preciſely ſimilar. If we dip the end of a flat ruler into water, and if, after allowing the water to become perfectly ſtill, we move the ruler gently along in a direction perpendicular to the face, we ſhall obſerve a ſingle wave heap up before the ruler, and keep before it, all the reſt of the water before it remaining ſtill: but if we do the ſame thing in a veſſel of clammy fluid, eſpecially if the clammy part is ſwimming on the ſurface of a more perfect fluid, like a cream, we ſhall obſerve a ſeries of ſuch waves to curl up before the ruler, and form before it in ſucceſſion; and if we have previouſly ſpotted the ſurface of the cream, we ſhall ſee that it is not the ſame individual waves that are puſhed before the ruler, but that they are ſucceſſively formed out of different parts of the ſurface, and that the particles which, at one time, form the ſummit of a wave, are, immediately after, at the bottom, &c. In like manner, when a cannon is fired in clear air, at no great diſtance, we hear a ſingle ſnap; but, in a thick fog, we hear the ſnap both preceded and followed by a quivering noiſe, reſembling the ruſhing of a fluttering wind, which laſts perhaps half a ſecond. A ſlight reflection on theſe facts will ſhew that they are neceſſary reſults of the mechanical laws of ſuch obſtruction.

Several neutral points. The conſequence of this mode of action muſt be, that an imperfect conductor may have more than one neutral point, and more than one overcharged and undercharged portion, ſo that its action on diſtant bodies may be extremely various. The formula of n° 28. was accommodated to this caſe, and will be found to have very curious reſults. Another body may be placed in the direction of the axis, and will be attracted at one diſtance, repelled when this diſtance is increaſed, and again attracted when at a ſtill greater diſtance, &c. &c.

Suppoſe the obſtruction not to be conſiderable: The immediate operation of the neighbouring overcharged body will be the production of an undercharged part in the adjoining extremity, an overcharged part beyond this, an undercharged portion farther on, &c. In a little while theſe will ſhift along the conductor; one after another will diſappear at the farther end, and the body will have at laſt but one neutral point. A greater obſtruction will leave the body, finally, with more than one neutral point, and their ultimate number will be greater in proportion as the obſtruction to the fluid's motion is ſuppoſed greater.

58 Induced electricity, rendered permanent. Now, let the overcharged body, the cauſe of this unequal diſtribution, be removed. We have ſeen, n° 17. that when a body contains its natural quantity of fluid, but unequally diſtributed, there is a force acting on every particle, and tending to reſtore the original equable diſtribution; and that ſuch a force remains as long as there is any inequality in this reſpect. If, therefore, there be no obſtruction, the uniform diſtribution will take place immediately; for it is well known, that the ſpeed with which electricity is propagated is immenſe. The elaſticity, or the attractive and repulſive forces, muſt be very great indeed when compared with any that we know, except, perhaps, the force which impels the particles of light. The electricity, therefore, of a perfect conductor, that is, its power of acting on other bodies in the ſame way that an original electric acts on them, muſt be quite momentary, and ceaſe as ſoon as the inducing cauſe is removed. The conductor is electrical merely in conſequence of its poſition. Hence the propriety of our denominations. Nothing material is ſuppoſed in this theory to be communicated from the overcharged body: Nay, this theory teaches, that the ſenſible electricity of the overcharged body is augmented in ſome reſpects; for it becomes more overcharged in the part neareſt to the conductor. Indeed it becomes leſs overcharged on the other end, and will act leſs forcibly on that ſide than if the conductor were away. It may be remarked here (it ſhould have been mentioned in n° 5 .) that when F is preſented in the manner ſhewn in fig. 6. the body B becomes more ſtrongly overcharged at the end remote from A, and more ſtrongly undercharged at the end next to A, than when F is away. The contrary *may* happen, by preſenting a body in the manner of E. We wiſh theſe particulars to be kept in mind. In the mean time, all theſe circumſtances are neceſſary conſequences of the ſuppoſition, that nothing is communicated from A to B or C. The electricity induced on perfect conductors is momentary, requiring the continual preſence of a body that is electrified in ſome way or other.

But the caſe is quite otherwiſe in imperfect conductors. When the overcharged, or otherwiſe electrical body A is removed, the forces which tend to reſtore the uniform diſtribution of the fluid immediately operate, and muſt reſtore it in part. They cannot, however, do it completely: For when the force which urges any particle from an overcharged to an undercharged part, is juſt in equilibrio with the obſtruction, it will remain, juſt as a number of grains of ſmall ſhot may lie, uniformly mixed with a maſs of clammy fluid, or, as ſuch fluids retain heavy mud, in a ſtate of equable or inequable diffuſion. If the reſiſtance ariſe merely from the inertia of the tangible matter, there is no force ſo ſmall but it will in time reſtore the uniform diſtribution. But this cannot be the caſe in ſolid bodies. Their particles exert lateral forces, by which they maintain themſelves in particular ſituations: theſe muſt be overcome by *ſuperior* forces.

We ſhould therefore expect, that imperfect conductors will retain part of their inequable conſtitution; and, *in conſequence of this*, their power of affecting other bodies like electrics; that is, their Electricity. For we muſt obſerve (having neglected to do it in the beginning), that the term *electricity* is as often uſed to expreſs this power of producing electrical phenomena as it is uſed for expreſſing a ſubſtance ſuppoſed to be the original cauſe of all theſe appearances. It is neceſſary to keep this diſtinction in mind; becauſe there are many phenomena which clearly indicate the transference of this cauſe, and they muſt not be confounded with others, where the exhibition of electric phenomena is evidently propagated to a diſtance. We muſt not always ſuppoſe, that when the electric appearances are exhibited in an inſtant at the far end of a wire 4½ miles long, the ſame numerical particles of the electric fluid have moved over this ſpace. We muſt diſtinguiſh thoſe caſes where this muſt be granted from thoſe in which it certainly has not happened. Of theſe there are innumerable inſtances.

59 Imperfect conductors are neceſſarily idio-electrics.

We have now to obſerve, that by this theory the ſingle circumſtance of perfect and imperfect conducting power is ſufficient for eſtabliſhing the whole difference between idio-electrics and non-electrics. The idio-electrics are ſuſceptible of excitation in various ways, and retain their electricity; and this may be done in any part of them without affecting the reſt in any remarkable degree. This cannot be done in perfect conductors, plainly *becauſe they are perfect conductors*. Any inequality of diſtribution of the electric fluid, which is all that is neceſſary for rendering them electric, is immediately deſtroyed by its uniform diffuſion. We can have no direct proof of their incapability of excitation; but if they can be excited, they cannot ſhew it. We doubt, however, their excitability; becauſe the appearances in the excitation of electrics ſeem to indicate, that oppoſite ſtates of two bodies are neceſſary previous to the appearance of electricity. This is impoſſible in perfect conductors. By this theory, therefore, perfect conductors are neceſſarily non-electrics; and non-conductors are neceſſarily (if excitable) idio-electrics.

With reſpect to the particular phenomena which may be expected on the removal of the original electric; it may juſt be remarked, that the electric appearances of the imperfect conductor will go off in the contrary order to that of their indication. The accumulation and deficiency will diminiſh gradually, and the neutral point or points will gradually approach the end which had fronted the original electric. The imperfect conductor will be finally left with one or more neutral points, according to the magnitude of the obſtructions, and the force which had been employed in its electrification: And their final ſtate will be ſo much the more inequable, and conſequently they will retain ſo much the greater electric powers, as they are leſs perfect conductors.

60 Electrics are only ſuperficially ſo.

The laſt obſervation which we ſhall make on this head at preſent is, that whether electrified by induction, or by friction, or moſt other modes of excitation, the electrification will be nearly ſuperficial in bodies which conduct very imperfectly; and bodies which are altogether impervious (if there be any ſuch) muſt have the accumulation or deficiency altogether at their ſurface. If a glaſs globe be ſuch a body, it will hardly be poſſible to electrify it to any depth; and all that we can expect is alternate ſtrata of overcharged and undercharged glaſs. If theſe ſtrata are once formed, they tend greatly to make the body retain its ſuperficial electricity. A ſuperficial ſtratum of redundant fluid, tending, by the mutual repulſion of its particles, to eſcape, is retained by the ſtratum of redundant matter immediately below it: And the almoſt inſuperable obſtruction prevents the fluid of the ſtratum beyond this from coming up to ſupply the vacancy. If we can fall on any contrivance to produce ſuch deficient ſtrata within the glaſs, we ſhall make it much more retentive and capable of holding faſt a much greater quantity. We have already mentioned ſomething of this in n° 14. and we recommend the caſe to the attentive conſideration of the reader.

61 Compariſon of the theory with experiment.

Thus have we given a ſketch of the leading doctrines of this elegant theory of Mr Æpinus, all legitimately deduced from the circumſtances aſſumed in the hypotheſis concerning the *mechanical* properties of that ſubſtance which he calls *the electric fluid*. Let us now ſee with what ſucceſs this hypotheſis may be applied to account for the phenomena. It would have been more philoſophical to have arranged the phenomena, and from the compariſon to have deduced the hypotheſis. But this would have required much more room than can be afforded in a Work like ours.

We preſume, that many of our readers, namely, all ſuch as are already converſant with electrical phenomena and with electric experiments, have ſeen, as we went along, the perfect agreement of the hypotheſis with the various phenomena of attraction and repulſion, and all thoſe which are uſually claſſed under the name of electric atmoſpheres: and we are confident, that when they compare the conſequences that ſhould neceſſarily reſult from ſuch a fluid with the legitimate conſequences of the mechanical action of elaſtic atmoſpheres, they will acknowledge the great ſuperiority of this hypotheſis in point of ſimplicity, perſpicuity, and analogy with other general operations of nature. To ſuch readers it would not be neceſſary to ſtate any farther compariſon; but there are many who have not yet formed any diſtinct *ſyſtematic* view of the appearances called *electrical*. We do not know any way of giving ſuch a view of them as by means of this hypotheſis; and we may venture to ſay, that it will enable the ſtudent of Nature to claſs them all, with hardly a ſingle exception. After which, the hypotheſis may be thrown aſide by the faſtidious philoſopher; and the uſeful claſſification, and general laws of the electric phenomena, will remain ready foundations for a more perfect theory. For the ſake of ſuch readers, therefore, we ſhall take a ſhort review of thoſe general appearances which are accompanied by attractions and repulſions, and compare them with this Æpinian theory.

We ſhall not at preſent conſider the various modes of excitation, although this theory alſo affords much inſtruction

ſtruction on the ſubject, but confine ourſelves entirely to the facts which are moſt immediately dependent on it, and ſhould be employed to ſupport or overturn it; and we ſhall ſuppoſe the reader acquainted with moſt parts of the common apparatus; ſuch as electrometers, inſulation, &c. We alſo preſume that he knows, that when a ſmall pith-ball has been electrified by touching a piece of glaſs which has been excited by rubbing with dry flannel, it will repel another body ſo electrified; and that balls, which have received their electricity in this manner from ſealing-wax excited by the ſame rubber, alſo repel each other; but that balls, thus electrified by glaſs, attract thoſe which are electrified by ſealing-wax.

The following ſimple apparatus will ſerve for all the experiments which are neceſſary for eſtabliſhing the theory:

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1. Two ſlender glaſs rods A (fig. 8.), having a braſs ball B at the end, about a quarter of an inch in diameter, ſuſpending a very ſmall and delicate pith-ball electrometer C.

2. Some electrometers (fig. 9.), conſiſting of two pieces of ruſh pith, about four inches long, nicely ſuſpended, and hanging parallel, and almoſt in contact with each other. It is proper to have them as ſmooth as poſſible, and neatly rounded at the ends, to prevent unneceſſary diſſipation.

3. Some pith-ball electrometers (fig. 10.), whoſe threads are of ſilk, about four inches long, and ſome with flaxen threads moiſtened with a ſolution of ſome deliqueſcent ſalt, that they may be always in a good conducting ſtate.

4. Several braſs conductors (fig. 11.), each ſupported on an inſulating ſtalk and foot. They ſhould be about an inch and half or two inches long, and about three-fourths of an inch in diameter, with round ends, and well poliſhed, to prevent all diſſipation. The foot muſt be ſo narrow as to allow them to touch each other at the ends.

5. Two balls (fig. 12.), one of glaſs, and the other of glaſs coated with ſealing-wax, each furniſhed with an inſulating handle, the other end of which may be occaſionally ſtuck into a foot, or into the ſide of a block of wood, which can be ſlid up or down on a wooden pillar, and fixed at any height. Theſe balls ſhould be about three inches in diameter. They muſt be excited by rubbing with dry warm flannel.

6. Some little pieces of gilt card (fig. 13.), about two inches long, half an inch broad, and rounded at the ends, and made as ſmooth as poſſible. Each muſt have a dimple ſtruck in the middle with a poliſhed blunt point, ſo that it will traverſe freely like a mariner's needle when ſet on a glaſs point, rounded in the flame of a lamp. More artificial needles may be made of ſome light wood, having ſmall cork balls at the ends, all gilt and poliſhed, and turning, in like manner, on glaſs ſtalks: alſo ſome ſimilar needles made of ſealing-wax, one end of each being black, and the other red.

The mechanical phenomena of electricity may be expreſſed in a few ſimple propoſitions. The moſt general fact that we know, and from which all the reſt may be deduced, is the following:

If any body A is electrified, by any means whatever, and if another body B is brought into its neighbourhood, the laſt becomes electrical by poſition.

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A neutral body attracted, becauſe rendered electrical by induction.

Set the braſs conductors in a row, touching each other, as repreſented in fig. 11. by A, B, C; and let a pith-ball electrometer, having ſilk threads, be ſet near one end of the conductors. Excite one of the globes, by rubbing it with dry flannel. When this is brought near the end of the conductor, the pith-ball will approach the other end. But the globe muſt not be brought ſo near as to cauſe the pith-ball to ſtrike againſt the other end. On removing the globe, the pith-ball will move off and hang perpendicularly. The ſame effect is produced by both globes.

Thus the mere vicinity of the electric renders the conductor electric, and the electricity ceaſes on removing the globe. This is perfectly conformable to the theory, whether we ſuppoſe the fluid to be made redundant or deficient at the remote end of the conductor. If one ſhould aſcribe the approach of the pith-ball to the immediate action of the globe, it is ſufficient to obſerve, that if the ball be ſuſpended near the *ſide* of the conductor, it will approach the conductor, ſhewing that it is affected by the conductor, and not by the globe.

State of diſtribution aſcertained experimentally.

Let the globe be held in the poſition D (fig. 12), about ſix inches from the conductor, and a little above the line of its axis. Take the glaſs rod (fig. 8.), and bring its knob into contact with the under ſide of the remote end *c* of the conductor. The balls of the electrometer will ſeparate, ſhewing that they are electrified in the ſame manner, and repel each other. Slide the braſs knob along the under ſide of the conductors, quite to the end *a*. The balls will gradually collapſe as the knob approaches a point near the middle of the conductors, where they will hang parallel. Paſſing this point, they will again ſeparate, and moſt of all when the knob is at *a*. In this ſituation they will deviate toward the globe, and will be directed ſtraight toward it, if it be held too near, or in the direction of the axis. This would diſturb the experiment, and muſt be avoided. Theſe phenomena are conformable to the account given of the diſpoſition of the fluid in the conductor. The electrometer may be conſidered as making a part of the conductor; and when its threads hang parallel, it is in its natural ſtate, having its fluid of its natural denſity. This, however, cannot be ſtrictly true, according to the theory; becauſe the balls of the electrometer muſt be conſidered as more remote from the electric, and their electrical ſtate muſt correſpond to a point of the conductor more remote than that where the knob of the electrometer touches it. This will be more remarkably the caſe as the threads are longer. Accordingly, an electrometer with very long threads will never collapſe. The place of the neutral point cannot be accurately aſcertained in this way. Lord Mahon imagined that its ſituation B was determined (in his experiments with a long conductor) to be ſuch, that D *c* was harmonically divided in B and *a*; and he finds this to be agreeable to the reſult of an electric atmoſphere whoſe denſity is inverſely proportional to the ſquare of the diſtance. But we cannot deduce this from his narration of the experiment. He gives no reaſon for his ſelection of the point D, nor tells us the form and dimenſions of the electric employed, nor takes into account the action of the fluid in the long conductor. It is evident that no computation can be inſtituted, even on his Lordſhip's principles, till all this be done. We have

Lord Mahon's determination of the neutral point not warranted by his explanation.

always found that the neutral point was farther from the electric, in proportion as the conductor was ſmaller, and when the electricity was ſtronger; and that the differences in this reſpect were ſo very conſiderable, that no dependence could be had on this experiment for determining the law of action. It ſhould be ſo, both according to Lord Mahon's and Mr Æpinus's theory. But to proceed with our examination:

Having touched the end *c* of the conductor with the knob of the electrometer, bring it away. The balls will continue to repel each other, and they are attracted by any body that is in its natural ſtate. Touch the ſame end with the knob of the other electrometer, and bring it alſo away; the balls of the two electrometers will be found to repel each other: but if one has touched the conductor at *c*, and the other has touched it at *a*, the electrometers will ſtrongly attract each other. All this is quite conformable to the theory. If the fluid has been compreſſed at *c*, and therefore the balls of that electrometer are overcharged, they muſt repel each other, and repel any other body electrified in the ſame way. They muſt attract and be attracted by any natural body. But the balls of the other electrometer having touched the conductor at *a*, muſt be undercharged, and the redundant fluid of the one muſt attract the redundant matter of the other.

If the conductor has been electrified by the vicinity of excited glaſs, the electrometer which touched it in the remote end *c*, will be repelled by a piece of excited glaſs, but attracted by excited ſealing wax. The electrometer which touched the conductor in *a* will be attracted by excited glaſs, and repelled by excited ſealing-wax. The contrary will be obſerved if the conductor has had its electricity induced on it by the vicinity of the globe covered with ſealing-wax. This is a complete proof that Mr Dufuy's doctrine of *vitreous* and *reſinous* electricity is unfounded. Both kinds of electricity are produced in a conducting body, without any material communication, by mere juxta-poſition to a body poſſeſſed of either the vitreous or the reſinous electricity.

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Conſtant diſtinctions of redundancy and deficiency.

We have not yet mentioned any reaſons which indicate which end of the conductor is electrical by the redundancy of electric fluid, nor is the reader prepared for ſeeing their force. It is generally believed that the remote end of a conductor which is electrified by glaſs, excited by rubbing it with flannel or amalgamated leather, is electrical by redundancy. No difference has been obſerved in the attractions and repulſions. But there are other marks of diſtinction which are conſtant, and undoubtedly ariſe from a difference in the mode of action of thoſe of mechanical forces. If, while the excited glaſs globe remains at D, a glaſs mirror, foiled as uſual with tin-leaf, be made to touch the remote end of the conductor, and ſlowly drawn tranſverſely, ſo that the conductor draws a line as it were acroſs it—this mirror being laid down with the foiled ſide undermoſt, the duſt, which ſettles on it in the courſe of a day or two, will be chiefly collected along this line, ſomewhat in the form of the fibres of a feather. But if the conductor was rendered electrical by the globe covered with ſealing-wax, the duſt will be collected along this line in little ſpots like a row of beads. The appearances will be reverſed if the mirror has been paſſed acroſs the end of the conductor which is neareſt to the excited electric. In ſhort, in whatever way the drawing point has been electrified, if it repel a ball which has touched excited glaſs, the line will be feathered; but if it attract ſuch a ball, the line will be ſpotted. There are many ways of making this appearance much more remarkable (ſee Electricity, *Encycl.* Sect. viii. n° 48.) than this; but we have mentioned it on this occaſion, becauſe the circumſtances which occaſion the difference, whatever it is, are the moſt ſimple poſſible. Nothing is communicated; and therefore the effect muſt ariſe from the unnatural ſtate of a ſubſtance or power reſiding in the body. If it be a ſubſtance *ſui generis*, the electric action muſt ariſe from a different diſtribution of this ſubſtance; from a redundancy and deficiency of it in the different portions of the conductor. Without pretending as yet to ſay which is redundant, we ſhall ſuppoſe, with Dr Franklin, that the electricity of excited glaſs is ſo; and we ſhall uſe the words *redundant* and *poſitive* to diſtinguiſh this electricity from the other. This is merely that we may, on many occaſions, conſiderably abbreviate language.

The different electrical ſtates of the different portions of the conductor may be ſeen in another way, which is perhaps more ſimple and unexceptionable than that already narrated. While the globe remains at D, take the two extreme pieces A and C aſide; or, if only two pieces have been uſed, draw the remote piece farther away. Now remove the excited globe. When we examine A ſeparately, we ſhall find it wholly negative, or undercharged, ſtrongly repelling a ball electrified by ſealing-wax, and attracting a ball electrified by glaſs. The other piece C exhibits poſitive electricity, attracting and repelling what A repelled and attracted. If only three pieces of the conductor have been employed, the middle piece B is generally poſitive; but this in a very faint degree.

If all the pieces be again joined, they are void of electricity. If, inſtead of ſuch conductors, a row of metal balls, ſuſpended by ſilk lines, are employed, one of them may generally be found without any ſenſible electricity, when ſeparated from the reſt, having been the neutral part of the row while united.

Theſe very ſimple facts ſhew, as completely as can be wiſhed, that if the electric phenomena depend on a fluid moveable in the pores of the body, the conſtitution given it by Mr Æpinus is adequate to the explanation. We may now venture to aſſert, that every other phenomenon of attraction and repulſion will be found in exact conformity with the legitimate conſequences of this conſtitution of the electric fluid.

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In the induction of electricity nothing is communicated. Inherent powers are excited.

That nothing is communicated from the electric will appear ſtill more forcibly by the following experiment: Let a conductor be rendered electrical in the way now deſcribed, and touch either extremity of it with the little electrometer, and obſerve attentively the divergency of its threads. Now approach its remote extremity with another conducting body, ſuch as a ſingle piece of thoſe conductors, it will be rendered electrical; as may be diſcovered by a delicate electrometer. Obſerve carefully whether the electrometer in contact with the firſt conductor be affected:—it will generally be found to ſpread its threads wider. It will *certainly* be thus affected if the other conductor be very long and bulky, or touched by the hand; or if, inſtead of this ſecond conductor, we approach the firſt with the extended palm

palm of the hand. As the ſecond conductor was rendered electrical, ſo, undoubtedly, is the hand alſo: and its electrification has not deprived the firſt conductor of any of its electric power, but, on the contrary, has increaſed it. And this augmentation of its power is equally ſenſible at both ends: For an electrometer at the other end will alſo diverge more when the hand is brought near the remote end. This theory explains this in the moſt ſatisfactory manner. The firſt conductor renders the ſecond electric, by propelling its fluid to a greater diſtance. The ſecond conductor now acts on the fluid that is moveable in the firſt, and cauſes a greater accumulation in its end which is fartheſt from the electric; that is, renders it more electric.

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Suppoſe that, inſtead of employing an excited globe of glaſs, we had made uſe of a conducting body, ſlightly overcharged. Thus if we employ the conductor A, overcharged, to induce electricity on C; this will produce the ſame general effect on our ſet of conductors. But if we have previouſly examined the force of the redundant body, by ſuſpending a pith-ball near it, and obſerving its deviation from the perpendicular, we may ſometimes be led to think that it has imparted ſomething to the other body. For if the other body and the pith-ball be on oppoſite ſides of the redundant body, the pith-ball will fall a little; indicating a diminution of electric force. But this *ſhould happen* according to the theory; for it was ſhewn, in nº 52. that the conſtipation in the remote end of the overcharged body will be diminiſhed, and along with this, its action on the pith ball. We ſhould find the electricity of the other end, next the conductor, increaſed, could we find an eaſy way of examining it; but an electrometer applied there will be too much affected by the conductor.

The ſame concluſions may be drawn from the following facts: Hang up a ruſh-pith electrometer. Approach it below with a body ſlightly electrified. The legs of the electrometer immediately diverge, though attracted by the electrified body. Hold the hand above the electrometer, and they will diverge ſtill more; touch the top of it, and they ſpread yet farther. Hold the electrified body (very weakly electrified) above the electrometer, ſo that its legs may diverge a little. Hold the hand above the electrified body; the legs of the electrometer will come nearer each other.

Theſe appearances are obſerved whether the electric be poſitive or negative. We need not take up time in explaining this by the theory, its agreement is ſo obvious.

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Laſtly, on this head, if, in place of a fixed conductor, we uſe one of the needles of gilt card, ſet on its pivot, and if we then approach it with another conducting body, in the manner repreſented by E and C of fig. 6. we ſhall obſerve that end of the needle to avoid the other body; but if we bring them together, in the manner repreſented by F and B, they will attract each other. The attraction will be greater when the body F is long; and moſt of all when it communicates with the ground. Theſe phenomena are therefore in perfect conformity with the theory; but it may ſometimes happen that E will attract the end of C that is neareſt to A, and E will be electrified poſitively if A be poſitive. This ſeems inconſiſtent with the theory; and, accordingly, it has been adduced by Volta againſt Lord Mahon's account of the electrical ſtate of a conductor in a ſituation ſimilar to that of C. But the theory of Æpinus ſhews the poſſibility of this caſe. When E is very long, or when it is held in the hand, it is rendered *much more* undercharged than the adjacent part of C; and the fluid in the remoter, but not much remoter, part of C is ſtrongly attracted by the copious redundant matter in the near end of E, and is brought back again, and paſſes over into E, in the way to be deſcribed immediately The caſe is rare, and it will not happen at any conſiderable diſtance from the neutral point of C. If, indeed, E touch the near end of C before A is brought near, the approach of A will cauſe fluid to paſs into E immediately, and C will be left undercharged on the whole.

The reader, who is at all converſant with electrical experiments, will be ſenſible, that theſe experiments are delicate, requiring the greateſt dryneſs of air, and every attention to prevent the diſſipation of electricity during the performance. This, by changing the ſtate of the conductors and electrometers, will frequently occaſion irregularities. The electrometers are moſt apt to change in this reſpect, it being ſcarcely poſſible to make them perfectly ſmooth and free from ſharp angles. It may therefore happen, that when the conductors have affected them *for ſome time*, by the action of the diſturbing electric, the removal of this electric will not cauſe the electrometers to hang perpendicular; they will often be attracted by the conductors, and often repelled; but the intelligent experimenter, aware of theſe circumſtances, will know what allowances to make.

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Phenomena
of imperfect conductors
greatly corroborate
the theory.

The theory obtains a ſtill more complete ſupport from a compariſon with ſimilar experiments made with imperfect conductors. If, in place of the ſeries A, B, C, of metalline conductors, we employ cylinders of glaſs or ſealing wax, or even dry wood or marble, and electrometers with ſilk threads in place of the ruſh-pith electrometers, we ſhall find all the appearances to be ſuch as the theory enables us to predict. If, for example, we uſe a ſingle cylinder A of glaſs, we ſhall find that the neighbourhood of the electric D ſcarcely induces any electricity on A. The electrometer will hardly exhibit the ſmalleſt attraction, and its motions will be almoſt entirely ſuch as ariſe from the immediate influence of the electric body D. A cylinder of very dry wood will be more affected by the electric D; and a circumſtance of theoretical importance is very diſtinctly obſerved, namely, the gradual ſhifting of the neutral point. It will be found to advance along the cylinder for a very long while, when every circumſtance is very favourable, the air very dry, and the wood almoſt a nonconductor; and its final ſituation will be found much nearer to the electric than in the braſs conductor. Several inſtructive experiments of this kind may be found in a treatiſe publiſhed in 1783 by Dr Thomas Milner at Maidſtone in Kent, entitled, "Experiments and Obſervations on Electricity." The author does not profeſs to advance any new doctrines, but only to exhibit experiments ſcientifically arranged for forming a ſyſtem. He ſupports the Franklinian ſyſtem as it was generally underſtood at that time; but is much embarraſſed for the explanation of the repulſion of negative electrics. The Æpinian correction of this theory did not offer itſelf to his mind.

68
Irregularities.

We need not go over the ſame ground again with imperfect conductors. It is well known that ſuch bodies

dies are more weakly attracted and repelled; that the balls of an electrometer with linen threads diverge vaſtly more when an electrified body is held below it, than if the threads are ſilken: that ſuch electrometers frequently exhibit very capricious appearances from the ſlow but real progreſs of the electricity along the threads. Theſe anomalies will be better underſtood when we explain the diſſipation of electricity along imperfect conductors.

69 Induced electricity of imperfect conductors is really permanent.

A very eſſential deduction from the theory is, that the electricity induced on an imperfect conductor muſt have ſome permanency. This is fully confirmed by experiment. But the remarkable inſtances of this particular cannot be produced till we be better acquainted with the methods of producing great accumulations of fluid. It is enough to obſerve at preſent, that a permanent electricity may always be obſerved at the junction of the conductors with their inſulating ſtalks. The braſs conductor A ceaſes to be electric as ſoon as the excited globe is removed; but the very top of the glaſs ſtalk on which it is ſupported will ſenſibly affect a delicate electrometer for a long while after. The following pretty experiment ſhews this permanency very diſtinctly. Set one of the ſealing-wax needles on its pivot, and place it between two inſulated metal ſpheres of conſiderable ſize, at ſuch a diſtance from both as not to receive a ſpark. Electrify theſe balls moderately, one of them poſitively, and the other negatively, and keep them thus electrified for ſome hours by renewing their electrification. The needle quickly arranges itſelf in the line adjoining the two ſpheres, juſt as a magnetic needle will do when placed between two magnets whoſe diſſimilar poles front each other. Any gentle force will derange the needle; but it will vibrate like a magnetic needle, and finally ſettle in its former poſition. When this has been continued ſome time, that end of the needle which pointed to the poſitive globe will be found negative, and the other will be found poſitive, if examined with an electroſcope. And now, if the two globes be removed, this little needle will remain electrical for entire days in dry froſty weather, and its ends will approach any body that is brought near it (taking care not to come too cloſe); and the end which pointed to the poſitive globe will avoid a piece of rubbed ſealing wax, but will approach a piece of rubbed glaſs; but the other end will be affected in the oppoſite way. In ſhort, it proves an electric needle with a poſitive and negative pole.

If two ſmall inſulated balls are moderately electrified, and placed about ſix inches aſunder, this needle, when carried round them, will arrange itſelf exactly as a magnetic needle does when carried round a magnet of the ſame length. If the ſame trial be made with the needle of gilt card, it will arrange itſelf in the ſame manner that a ſoft iron needle arranges itſelf near a magnet, but either end will turn indifferently to either globe.

Electrical meridians.

If a thin glaſs plate, coated with red ſealing wax, be ſet on the poſitive and negative globes, and we ſprinkle (from a conſiderable height) a fine powder of black ſealing wax, and then pat the plate gently with a glaſs rod ſo as to agitate it a little, the particles of wax powder will gradually arrange themſelves into curve lines, diverging from the point over one of the globes, and converging to the point over the other, preciſely like the curves formed by iron-filings ſprinkled on a paper held over a magnet. Each little rag of wax becomes electrical by poſition, acquires two poles, and the poſitive pole of one attracts the negative pole of another; and they adhere in a certain determinate poſition, nearly a tangent to the curve, which was mentioned in n° 50, and indicates the law of magnetic action. When in this ſtate, if a hot brick be held over the plate till the wax ſoften a little, the particles of black wax will adhere to the red coating, and give us a permanent ſpecimen of the action.

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It is well known that liquid ſealing wax is a conductor. The writer of this article filled a glaſs tube with powdered ſealing wax, and melted it, and then expoſed it, in its melted ſtate, to the influence of a poſitive and a negative globe, hoping to make a powerful and permanent electric needle, which ſhould have two poles, and exhibit a ſet of phenomena reſembling thoſe of magnetiſm. Accordingly he, in ſome meaſure, ſucceeded, by keeping the globes continually electrified for ſeveral hours, till the wax was quite cold. It had two diſtinct poles, and preſerved this property, *even though plunged in water, and while immerſed in the water;* but he was greatly diſappointed as to the degree of its electricity. It juſt affected a ſenſible electrometer at the diſtance of ſix inches from either pole. It was conſiderably ſtronger than if it had not been melted during the impregnation, but by no means in the degree that he expected. It retained ſome electricity for about ſix weeks, although lying neglected among conducting bodies. After its power ſeemed quite extinct, he was melting it again in order to renew it. Some light fibrous things chanced to be near it. While it was ſoftening, it became very ſenſibly electrical, cauſing theſe fibres to bend towards it, and even to cling to the tube. We ſhall ſee by and bye, that he was miſtaken in expecting more remarkable appearances, and that the theory, when properly applied, does not promiſe them. Having thus eſtabliſhed (as we think) this theory on ſufficient foundations for making it a very perſpicuous way of explaining the phenomena of induced electricity, we proceed to compare it with the ſecond general fact in electricity.

71 Electricit by comm nication

Prop. II. When an inſulated body B is brought very near an electrified body A, a ſpark is obſerved to paſs between them, accompanied with a noiſe (which we ſhall call the electric Snap), and B is now electrified permanently, and the electricity of A is diminiſhed.

Although this be one of the moſt familiar facts in electricity, it will be proper to conſider its attending circumſtances in a way that connects it with what we have now learned concerning electricity by poſition.

Let the inſulated body A (fig. 14.) be furniſhed with a cork-ball, hanging by a ſilk thread from a glaſs ſtalk connected with A; let B be fitted up in the ſame manner; let A be electrified weakly, and its degree of electricity be eſtimated by the inclination of the ball *towards* A: ſince B is not electrified, its electrometer will hang perpendicular; but when it approaches A (keeping the electrometers on the remote ſides of both), its electrometer will approach it, and the electrometer of A will gradually approach the perpendicular. When the bodies are brought very near, a ſpark is ſeen between them; and, at that inſtant, the electrometer of B comes

B comes much nearer to it, and that of A drops farther from it. If they be now ſeparated, their electrometers will retain their new poſitions with very little change, and B will now manifeſt the ſame kind of electricity with A.

Such is the appearance when A has been but weakly electrified. Bringing B near A, the fluid in B is drawn to the remote ſide, if A be overcharged, or drawn to the ſide neareſt to A, if A has been undercharged. B acts on its electrometer in conſequence of the change made in the diſpoſition of its fluid. The electrometer is attracted. In the mean time, the change made in the diſpoſition of the fluid in B affects the moveable fluid in A. If A was overcharged, the adjacent ſide of B becomes undercharged, and its redundant matter, attracting the fluid in A, condenſes it in the adjacent ſide, abſtracting part of the redundant fluid from that ſide which is next to the pith-ball. Then the joint action of the whole redundant fluid in A on the pith-ball is diminiſhed.

ſt hap- abrupt-

As there is now an attraction in the redundant fluid in A for the redundant matter on the adjacent ſide of B, it is reaſonable to ſuppoſe that when this attraction, joined to the repulſion of the redundant fluid behind it, is able to overcome the attraction which connects it with the ſuperficial particles of the matter, it will then eſcape and fly into B: but this will not happen gradually, but at once, as ſoon as the expelling force has ariſen to a very conſiderable intenſity. We cannot ſay what is the preciſe augmentation that is neceſſary; but we can clearly ſee, that however great the attraction for the adjoining particles may be, while the particle is ſurrounded by them on *all* ſides, it will yield to the ſmalleſt inequality of force, becauſe the particles before it attract as much as thoſe behind it; but when it is juſt about to quit the laſt or ſuperficial particles of A, a much greater force is now neceſſary. It can be ſtrictly demonſtrated, that when the mutual tendency is inverſely as the ſquare of the diſtance, the action of a particle placed immediately without a ſphere of ſuch matter is double of its action when ſituated in the very ſurface *. A *ſaltus* of this kind muſt obtain whatever be the law of electric attraction. We ſhall ſee other cauſes alſo which ſhould prevent the eſcape of redundant fluid, and alſo its admiſſion, till the impelling force is encreaſed in a certain abrupt degree.

72. These obſervations muſt ſuffice at preſent to explain the deſultory nature of this tranference, if there be really a transference. That this has happened, may be confidently inferred from the ſudden diminution of the electricity of A, indicated by the ſudden fall of its electrometer; but it is more expreſsly eſtabliſhed, that there has been a transference by the change produced on B. It is now permanently electrified, and its electricity is of the ſame kind with that of A, poſitive or negative according as A is poſitive or negative. And now we are enabled to explain the third general fact in electricity.

73 arted tricity duces ual re ion.

PROP. III. When a body has imparted electricity to another, it conſtantly repels it, unleſs that other has afterwards imparted all its electricity to other bodies. This fact, from which there is no exception, is an immediate conſequence of the theory. Before the transference ſuppoſed by it, B was in its natural ſtate; after the transference, both bodies contain redundant fluid, or redundant matter; therefore they muſt mutually repel.

We may now take another form of the experiment, which will be much more convincing and inſtructive. Let A be electrified poſitively, or by redundancy, and let its electrometer be attached to it by a conducting ſtalk, and have a flaxen thread; let this be the caſe alſo with the electrometer of B; then the appearances ſhould happen in the following order: When A is made to approach B, the electrometer of B muſt gradually riſe, diverging *from* B; becauſe the fluid condenſed on the ſide remote from A, and in the electrometer, will act more ſtrongly on it than the deſerted matter on the other ſide of B; and when the ſudden transference is made, and B is wholly overcharged, its electrometer will immediately riſe much higher, and muſt remain at that height, nearly, when A is removed. On the other hand, the electrometer attached to the remote ſide of A muſt deſcend, by reaſon of the change made in the diſpoſition of the fluid in A by the induced electrical ſtate of B: and when a conſiderable portion of the redundant fluid in A paſſes into B, the electrometer of A muſt ſudenly ſink much lower, and remain in that ſtate when B is removed.

Transference of a peculiar ſubſtance highly probable.

Many circumſtances of this phenomenon corroborate our belief of a real transference of matter. The cauſe of electric action reſided formerly in A alone; it now reſides alſo in B. The larger that B is, the greater is the diminution of A's electric power, and the ſmaller is the power acquired by B. It perfectly reſembles, in this reſpect, the communication of ſaltneſs, ſweetneſs, &c. by mixing a ſolution of ſalt or ſugar with different quantities of water; and the evidence of a transference of a ſubſtance, the cauſe of electric attractions and repulſions, is at leaſt as cogent as the evidence of the transference of heat, when we mix hot water with a quantity of cold, or when a hot ſolid body is applied to the ſide of a cold one. We alſo ſee ſo many chemical and other changes produced by this communication of electricity, that we can hardly refuſe admitting that *ſome material ſubſtance* paſſes from one body to another, and, in its new ſituation, exerts its attractions and repulſions, and produces all their effects.

We may deduce the following corollaries; all of which are exactly conformable to the phenomena, ſerving ſtill more to confirm the juſtneſs of the theory.

74 Degrees of vivacity proportioned to the quantity imparted.

1. A certain quantity of what poſſeſſes theſe powers of attraction and repulſion is neceſſary for giving a determined vivacity to the appearances. Another ſpark muſt paſs between the bodies, *only if they be brought ſtill nearer*, and their electrometers muſt riſe and fall ſtill farther. For by the firſt transference of electric fluid into B, the expelling power of A is diminiſhed, and the ſuperior attraction of the redundant matter in the adjacent ſide of B is alſo counteracted by the repulſion of the fluid which has entered into it; therefore no more will follow unleſs theſe forces be encreaſed, at leaſt to their former degree. When this addition has been made to B, and this abſtraction from A, their reſpective electrometers muſt be affected. All this is in perfect conformity to experience.

75 Communication moſt remarkable in conductors.

2. All the phenomena of communicated electricity muſt be more remarkable in proportion to the conducting power of the bodies. A very imperfect conductor,

puſcles Alem- , t. 1.

ductor, ſuch as glaſs or ſealing wax, will impart or receive fluid only between the very neareſt parts; whereas a metalline body is inſtantly affected through its whole extent. This deduction is perfectly agreeable to the whole train of electric experiments. The finger receives a ſtrong ſpark from a large metalline electrified body, which diſcharges *every part of it* of a portion of its electricity. But an excited globe, which ſhews, by its action on a diſtant body, as great a degree of electricity, will give only a very ſmall ſpark; and it is found not to be affected at any conſiderable diſtance from the point of its ſurface from which the transference was made. The whole electricity of a perfect conductor is diſcharged by touching it; but a non-conductor will ſucceſſively give ſparks, if touched in many different parts; and it may be ſeen by a nice electrometer, that each contact takes away the electricity only from a very ſmall ſpace round it: and it is further highly deſerving of notice, that ſome time after a ſpark has been obtained from a particular ſpot of the electric, a ſecond ſpark may be obtained from it, the electricity of the neighbouring parts having been gradually diffuſed through it.

76 Inſulation neceſſary for electric appearances.

3. If an electrified conducting body touch any thing communicating with the ground by perfect conductors, all its electricity muſt diſappear, and none can appear in the body touched by it; for the maſs of the earth bears ſuch an unmeaſurable proportion to that of the greateſt body that we can electrify, that when the redundancy or deficiency is divided between them, it muſt be imperceptible in both.

77. Hence the neceſſity of *inſulation*, as it is called, or the ſurrounding by non-conductors every body which we would have exhibit electric appearances. We muſt refer the reader to the article Electricity in the *Encycl.* for all the obſervations on this head, and the reaſons of preference given to certain ſubſtances to be employed for inſulating ſupports. But we muſt conſider, in its proper place, the manner in which the electric fluid is diſſipated by imperfectly inſulating ſubſtances; a ſubject intimately connected with the theory.

78 An electrified body attracts and then repels any unelectrified body.

4. Any unelectrified body will be firſt attracted by an electrified body, will touch it, and will then be repelled. The neutral body is rendered electrical by induction. It is, *in conſequence of this*, attracted, comes near enough to receive a ſpark, or even touches it, and is then electrified by communication; and, *in conſequence of this*, it is repelled. This is confirmed by an endleſs train of experiments. It was firſt taken notice of (we think) by Sir Iſaac Newton. Otho Guericke, a gentleman of Magdeburgh, to whom we owe the air pump, mentions many inſtances of the repulſion, but did not obſerve that it was an univerſal law. Newton was ſo ſtruck with it as to engage in a conſiderable train of experiments in the early part of his life, while meditating on the power of gravity; but even his ſagacious mind did not obſerve the whole proceſs of nature in his experiments. He obſerved, that the light bodies which roſe and adhered to the rubbed plate of glaſs were ſoon after repelled by it; but did not obſerve that the ſame piece would again riſe to the glaſs after it had touched the table. This fact is now the foundation of many experiments, which the itinerant electricians vie with each other in rendering very amuſing. We may render them inſtructive. Take away the middle conductor B (fig. 11.), and hang in its place a cork ball by a long ſilk thread. As ſoon as the electric body D is brought near to A, the ball is attracted by its remote end, comes into contact, is repelled by it, and attracted by the adjacent end of C, touches it, is faintly repelled by it, and again attracted by A; and the operation is repeated ſeveral times. When all has ceaſed, remove C, and alſo the electric D. C is found to have the ſame electricity with D, and A has the oppoſite electricity. The proceſs is too obvious to need any detailed application of the theory. The cork ball was the carrier of fluid from A to C if D was electric by redundancy, or from C to A if D was undercharged. If inſtead of removing C when the vibrations of the ball have ceaſed, we bring D a little nearer, they will be renewed, and after ſome time will again ceaſe. The reaſon is plain. The carrier ball had brought the conductor A into a ſtate of equilibrium with the action of D. But this action is now increaſed, and the effects are renewed. If we now remove D, the ball will vibrate between A and C with great rapidity for a conſiderable time before the vibrations come to an end; and we ſhall find their number to be the ſame as before. The cauſe of this is alſo obvious from the theory. We may ſuppoſe A to be negative, and C poſitive. One of them will attract the ball into contact, and will repel it, having put it into an electric ſtate oppoſite to that of the other conductor. It now becomes a carrier of fluid from the poſitive to the negative conductor, till it nearly reſtore both to their primitive ſtate of neutrality.

79 Irregularities frequent—Why.

There is frequently a ſeeming capricioufneſs in thoſe attractions and repulſions. A pith ball, or a down feather, hung by ſilk, will cling to the conductor, or otherwiſe electrified body, and will not fly off again, at leaſt for a long while. This only happens when thoſe bodies are ſo dry as to be almoſt non-conductors. They acquire a poſitive and negative pole, like an iron nail adhering to a magnet, and are not repelled till they become almoſt wholly poſitive or negative. It never happens with conducting light bodies.

80 Electric a tion, like gravitati is not hi red by the inter ofition non-conductors.

5. It ſhould follow from the theory, that the electric attractions and repulſions will not be prevented by the intervention of non-conducting ſubſtances in their neutral ſtate. Accordingly, it is a fact, that the interpoſition of a thin pane of glaſs, let it be ever ſo extenſive, does not hinder the electrometer from being affected. Alſo, if an inſulated electric be covered with a glaſs bell, an electrometer on the outſide will be affected. Nay, a metal ball, covered to any thickneſs with ſealing wax, when electrified, will affect an electrometer in the ſame way as when naked. We cannot ſee how theſe facts can be explained by the action of electric atmoſpheres. It is indeed ſaid, that the atmoſphere on one ſide of the glaſs produces an atmoſphere on the other; but we have no explanation of this production. If the interpoſed plate be a non-conductor, how does the one atmoſphere produce the other? It muſt produce this effect by acting at a diſtance on the particles which are to form this atmoſphere. Of what uſe, then, is the atmoſphere, even if thoſe atmoſpheres could effect the obſerved motions of the electrometer in conſiſtency with the laws of mechanics? The atmoſpheres only ſubſtitute millions of attractions or repulſions in place of one. We muſt obſerve, however, that the motions of

of the electrometer are modified, and ſometimes greatly changed, by the interpoſed non-conducting plate; but this is owing to the electricity induced on the plate. If the electric is poſitive, the adjacent ſurface of the plate becomes faintly negative, and the ſide next the electrometer ſlightly poſitive. This affects the electrometer even more than the more remote electric does. That this is the cauſe of the difference between the ſtate of the electrometer when the plate is there and when it is removed, will appear plainly by breathing gently on the glaſs plate to damp it, and give it a ſmall conducting power. This will make ſome change in the poſition of the electrometer. Continue this more and more, till the plate will no longer inſulate. The changes produced on the electrometer's poſition will form a regular ſeries, till it is ſeen to aſſume the very poſition which it would have taken had the plate been braſs. Then, conſidering thoſe changes in a contrary order, and ſuppoſing the ſeries continued a little farther, we ſhall always find that it leads to the poſition which it would have taken when no plate whatever is interpoſed. We conſider this as an important fact, ſhewing that the electric action is ſimilar to gravitation, and that there is no more occaſion for the intervention of an atmoſphere for explaining the phenomena of electricity than for explaining thoſe of gravitation.

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6. Since non-electrics are conductors, and ſince electrics may be excited by friction with a non-electric, it follows, that if this non-electric be inſulated, and ſeparated from the electric, it will exhibit ſigns of electricity; but when they are together, there muſt not appear any marks of it, however ſtrong the excitation may be. We do not pretend to comprehend diſtinctly the manner in which friction, or the other modes of excitation, operate in changing the connection between the particles of the fluid and thoſe of the tangible matter; nor is this explained in any electric theory that we know: but if we are ſatisfied with the evidences which we have for the exiſtence of a ſubſtance, whoſe preſence or abſence is the cauſe of the electric phenomena, we muſt grant that its uſual connection with the tangible matter of bodies is changed in the act of excitation, by friction, or by any other means. In the caſe of friction producing poſitive electricity on the ſurface of the electric, we muſt ſuppoſe that the act of friction cauſes one body to emit or abſorb the fluid more copiouſly than the other, or perhaps the one to emit and the other to abſorb. Whichever is the caſe, the adjoining ſurfaces muſt be in oppoſite ſtates, and the one muſt be as much overcharged as the other is undercharged. When the bodies (which we may ſuppoſe to have the form of plates) are joined, and the one exactly covers the other, the aſſemblage muſt be inactive; for a particle of moveable fluid, ſituated anywhere on the ſide of the overcharged plate, will be as much attracted by the undercharged ſurface of the remote plate as it is repelled by the overcharged ſurface of the near plate. The ſurfaces are equal, and equally electric, and act on either ſide with equal intenſity; and they are coincident. Therefore their actions balance. The action is expreſſed by the formula of n° 43; namely, $F' m' \times \overline{z - z'}$; and $z - z'$ is $= 0$, by reaſon of the equal diſtances of theſe ſurfaces from the particle of exterior fluid.

But let the plates be ſeparated. Part, and probably the greateſt part, of the redundant fluid on one of the rubbed ſurfaces will fly back to the other, being urged both by the attraction of the redundant matter and the repulſion of its own particles. But the electric, being electric becauſe, and only becauſe, it is a non-conductor, muſt retain ſome, or will remain deprived of ſome, in a ſtratum a little within the ſurface. The two plates muſt therefore be left in oppoſite ſtates, and the conducting, or non electric plate, if inſulated before ſeparation, muſt now exhibit electric action.

All this is exactly agreeable to fact. We alſo know that electrics may be excited by rubbing on each other; and if of equal extent, and equally rubbed, they exhibit no electric powers while joined together; but when parted, they are always in oppoſite ſtates. The ſame thing happens when ſulphur is melted in a metal diſh, or when Newton's metal is melted in a glaſs diſh. While joined, they are moſt perfectly neutral; but manifeſt very ſtrong oppoſite electricities when they are ſeparated. This completely diſappears when they are joined again, and reappears on their ſeparation, even after being kept for months or years in favourable circumſtances. We have obſerved the plates of talc, and other laminated foſſils, exhibit very vivid electricity when ſplit aſunder.

82
Principles of the conſtruction of electric machines.

Attention to theſe particulars enables us to conſtruct machines for quickly exciting vivid electricity on the ſurface of bodies, and for afterwards exhibiting it with continued diſpatch. The whirling globe, cylinder, or plate, firſt employed by Mr Haukſbee, for the ſolitary purpoſe of examining the electricity of the globe, was moſt ingeniouſly converted by Hauſen, a German profeſſor, into a rapid collector and diſpenſer of electricity to other bodies, by placing an inſulated prime conductor cloſe to that part of the ſurface of the globe which had been excited by friction. Did our limits give us room, we ſhould gladly enlarge on this ſubject, which is full of moſt curious particulars, highly meriting the attention of the philoſopher: But it might eaſily occupy a whole volume; and we have ſtill before us the moſt intereſting parts of the mechanical department of electricity, and ſhall hardly find room for what is eſſentially requiſite for a clear and uſeful comprehenſion of it. We muſt therefore requeſt our readers to have recourſe to the original authors, who have conſidered the excitation by friction minutely. And we particularly recommend the very careful peruſal of Beccaria's Diſſertations on it, comparing the phenomena, in every ſtep, with this theory of Æpinus. Much valuable information is alſo obtained from Mr Nicholſon's Obſervations, of which an abſtract is given in the article ELECTRICITY in the *Encyclopædia Britannica*. The Æpinian theory will be found to connect many things, which, to an ordinary reader, muſt appear ſolitary and accidental.

83
Evidences of the materiality of the electric fluid.

Seeing that this very ſimple hypotheſis of Æpinus ſo perfectly coincides in its legitimate conſequences with all the general phenomena of attraction and repulſion, and not only with thoſe that are ſimple, but even ſuch as are compounded of many others—we may liſten, without the imputation of levity, to the other evidences which may be offered for the materiality and mobility of the cauſe of thoſe mechanical phenomena. Such evidences are very numerous, and very perſuaſive. We have ſaid that the tranſference of electricity is deſultory, and that the change made in the electric ſtate of the communicating bodies is always conſiderable. It appears to keep ſome ſettled ratio to the whole electric power of the body. When the form of the parts where the communication takes place, and other circumſtances, remain the ſame, the transference increaſes with the ſize of the bodies; and all the phenomena are more vivid in proportion. When the conductor is very large, the ſpark is very bright, and the ſnap very loud.

Snap,

1. This ſnap alone indicates ſome material agent. It is occaſioned by a ſonorous undulation of the air, or of ſome elaſtic fluid, which ſuddenly expands, and as ſuddenly collapſes again. But ſuch is the rapidity of the undulation, that when it is made in cloſe veſſels it does not exiſt long enough, in a very expanded ſtate, to affect the column of water, ſupported in a tube by the elaſticity of the air, for the purpoſe of a delicate thermometer or barometer; juſt as a muſket ball will paſs through a looſe hanging ſheet of paper without cauſing any ſenſible agitation.

Spark, and heat.

2. The ſpark is accompanied by intenſe heat, which will kindle inflammable bodies, will melt, explode, and calcine metals.

Chemical effects.

3. The ſpark produces ſome very remarkable chemical effects. It calcines metals even under water or oil; it renders Bolognan phoſphorus luminous: It decompoſes water, and makes new compoſitions and decompoſitions of many gaziform fluids; it affects vegetable colours; it blackens the calces of biſmuth, lead, tin, luna cornea; it communicates a very peculiar ſmell to the air of a room, which is diſtinct from all others; and in the calcination of metals, it changes remarkably the ſmells with which this operation is uſually accompanied: it affects the tongue with an acidulous taſte; it agitates the nervous ſyſtem.—When we compare theſe appearances with ſimilar chemical and phyſiological phenomena, which naturaliſts never heſitate in aſcribing to the action of material ſubſtances, transferable from one body, or one ſtate of combination, to another, we can ſee no greater reaſon for heſitating in aſcribing the electric phenomena to the action of a material ſubſtance; which we may call *a fluid*, on account of its connected mobility, and *the electric fluid*, on account of its diſtinguiſhing effects. We are well aware, that theſe evidences do not amount to demonſtration; and that it is poſſible that the electric phenomena, as well as many chemical changes, may reſult from the mere difference of arrangement, or poſition, of the ultimate particles of bodies, and may be conſidered as the reſult of a change of modes, and not of things. But in the inſtances we have mentioned, this is extremely improbable.

This is therefore aſſumed.

We therefore venture to aſſume the exiſtence of this ſubſtance, which philoſophers have called *the electric fluid*, as a propoſition abundantly demonſtrated; and to affirm, on the authority of all the above-mentioned facts, that its mechanical character is ſuch as is expreſſed in Mr Æpinus's hypotheſis.

We proceed, therefore, to explain the moſt intereſting phenomena of electricity from theſe principles.

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Diſtribution of it depends on its law of action.

We have ſeen that, in a perfect conductor, in its natural ſtate, the electric fluid is uniformly diſtributed, and cannot remain in any other condition. We are particularly intereſted to know how it is diſtributed in an overcharged or undercharged body, and how this is affected by the circumambient non-conducting air. It is evident that much depends on this. The tendency to eſcape, and particularly the tendency to transference from one body to another, muſt be greateſt where the fluid is moſt conſtipated. We know that it tends remarkably to diſſipate from all protuberances, edges, and long bodies, and that it is impoſſible to confine it in a body having very acute far-projecting points; and, what is more paradoxical, it is hardly poſſible to prevent its entering into a body furniſhed with a ſharp point. The ſmalleſt reflection muſt ſuggeſt to our imagination, that a perfectly moveable fluid, whoſe particles mutually repel, even at conſiderable diſtances, and which is confined in a veſſel from which it cannot eſcape, muſt be compreſſed againſt the ſides of the veſſel, and be denſer there than in the middle of the veſſel. But in what proportion its denſity will diminiſh as we recede from the walls of the veſſel, muſt depend on the change of electric repulſion by an increaſe of diſtance. The intenſity varies in the proportion of ſome function of the diſtance, and may be expreſſed by the ordinates of a curve, on whoſe axis the diſtances are meaſured. But we are ignorant of this function. We muſt therefore endeavour to diſcover it, by obſerving a proper ſolution of phenomena. Having made ſome approximation to this diſcovery, ſuch as ſhall give riſe to a *probable conjecture* concerning the function which expreſſes the intenſity of electric repulſion, mathematics will then enable us to ſay how the fluid muſt be diſtributed (at leaſt in ſome ſimple and inſtructive caſes) in a perfectly conducting body ſurrounded by the air, and what will be its action on another body. Thus we ſhall obtain oſtenſible reſults, which we can compare with experiments. The writer of this article made many experiments with this view above 30 years ago, and flatters himſelf that he has not been unſucceſsful in his attempts. Theſe were conducted in the moſt obvious and ſimple manner, ſuggeſted by the reaſonings of Mr Æpinus; and it was with ſingular pleaſure that, ſome years after, he peruſed the excellent diſſertation of Mr Cavendiſh in the Philoſophical Tranſactions, vol. 61. where he obtained a much fuller conviction of the truth of the concluſion which he had drawn, in a ruder way, from more familiar appearances. Mr Cavendiſh has, with ſingular ſagacity and addreſs, employed his mathematical knowledge in a way that opened the road to a much farther and more ſcientific proſecution of the diſcovery, if it can be called by that name. After this, Mr Coulomb, a diſtinguiſhed member of the French Academy of Sciences, engaged in the ſame reſearch in a way ſtill more refined; and ſupported his concluſions by ſome of the moſt valuable experiments that have been offered to the public. We ſhall now give a very brief account of this argument: and have premiſed theſe hiſtorical remarks; becauſe the writer, although he had eſtabliſhed the general concluſion, and had read an account of his inveſtigation in a public ſociety in 1769, in which it was applied to the moſt remarkable facts then known in electricity, has no claim to the more elaborate proofs of the ſame doctrine, which is given in ſome of the following paragraphs. Theſe are but an application of Mr Cavendiſh's more cautious and general mathematical procedure, to the function which the writer apprehends to be ſufficiently eſtabliſhed by obſervation.

Proceſs for diſcovering this law.

The moſt unexceptionable experiments with which we can begin, ſeem to be the repulſions obſervable between

tween two *ſmall* ſpheres. Whatever be the law of diſtribution of the particles in a ſphere, the general action of its particles on the particles of another ſphere will follow a law which will not differ much from the law of action between two particles, if the diameters of the ſpheres be ſmall in proportion to their diſtance from each other. The inveſtigation was therefore begun with them. But the ſubject required an electrometer ſuſceptible of compariſon with others, and that could exhibit abſolute meaſures. The one employed was made in the following manner; and we give it to the public as a valuable philoſophical inſtrument.

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Comparable electrometer.

Fig 15. repreſents the electrometer in front. A is a poliſhed braſs ball, $\frac{1}{4}$th of an inch in diameter. It is fixed on the point of a needle three inches long, as ſlender as can be had of that length. The other end of the needle paſſes through a ball of amber or glaſs, or other firm non-conducting ſubſtance, about half or three-fourths of an inch in diameter; but the end muſt not reach quite to the ſurface, although the ball is completely perforated. From this ball riſes a ſlender glaſs rod FEL, three inches long from F to E, where it bends at right angles, and is continued on to L, immediately over the centre of the ball A. At L is fixed a piece of amber C, formed into two parallel cheeks, between which hangs the ſtalk DCB of the electrometer. This is formed by dipping a ſtrong and dry ſilk thread, or fine cord in melted ſealing-wax, and holding it perpendicular till it remain covered with a thin coating, and be fully penetrated by it. It muſt be kept extended, that it may be very ſtraight; and it muſt be rendered ſmooth, by holding it before a clear fire. This ſtalk is faſtened into a ſmall cube of amber, perforated on purpoſe, and having fine holes drilled in two of its oppoſite ſides. The cheeks of the piece C are wide enough to allow this cube to move freely between them, round two fine pins, which are thruſt thro' the holes in the cheeks, and reach about half way to the ſtalk. The lower part of the ſtalk is about three inches long, and terminates in a gilt and burniſhed cork-ball (or made of thin metal), a quarter of an inch in diameter. The upper part CD is of the ſame length, and paſſes through (with ſome friction) a ſmall cork-ball. This part of the inſtrument is ſo proportioned, that when FE is perpendicular to the horizon, and DCB hangs freely, the balls B and A juſt touch each other. Fig. 16. gives a ſide perſpective view of the inſtrument. The ball F is fixed on the end of the glaſs rod FI, which paſſes perpendicularly through the centre of a graduated circle GHO, and has a knob handle of boxwood on the farther end I. This glaſs rod turns ſtiffly, but ſmoothly, in the head of the pillar HK, &c. and has an index NH, which turns round it. This index is ſet parallel to the line LA, drawn through the centre of the fixed ball of the electrometer. The circle is divided into 360 degrees, and 0 is placed uppermoſt, and 90 on the right hand. Thus the index will point out the angle which LA makes with the vertical. It will be convenient to have another index, turning ſtiffly on the ſame axis, and extending a good way beyond the circle.

This inſtrument is uſed in the following manner: A connection is made with the body whoſe electricity is to be examined, by ſticking the point of the connecting wire into the hole at F, till it touch the end of the needle; or, if we would merely electrify the balls A and B, and then leave them inſulated, we have only to touch one of them with an electrified body. Now, take hold of the handle I, and turn it to the right till the index reach 90. In this poſition, the line LA is horizontal, and ſo is CB; and the moveable ball B is reſting on A, and is carried by it. Now electrify the balls, and gently turn the handle backwards, bringing the index back toward 0, &c. noticing carefully the two balls. It will happen that, in ſome particular poſition of the index, they will be obſerved to ſeparate. Bring them together again, and again cauſe them to ſeparate, till the exact poſition at ſeparation is aſcertained. This will ſhew their repulſive force in contact, or at the diſtance of their centres, equal to the ſum of their radii. Having determined this point, turn the inſtrument ſtill more toward the vertical poſition. The balls will now ſeparate more and more. Let an aſſiſtant turn the long index ſo as to make it parallel to the ſtalk of the electrometer, by making the one hide the other from his view. The mathematical reader will ſee that this electrometer has the properties aſcribed to it. It will give abſolute meaſures: for by poizing the ſtalk, by laying ſome grains weight on the cork-ball D, till it becomes horizontal and perfectly balanced, and computing for the proportional lengths of BC and DC, we know exactly the number of grains with which the balls muſt repel each other (when the ſtalk is in a horizontal poſition), in order *merely to ſeparate*. Then a very ſimple computation will tell us the grains of repulſion when they ſeparate in any oblique poſition of the ſtalk; and another computation, by the reſolution of forces, will ſhew us the repulſion exerted between them when AL is oblique, and BC makes any given angle with it. All this is too obvious to need any farther explanation. The reaſon for giving the connection between A and C ſuch a circuitous form, was to avoid all action between the fixed and the moveable part of the electrometer, except what is exerted between the two balls A and B. The needle AF, indeed, may act a little, and might have been avoided, by making the horizontal axis FI to join with A: but as it was wanted to make the inſtrument of more general uſe, and frequently to connect it with an electrical machine, a battery, or a large body, no mode of connection offered itſelf which would not have been more faulty in this reſpect. The ueateſt and moſt compendious form would have been to attach the axis FI to C, and to make CA and CB ſtiff metalline wires, in the ſame manner as Mr Brookes's electrometer is made. But as the whole of their lengths would have acted, this conſtruction would have been very improper in the inveſtigation of the law of electric repulſion. As it now ſtands, we imagine that it has conſiderable advantages over Mr Brookes's conſtruction; and alſo over Mr De Luc's comparable electrometer, deſcribed in his Eſſays on Meteorology. It has even advantages over Mr Coulomb's incomparably more delicate electrometer, which is ſenſible, and *can meaſure* repulſions which do not exceed the 50,000 of a grain; for the inſtrument which we have deſcribed will meaſure the *attractions* of the oppoſitely electrified bodies; a thing which Mr Coulomb could not do without a great circuit of experiments. For inſtead of making the ball B *above* A, by inclining the inſtrument to the right hand, we may incline it to the left; and then, by electrifying one of the balls poſitively, and the other negatively, when at a great diſtance from each other, their mutual attraction will cauſe them to approach; CB will deviate from the vertical toward A; and we can compute the force by means of this deviation.

We muſt remind the perſon who would make obſervations with this inſtrument, that every part of it muſt be ſecured againſt diſſipation as much as poſſible, by varniſhing all its parts, by having all angles, points, and roughneſſes removed, and by chooſing a dry ſtate of the air, and a warm room; and, becauſe it is impoſſible to prevent diſſipation altogether, we muſt make a previous courſe of experiments, in a variety of circumſtances, in order to determine the diminution per minute correſponding to the circumſtances of the experiments that are to be made with further views.

We truſt that the reader will accept of this particular account of an inſtrument which promiſes to be of conſiderable ſervice to the curious naturaliſt; and we now proceed with an account of the concluſions which have been drawn from obſervations made with it.

Here we could give a particular narration of ſome of the experiments, and the computations made from them; but we omit this, becauſe it is really unneceſſary. It ſuffices to ſay, that the writer has made many hundreds, with different inſtruments, of different ſizes, ſome of them with balls of an inch diameter, and radii of 18 inches. Their coincidence with each other was far beyond his expectation; and he has not one in his notes which deviate from the medium $\frac{1}{8}$th of the whole force, and but few that have deviated $\frac{1}{12}$th. The deviations were as frequently in exceſs as in defect. His cuſtom was to meaſure all the forces by a linear ſcale, and expreſs them by ſtraight lines erected as ordinates to a baſe, on which he ſet off the diſtances from a fixed point; he then drew the moſt regular curve that he could through the ſummits of theſe ordinates. This method ſhews, in the moſt palpable manner, the coincidence or irregularity of the experiments.

86 Spheres, when electrified, repel with a force proportional to $\frac{1}{x^2}$;

The reſult of the whole was, that the mutual repulſion of two ſpheres, electrified poſitively or negatively, was very nearly in the inverſe proportion of the ſquares of the diſtances of their centres, or rather in a proportion ſomewhat greater, approaching to $\frac{1}{x^{2,06}}$. No difference was obſerved, although one of the ſpheres was much larger than the other; and this circumſtance enables us to make a conſiderable improvement on the electrometer. Let the ball A be made an inch in diameter, while B is but $\frac{1}{3}$th of an inch. This greatly diminiſhes the proportion of the irregular actions of the reſt of the apparatus of the whole force, and alſo diminiſhes the diſſipation when the general intenſity is the ſame.

87 And attract according to the ſame law.

When the experiments were repeated with balls having oppoſite electricities, and which therefore attracted each other, the reſults were not altogether ſo regular, and a few irregularities amounted to $\frac{1}{6}$th of the whole; but theſe anomalies were as often on one ſide of the medium as on the other. This ſeries of experiments gave a reſult which deviated as little as the former (or rather leſs) from the inverſe duplicate ratio of the diſtances; but the deviation was in defect as the other was in exceſs.

We therefore think that it may be concluded, that the action between two ſpheres is exactly in the inverſe duplicate ratio of the diſtance of their centres, and that this difference between the obſerved attractions and repulſions is owing to ſome unperceived cauſe in the form of the experiment.

88 Attractions and repulſions are equal at equal diſtances.

It muſt be obſerved alſo, that the attractions and repulſions, with the ſame denſity and the ſame diſtances, were, to all ſenſe, equal, except in the forementioned anomalous experiments. The mathematical reader will ſee that the above-mentioned irregularities are imperfections of experiment, and that the gradations of this function of the diſtances are too great to be much affected by ſuch ſmall anomalies. The indication of the law is preciſe enough to make it worth while to adopt it, in the mean time, *as a hypotheſis*, and then to ſelect, with judgment, ſome legitimate conſequences which will admit of an exact compariſon with experiment, on ſo large a ſcale, that the unavoidable errors of obſervation ſhall bear but an inſignificant proportion to the whole quantity. We ſhall attempt this: and it is peculiarly fortunate that this obſerved law of action between two ſpheres gives the moſt eaſy acceſs to the law of action between the particles which compoſe them; for Sir Iſaac Newton has demonſtrated (and it is one of his moſt precious theorems), that if the particles of matter act on each other with a force which varies in the inverſe duplicate ratio of the diſtances, then ſpheres, conſiſting of ſuch particles, and of equal denſity at equal diſtances from the centre, alſo act on each other with forces varying in the ſame proportion of the diſtances of their centres. He demonſtrates the ſame thing of hollow ſpherical ſhells. He demonſtrates that they act on each other with the ſame force as if all their matter were collected in their centres. And, laſtly, he demonſtrates, that if the law of action between the particles be different from this, the ſenſible action of ſpheres, or of hollow ſpherical ſhells, will alſo be different (ſee *Principia*, I. Prop. 74, &c. alſo ASTRONOMY, *Encycl.* 307.)

89 Electric action is inverſely as the ſquare of the diſtance.

Therefore we may conclude, that the law of electric attraction and repulſion is ſimilar to that of gravitation, and that each of thoſe forces diminiſhes in the ſame proportion that the ſquare of the diſtance between the particles increaſe. We have obtained much uſeful information from this diſcovery. We have now full confirmation of the propoſitions concerning the mutual action of two bodies, each overcharged at one end and undercharged at the other. Their evidence before given amounted only to a reaſonable probability; but we now ſee that the curve line, whoſe ordinates repreſent the forces, is really convex to the abſciſſa, and that $Z + z'$ is always greater than $Z' + z$; from which circumſtance all the reſt follows of courſe.

90 Diſpoſition of ſuch fluid when redundant or deficient.

Let us now enquire into the manner in which the redundant fluid, or redundant matter, is diſtributed in bodies; the proportion in which it ſubſiſts in bodies communicating with each other; the tendencies to eſcape; the forces which produce a transference, &c. &c.

In the courſe of this enquiry, a continual reference will be made to the following elementary propoſition:

91 Lemma.

Let ABD (fig. 17.) be the baſe of a cone or pyramid, whoſe vertex is P, and axis PC; and let *abd* be another ſection of it by a plane parallel to the baſe; let theſe two circles, or ſimilar polygons, conſiſt of matter or fluid of equal and uniform denſity; and let P be a particle of fluid or matter; the attraction or repulſion of this particle for the whole matter or fluid in the figure ABD is equal to its attraction or repulſion for the

the whole matter or fluid in *a b d*. For the attraction for a particle in ABD is to the attraction for a particle ſimilarly placed in *a b d* as Pc^2 to PC^2; and the number of particles in ABD is to that of thoſe in *a b d* as PC^2 to Pc^2; therefore the whole attraction for ABD is to that for *a b d* as $Pc^2 \times PC^2$ to $PC^2 \times Pc^2$, or in the ratio of equality.

Cor. 1. The ſame will be true of the action of plates of equal thickneſs and equal denſity; or, in general, having ſuch thickneſs and denſity as to contain quantities of matter or fluid proportional to their areas.

2. The action of all ſuch ſections made by parallel planes, or by planes equally inclined to their axis, are equal.

3. The tendency of a particle P to a plane, or plate of uniform thickneſs and denſity, and infinitely extended, or to a portion of it bounded by the ſame pyramid, is the ſame, at whatever diſtance it be placed from the plate, and it is always perpendicular to it.

4. This tendency is proportional to the denſity and thickneſs of the plate or plates jointly.

It is only in two or three ſimple caſes that we can propoſe to ſtate with preciſion what will be the diſpoſition and action of the electric fluid in bodies; but we ſhall ſelect thoſe that are moſt inſtructive, and connected with the moſt remarkable and important phenomena.

92 Diſpoſition in parallel plates,

Let A *a d* D (fig. 18.) and E *e h* H repreſent the ſections of a part of two infinitely extended parallel plates (which we ſhall call A and E), conſiſting of ſolid conducting matter, in which the electric fluid can move without any obſtruction, but from which it cannot eſcape.

When both are over-charged,

Firſt, Let them be both overcharged, A containing the quantity *r* of redundant fluid, and E containing the quantity *s*, and let *r* be greater than *s*.

The fluid will be diſpoſed in the following manner:

1. There will be two ſtrata, A *a b* B and G *g h* H, adjoining to the remote ſurfaces, in each of which the quantity $\frac{r+s}{2}$ will be crowded together as cloſe as poſſible.

2. Adjoining to the interior ſurface (that is, the ſurface neareſt to E) of the plate A, there will be a ſtratum C *c d* D, containing the quantity $\frac{r-s}{2}$ crowded together.

3. The adjacent ſide of E will have a ſtratum E *e f* F, juſt ſufficient for containing the quantity $\frac{r-s}{2}$ at its natural denſity. This ſtratum will be entirely exhauſted of fluid.

4. The ſpaces B *b c* C and F *f g* G will be in their natural ſtate.

For a particle of fluid in the ſpace B *b c* C is urged in the direction *a d* by the force $\frac{r+s}{2}$ (n° 91, 3.), and in the direction *d a* by the force $\frac{r-s}{2}$, therefore it is, on the whole, urged in the direction *a d* with the force *s*, which will balance the repulſion of the redundant fluid in the other plate. A particle of fluid in the ſpace F *f g* G is repelled in the direction *h e* by a force $\frac{r+s}{2}$ by the fluid in G *g h* H, and it is attracted in the ſame direction by the redundant matter in E *e f* F, with the force $\frac{r-s}{2}$. Theſe make a force *r* which balances the repulſion *r* of the other plate. No other diſpoſition will be permanent; for if a particle be taken out from either ſtratum A *a b* B or C *c d* D into the ſpace between them, the repulſion from that ſtratum which it quitted is leſſened, and the repulſion of the oppoſite ſtratum, joined to that of the other plate, will drive it back again. The ſame thing holds with reſpect to the fluid in the other plate.

93. *Cor.* 1. If the two plates be equally overcharged, all the redundant fluid will be crowded on the remote ſurfaces, and the adjacent ſurfaces will be in the natural ſtate.

94 When they are under-charged,

In the *ſecond* place, let the plates be undercharged, and let *r* be the fluid wanting in A, and *s* the fluid wanting in E, and let *s* be greater than *r*; then,

1. The ſtrata adjoining to A *a* and H *h* will be completely exhauſted of fluid, and the redundant matter in each will be ſuch as would be ſaturated by $\frac{r+s}{2}$.

2. The ſtratum C *c d* D will contain redundant fluid $\frac{s-r}{2}$, crowded cloſe.

3. The ſtratum E *e f* F will be deprived of fluid, and the quantity abſtracted is $\frac{s-r}{2}$.

4. The ſpaces B *b c* C and F *f g* G are in the natural ſtate.

The demonſtration is the ſame as in the former caſe.

95 When they are in oppoſite ſtates,

Thirdly, Let A be overcharged, and E undercharged, A containing the redundant fluid *r*, and E wanting the fluid *s*; and let *r* be greater than *s*. Then,

1. The ſtrata A *a b* B and G *g h* H contain the redundant fluid $\frac{r-s}{2}$, crowded cloſe.

2. The ſtratum C *c d* D contains the quantity $\frac{r+s}{2}$, crowded cloſe.

3. The ſtratum E *e f* F is exhauſted, and wants the quantity $\frac{r+s}{2}$.

4. The reſt is in the natural ſtate.

96, *Cor.* 2. If the redundant fluid in A be juſt ſufficient to ſaturate the redundant matter in E, the two remote ſurfaces will be in their natural ſtate, all the redundant fluid in A being crowded into the ſtratum C *c d* D, and all the redundant matter being in E *e f* F.

This diſpoſition will be the ſame, whatever is the diſtance or thickneſs of the plates, unleſs the redundant fluid in A be more than can be contained in the whole of E when crowded cloſe.

97 Preſſure and tendency to eſcape.

When the two plates are overcharged, the fluid preſſes their remote ſurfaces with the force $\frac{\overline{r+s}^2}{4}$, and would eſcape with that force if a paſſage were opened. It would enter the remote ſurfaces of two undercharged plates with the ſame force; and, in either caſe, it would run from the inner ſurface of one to the adjacent ſurface of the other, with the force $\frac{\overline{r-s}^2}{4}$.

If one be overcharged and the other undercharged, fluid would eſcape from the remote ſurface with the force

force $\frac{\overline{r-s}^2}{4}$, and would run through a canal between them with the force $\frac{\overline{r+s}^2}{4}$.

Mutual actions.

They repel or attract each other with the force $\overline{r+s}^2$ according as they are both over or undercharged, or as one is overcharged and the other undercharged.

This example of parallel plates, infinitely extended, is the ſimpleſt that can be ſuppoſed. But it cannot obtain under our obſervation; and in all caſes which we can obſerve, the fluid cannot be uniformly ſpread in any ſtratum, but muſt be denſer near the edges, or near the centre, as they are overcharged or undercharged.

98 Diſpoſition in a ſphere.

Let ABD (fig. 19.) repreſent a ſphere of perfectly conducting matter, overcharged with electric fluid, which is perfectly moveable in its pores, but cannot eſcape from the ſphere. Let it be ſurrounded by conducting matter ſaturated with moveable fluid. It is required to determine the diſpoſition of the fluid within and without this ſphere.

Sir Iſaac Newton has demonſtrated (*Princ.* I. 70.) that a particle *p*, placed anywhere within this ſphere, is not affected by any matter that is without the concentric ſpherical ſurface *p q r* in which itſelf is ſituated, therefore not affected by what is between the ſurfaces ABD and *p q r*. He alſo demonſtrates, that the matter within the ſurface *p q r* acts on the particle *p* in the ſame manner as if the whole of it were collected in the centre C.

Hence it follows, that the redundant fluid will be all conſtipated as cloſe as poſſible within the external ſurface of the ſphere, forming a ſhell of a certain minute thickneſs, between the ſpherical ſurfaces ABD and *abd*; and all that is within this (that is, nearer the centre C) will be in its natural ſtate.

With reſpect to the diſtribution of the fluid in the ſurrounding matter, which we ſuppoſe to be infinitely extended, we muſt recollect that this ſhell of conſtipated redundant fluid repels any external particle of fluid in the ſame manner as if all were collected at C. Hence it is evident, that the fluid in the ſurrounding matter will be repelled, and, being moveable, it will recede from this centre; and there will be a ſpace all round the ſphere ABD which is undercharged, forming a ſhell between the concentric ſurfaces ABD and αβδ. This ſhell will contain ſuch a quantity of redundant matter, that its attraction for a particle of fluid is equal to the repulſion of the ſhell of fluid crowded internally on the ſurface ABD. All beyond this ſurface αβδ will be in its natural ſtate; for this redundant matter acts on a particle of fluid, ſituated farther from the centre, in the ſame manner as if all this redundant matter were collected in the centre C. So does the redundant fluid in the conſtipated ſhell. Therefore their actions balance each other, and there is no force exerted on any particle of fluid beyond this deficient ſhell. This deficient ſhell will not affect the fluid in the ſphere *a b d* by Newton's demonſtration. No other diſpoſition will be permanent. But farther: This undercharged ſhell muſt be completely exhauſted: for a particle of fluid placed between ABD and αβδ will be more repelled by the fluid in the crowded ſhell within the ſurface ABD, than it is attracted by the redundant matter of its own ſhell that is leſs remote from the centre; and it is not affected by what is more remote from the centre. Therefore the fluid without the ſphere ABD cannot be in equilibrio, unleſs the ſhell between ABD and αβδ be not only rarefied, but altogether exhauſted of fluid.

If the ſphere be undercharged, the ſpace between ABD and *a b d* will be entirely exhauſted of fluid, and there will be a ſhell αβδ of redundant matter ſurrounding the ſphere. All within *a b d*, and all without αβδ, will be in its natural ſtate. It is unneceſſary to repeat the ſteps of the ſame demonſtration.

This valuable propoſition is by the Hon. Mr Cavendiſh.

99 Conſequences of this diſpoſition.

This would be the diſpoſition in and about a glaſs globe filled and ſurrounded with an ocean of water, and having redundant fluid within it, on the ſuppoſition that glaſs is impervious to the electric fluid. But it would not affect an electrometer, even ſuppoſing that the movements of the electrometer could be effected under water. Suppoſe the globe of water to be ſurrounded with air, and that the fluid is diſpoſed in both in the manner here deſcribed; it will be perfectly neutral in its action on any electrometer ſituated in the air. But, by reaſon of the almoſt total immobility of the fluid in pure dry air, this ſtate cannot ſoon obtain; and, till it obtain, the conſtipated ſhell within the glaſs muſt repel the fluid in an electrometer more than the partially rarefied ſhell of air, which ſurrounds the glaſs, attracts it. By the gradual retiring of the fluid in the ſurrounding air from the globe, the attraction of the deſerted matter will come nearer to equality with the repulſion of the conſtipated ſhell within the glaſs, and the globe will appear to have loſt fluid. Yet it may retain all the redundant fluid which it had at the firſt. Therefore we are not to imagine that a body ſimilar to this globe has no redundant electric fluid, or only a ſmall quantity, becauſe we obſerve it inactive, or nearly ſo.

100 Verified by the phenomena. Electric Well explained.

Thus we ſee, as we proceed, that the Æpinian theory is adequate to the explanation of the phenomena. But we ſee it much more remarkably in a very familiar and amuſing experiment, uſually called the ELECTRIC WELL. See ELECTRICITY, *Encycl.* Sect. x. 4.

To ſee it in perfection, make a glaſs veſſel of globular ſhape, with a narrow mouth, ſufficiently wide, however, to admit an electrometer ſuſpended to the end of a glaſs rod of a crooked form, ſo that the electrometer can be preſented to any part of the inſide. Smear the outſide of the globe with ſome tranſparent clammy fluid, ſuch as ſyrup. Set it on an inſulating ſtand (a wine glaſs), and electrify it poſitively. Hold the electrometer near it, anywhere without, and it will be ſtrongly affected. Its deviations from the perpendicular (if the ball of the electrometer has alſo been electrified) will indicate a force inverſely as the ſquare of the diſtance from the centre of the globe, pretty exactly, if the thread of the electrometer is of ſilk. Now let down the electrometer into the inſide of the globe. It will not be affected in any ſenſible degree, nor approach or avoid any body that is lying within the globe. The electrometer may be held in all parts of the globe, and when brought out again, is perfectly inactive and neutral. But if the balls of the electrometer be touched with a wire, while hanging free within the globe, they will, on withdrawing the wire, repel each other; and when taken out, they will be found negatively electrified.

fied. The experiment ſucceeds as well with a metal globe; nay, even although the mouth be pretty wide; in which caſe, there is not a perfect balance of action in every direction. The electrometer may be made to touch the bottom of the globe, or anywhere not too near the mouth, without acquiring any ſenſible electricity; but if we touch the outſide with the electrometer, it will inſtantly be electrified and ſtrongly repelled. Deep cylinders, and all round veſſels with narrow mouths, exhibit the ſame faintneſs of electricity within, except near the brims, although ſtrongly electric without; and even open metal cups have the interior electricity much diminiſhed.

101
Electric bodies are only ſuperficially ſo.

Reflecting on this valuable propoſition of Mr Cavendiſh, we ſee clearly why an overcharged electric is only ſuperficially ſo; and that this will be the caſe even although we attempt to accumulate a great quantity of electricity in it, by melting it in a thin glaſs globe, and electrifying it while liquid, and keeping up the accumulating force till it becomes quite cold. The preſent writer, not having conſidered the ſubject with that judicious accuracy that Mr Cavendiſh exerted, had hopes of producing a powerful and permanent electric in this way, and was mortified and puzzled by the diſappointment, till he ſaw his miſtake on reading Mr Cavendiſh's diſſertation.

Cautions in certain experiments.

Theſe obſervations alſo point out a thing which ſhould be attended to in our experiments for diſcovering the electricity excited in the ſpontaneous operations of nature, as in chemical compoſition and decompoſition, congelation, fuſion, evaporation, &c. It has been uſual to put the ſubſtances into glaſs, or other non-conducting veſſels, or into veſſels which conduct very imperfectly. In this laſt caſe eſpecially, the very faint electricity which is produced, inſtantly forms a compenſation to itſelf in the ſubſtance of the veſſel, and the apparatus becomes almoſt neutral, although there may have been a great deal of electricity excited. It will be proper to conſider, whether the nature of the experiment will admit of metalline veſſels. In the experiments on metalline ſolutions, the beſt method ſeems to be, to make the veſſel itſelf the ſubſtance that is to be diſſolved.

102
Electricity more nearly proportional to the ſurface than to the quantity of matter.

For ſimilar reaſons we may collect, without a more minute examination, that bodies of all ſhapes, when overcharged, will have the redundant fluid much denſer near the ſurface than in the interior parts; and denſer in all elevations, bumps, projections, angles, and near the ends of oblong bodies; and that, in general, the quantity of redundant fluid, or redundant matter, will be much more nearly proportional to the ſurfaces of bodies than to their quantities of matter. All this is fully proved by experience. The experiment of the electrified chain is a very beautiful one. Lay a long metal chain in an inſulated metal diſh furniſhed with an electrometer. Let one end be held an inch or two above the coil by a ſilk thread. Electrify the whole, and obſerve the divergency of the electrometer; then, gradually drawing up the chain from the coil, the electrometer will gradually fall lower, and lowering the chain again will gradually raiſe it.

103. We now ſee with how little reaſon Lord Mahon concluded that the point of his conductor, obſerved to be neutral, correſponded with his theory; namely, one of the media of a harmonic diviſion. We ſee no reaſon for beginning the computation at the extremity of the prime conductor. It certainly ſhould not have been from the extremity. Had the prime conductor been a ſingle globe, it ſhould have begun from the centre of this globe. If it was of the uſual form, with an outſtanding wire, terminated by a large ball, the action of the body of the conductor ſhould certainly have been taken into the account. In ſhort, almoſt any point of the long conductor might have been accommodated to his Lordſhip's theory.

104. We might now proceed to inveſtigate the diſtribution of the electric fluid in bodies expoſed to the action of others, and particularly in the oblong conductors made uſe of in our preparatory propoſitions. The problem is determinate, when the length and diameter of cylindric conductors are given; but even when the electric employed for inducing the electricity is in the form of a globe, we muſt employ functions of the diſtances that are pretty complex, and oblige us to have recourſe to ſecond fluxions. The mutual actions of two oblong conductors, of conſiderable diameters, give a problem that will occupy the firſt mathematicians; but which is quite improper for this ſcanty abſtract. Nor is a minute knowledge of the diſpoſition of the fluid of very important ſervice. We may therefore content ourſelves with a general repreſentation of the ſtate of the fluid in the following manner, which will give us a pretty diſtinct notion how it will act in moſt caſes:

General repreſentation of the diſpoſition of the fluid.

Let A (fig. 20.) be an overcharged ſphere, and BC a conducting cylindric or priſmatic body; draw $b\,c$ parallel to BC, and erect perpendiculars B b, C c, P p, &c. to repreſent the equable denſity of the fluid, when the conductor is in its natural ſtate; but let B d, C r, P s, &c. repreſent the unequal denſities in its different points, while in the vicinity of the overcharged ſphere. Theſe ordinates muſt be bounded by a line $d\,n\,r$, which will cut the line $b\,c$ in the point n of the perpendicular, drawn from the neutral point N of the conductor. The whole quantity of fluid in the conductor is repreſented by the parallelogram BC $c\,b$; which muſt therefore be equal to the ſpace BC $r\,n\,d$: the redundant fluid in any portion CP or PN is repreſented by the ſpaces $c\,r\,t\,p$, or $t\,p\,n$; and the redundant matter, or deficient fluid, in any portion BQ, is repreſented by $b\,d\,v\,q$. The action of this body on any body placed near it, depends entirely on the area contained between this curve line and its axis $b\,c$. The only circumſtance that we can aſcertain with reſpect to this curve is, that *the variations of curvature* in every point are proportional to the forces exerted by the ſphere A; and are therefore inverſely as the ſquares of the diſtances from A. This property will be demonſtrated by and bye. The place of n, and the magnitude of the ordinates, will vary as the diameter of the conductor varies. We ſhall conſider this a little more particularly in ſome caſes which will occur afterwards. We may conſider the ſimpleſt caſe that can occur; namely, when the conductor is, like a wire, of no ſenſible diameter, nay, as containing only one row of particles.

In a very ſlender canal the fluid muſt be almuſt equally diſtributed.

Let AE (fig. 21.) be ſuch a ſlender conducting canal; and let B b, C c, E e, &c. repreſent the denſity of the fluid which occupies it, being kept in this ſtate of inequable denſity by the repulſion for ſome overcharged body. A particle in C is impelled in the direction CE by all the fluid on the ſide of A, and in the

direction

direction CA by all the fluid on the ſide of E. The moving force, therefore, ariſes from the difference of theſe repulſions. When the diameter of the canal is conſtant, this ariſes only from the difference of denſity. The force of the element adjacent to E may therefore be expreſſed by the exceſs of D d above C c, and the action at the diſtance CD jointly. Therefore, drawing $\beta c \varepsilon$ parallel to AE, this force of the element E will be expreſſed by $\frac{d\delta}{c\delta^2}\dot{x}$, repelling the particle in the direction CA. If CF be taken equal to CD, the force of the element at F will be expreſſed by $\frac{f\varphi}{c\gamma^2}\dot{x}$, or $\frac{f\varphi}{c\delta^2}\dot{x}$, alſo impelling the particle in the direction CA. The joint action of theſe two elements therefore is $\frac{d\delta+f\varphi}{c\delta^2}\dot{x}$. If $b c e$ were a ſtraight line, we ſhould have $d\delta+f\varphi$ always proportional to $c\delta$; and it might be expreſſed by $m\times c\delta$; m being a number expreſſing what part of $c\delta$ the ſum of $d\delta$ and $f\varphi$ amounts to (perhaps $\frac{1}{10}$th, or $\frac{1}{20}$th, or $\frac{1}{30}$th, &c.). But in the caſe expreſſed in the figure, $d\delta$ does not increaſe ſo faſt as $c\delta$, and $f\varphi$ increaſes faſter than $c\delta$. However, in the immediate neighbourhood of any point C, we may expreſs the accelerating force tending towards A by $\frac{mc\delta}{c\delta^2}\dot{x}$, without any ſenſible error; that is, by $m\frac{\dot{x}}{x}$; that is, by the fluxion of the area of a hyberbola HD′G, having CC′ and CK for its aſſymptotes; and the whole action of the fluid between F and D, on the particle C, will be expreſſed by the area C′CDD′H. Hence it follows, that the action of the ſmalleſt conceivable portion of the canal immediately adjoining to C on both ſides, or the difference of the actions of the two adjoining elements, is equal to the action of all beyond it. This ſhews, that the ſtate of compreſſion is hardly affected by any thing that is at a ſenſible diſtance from C; and that the denſity of the fluid, in an indefinitely ſlender canal, is, to all ſenſe, uniform. The geometer will alſo ſee, that the ſecond fluxion of D d is proportional to the force of the diſtant body. We learn, therefore, ſo much of the nature of the curve $b c e$.—(*Coulomb*).

We are now in a condition to examine the communication of electricity by means of conducting canals (which is one of the moſt important articles of the ſtudy,) having found that the fluid, in a very ſlender canal, is very nearly of uniform denſity throughout.

106 Communication and transference by canals.

There can be no doubt but that, if a body B (fig. 22.) be overcharged or undercharged, any other body C, which communicates with it by a conducting canal, will alſo be overcharged or undercharged. It is as evident, that if a body, in any ſtate of electricity, be in the neighbourhood of an overcharged or undercharged body A, while it communicates with C by a canal leading from the ſide moſt remote from A, fluid will be driven from B into C, or abſtracted from C into B.

107 By crooked canals.

It is not, however, ſo clear, that when the canal leads from the ſide neareſt to A (as in fig. 23.), fluid will be driven from B into C. We conceive the fluid to be moveable in the body and in this canal, but not to eſcape from it. Its motion, therefore, in this caſe, ſhould, in the opinion of Mr Cavendiſh, reſemble the running of water in a ſyphon by the preſſure of the air. While the repulſion of the redundant fluid in A allows the bend of the ſyphon neareſt to A to retain fluid, a current ſhould take place from B along the ſhort leg, in conſequence of the ſuperior action on the fluid in the long leg. But if the repulſion of A can drive the fluid out of the bend between B and F, Mr Cavendiſh thinks, that it does not appear that fluid will come up from B in oppoſition to the repulſion of A, and then run along to D. But fluid does not move, in either of theſe caſes, on the principle of a ſyphon; becauſe there is nothing to hinder the fluid from expanding in the part EDF. And we are rather diſpoſed to think, that it will always move from B, over the bend, to C; For even if the fluid can be completely driven out of the bend EF, it muſt be done by degrees, and the fluid in the long leg will, from the very beginning of the action of A, be more moved from its place than that in the ſhort leg; and therefore will yield to the compreſſion, which acts tranſverſely, and, by thus yielding more toward F than toward E, the fluid will ruſh through the contracted part, and go into C. We do not ſay this with full confidence; but are thus particular, on account of an important uſe that may be made of the experiment. For if the body A be undercharged, fluid will certainly be attracted from C, and paſs over the bend into B, however great the action of A may be. Perhaps this may be ſo contrived, therefore, as to decide the long agitated queſtion, *Whether the electricity of excited glaſs be plus or minus?* If it be found that this apparatus, being preſented to the rubber of an electrical machine, diminiſhes the poſitive electricity of C, and increaſes that of B; but that, preſenting the ſame apparatus to the prime conductor, makes little change—we may conclude, that the electricity of the prime conductor is poſitive. We have tried the experiment, paying attention to every circumſtance that ſeemed likely to inſure ſucceſs; but we have always found hitherto, that the apparatus was equally affected by both electricities.

Propoſal for diſcovering redundancy of fluid.

We muſt now conſider the action of electrified bodies on the canals of communication; becauſe this will give us the eaſieſt method of aſcertaining the proportion in which the expelling fluid is diſtributed between them. For when two bodies communicate by a canal, and have attained a permanent ſtate, we muſt conceive that their oppoſite actions on the fluid moveable along this canal are in equilibrio, or are equal. This will generally be a much eaſier problem than their action on each other, ſince we have ſeen a little ago, that the fluid in a ſlender canal is of uniform denſity very nearly. A very few examples of the moſt important of the ſimple caſes muſt ſuffice.

108 Action of a plate on a rectilineal canal.

Therefore let AC a (fig. 24.) repreſent the edge of a thin conducting circular plate, to which the ſlender canal CP is perpendicular in the centre. It is required to determine the action of the matter or fluid, uniformly ſpread over this plate, on the fluid moveable in the canal PC?

109. 1. Required the action of a particle in A on the fluid in the whole canal? Join AP; and call CP x, AP y, and AC r; and let f expreſs the intenſity of action at the diſtance 1, or the unit of the ſcale on which the lines are meaſured.

The action of A on P, in the direction AP, is $\frac{f}{y^2}$. This,

This, when eſtimated in the direction CD, is reduced to $\frac{f}{y^2} \times \frac{x}{y}$; and is therefore $= f \frac{x}{y^3}$. Therefore the fluxion of the action, in the direction CP, on the whole canal, is $f \frac{x}{y^3} \dot{x} = f \frac{y \dot{y}}{y^3}$ (becauſe $x : y = \dot{y} : \dot{x}$) $= f \times \frac{\dot{y}}{y^2}$. The variable part of the fluent is $= f \frac{-1}{y}$, and the complete fluent is $= f \left(\mathrm{C} - \frac{1}{y} \right)$, where C is a conſtant quantity, accommodated to the nature of the caſe. Now, the action muſt vaniſh when the canal vaniſhes, or when $x = 0$, and $y = r$. Therefore $\mathrm{C} - \frac{1}{r} = 0$, and $\mathrm{C} = \frac{1}{r}$; and the general expreſſion of the action is $f \left(\frac{1}{r} - \frac{1}{y} \right), = f \frac{y - r}{ry}$, expreſſing the action of a particle in the circumference of the plate on the fluid in the whole canal CP.

2. Required the action of the plate, whoſe diameter is A a, on the particle P?

110 . On a ſin- le particle n the ca- al.

Let a repreſent the area of a circle, whoſe diameter is $= 1$. Then $a r^2$ is the area of the plate, and $2 a r \dot{r}$ is the fluxion of this area: becauſe $r : y = \dot{y} : \dot{r}$, $2 a r \dot{r}$ is $= 2 a y \dot{y}$. Therefore the fluxion of the action of the plate on the particle P is $f \times 2 a y \dot{y} \times \frac{x}{y^3} = 2 f a x \times \frac{\dot{y}}{y^2}$. The fluent of this has for its variable part $2 f a x \times \frac{-1}{y}$ (for when the particle P is given, x does not vary). This is $= 2 f a \times \frac{-x}{y}$. To complete this fluent, we muſt add a conſtant quantity, which ſhall make the fluent $= 0$ when the particle P is at an infinite diſtance; and therefore when $x = y$. Therefore $\frac{y}{y} - \frac{x}{y} = 0$, or $1 - \frac{x}{y} = 0$, or $\mathrm{C} = 1$; and the complete fluent for the whole plate is $2 f a \left(1 - \frac{x}{y} \right)$.

111. The meaning of this expreſſion may not occur to the reader: For $1 - \frac{x}{y}$ is evidently an abſtract number; ſo is a. Therefore the expreſſion appears to have no reference to the ſize of the plate. But this agrees with the obſervation in n° 91. where it was ſhewn that, provided the angle of the cone or pyramid remained the ſame, the magnitude of the baſe made no change in its attraction or repulſion for a particle in the vertex.

It will appear by and bye, that $1 - \frac{x}{y}$ is a meaſure or function of a certain angle of a cone.

Cor. If PC be very ſmall in proportion to AC, the action is nearly the ſame as if the plate were infinite: For when the plate is infinite, $\frac{x}{y}$ is $= 0$, and the action is $= 1$, whatever is the diſtance (ſee n° 91—93.) Therefore, when x is very ſmall in compariſon of r, and conſequently of y, $1 - \frac{x}{y}$ is very nearly $= 1$.

112 2. On the whole canal.

3. To find the action of the plate on the whole column?

The fluxion of this muſt be $= 2 f a \times \left(1 - \frac{x}{y} \right) \dot{x}$, or $2 f a \left(\dot{x} - \frac{x \dot{x}}{y} \right)$, or $2 f a \times (\dot{x} - \dot{y})$; becauſe $\dot{y} = \frac{x \dot{x}}{y}$. The fluent of this has for its variable part $2 f a \times (x - y)$. A conſtant quantity muſt be added, which ſhall make it $= 0$ when the column $= 0$; that is, when $y = r$, and $x = 0$; that is, $\mathrm{C} - r = 0$, and $\mathrm{C} = r$. Therefore the complete fluent is $= 2 f a \, (x + r - y$.

113 Geometrical expreſſion of theſe actions.

Thus we have arrived at a moſt ſimple expreſſion of the attraction or repulſion of a plate for ſuch a column, or for portions of ſuch a column. And it is moſt eaſily conſtructed geometrically, ſo as to give us a ſenſible image of this action of eaſy conception and remembrance. It is as follows: Produce PC till CK = CA, and about the centre P deſcribe the arch AI, cutting CK in I. Then $2 f a \times$ IK is evidently the geometrical expreſſion of the attraction or repulſion. This is plainly a cylinder, whoſe radius is a unit of the ſcale, and whoſe height is twice IK.

In like manner, by deſcribing the arch Ai round the centre p, we have $2 f a \times i$ K for the action of the plate on the ſmall column Cp; and $2 f a \times$ Ii is the action of the plate on the portion Pp.

The general meaning of the expreſſion $2 f a \times$ IK is, that the action of the whole plate on the column PC is the ſame as if all the fluid in the cylinder $a \times 2$ IK, were placed at the diſtance 1 from the acting particle.

From this propoſition may be eaſily deduced ſome very uſeful corollaries by the help of the geometrical conſtruction.

1. If PC be very great in compariſon with AC, the action is nearly the ſame as if the column were infinitely extended; for in this caſe IK is very nearly = CK, the difference being to the whole nearly as AC to twice AP. 114.

115 Important corollary.

2. If, in addition to this laſt condition, another column pC be very ſmall in compariſon of AC, then the action on PC is to that on pC very nearly as pC to AC. For it will appear that iK : IK = pC : AC very nearly. It is exactly ſo when CP : CA = CA : Cp; and it will always be in a greater proportion than that of pC to IK.

This will be found to be a very important obſervation.

The redundant fluid has hitherto been ſuppoſed to be uniformly ſpread over the plate: but this cannot be; becauſe its mutual repulſion will cauſe it to be denſer near the circumference. We have not determined, by a formula of eaſy application, what will be the variation of denſity. Therefore let us conſider the reſult of the extreme caſe, and ſuppoſe the whole redundant fluid to be crowded into the circumference of the plate, as we ſaw that it muſt be on the ſurface of a globe.

116 Action of a circumference on a canal.

In this caſe, the action on the fluid in the canal will be $f a \left(r - \frac{r^2}{y} \right)$. For the area of the plate is $a r^2$, and the action of a particle in the circumference on the whole canal was ſhewn (nº109.) to be $f\left(\frac{y-r}{ry}\right)$. Therefore the action of the whole fluid crowded into the circumference is $f\,a\,r^2\times\frac{y-r}{ry}, = f\,a\,r\frac{y-r}{y}$. It may be repreſented as follows: Deſcribe the quadrant CbBE, cutting AP and Ap in B and b. Draw BD and $b\,d$ parallel to PC. Then PB $= y-r$, and DC $= r\frac{y-r}{y}$. Therefore the action is repreſented by f multiplying a cylinder, whoſe radius is 1 and height is DC. In like manner, dC is the height of the cylinder correſponding to the column pC, and Dd the height correſponding to Pp.

117. *Cor.* 1. When CP is very great in compariſon with CA, the point D is very near to A, and I is very near to C, and CD is to IK nearly in the ratio of equality. In this caſe the action of the fluid, uniformly ſpread over the plate, is nearly double of the action of the ſame fluid crowded round the circumference; for they are as cylinders, having the ſame baſes and heights in the ratio of 2 IK to DC, which is nearly the ratio of 2 to 1.

118. 2. On the other hand, when the column pC is very ſhort, the action of the fluid ſpread uniformly over the plate is to its action, when crowded round the circumference, nearly in the ratio of 4 AC to pC. For theſe actions are in the ratio of $2fa\times i$K to $1fa\times d$C, or as 2 iK to dC, or nearly as 2 pC to dC, or more nearly as 2 $b\,d$ to dC. But Cd : $b\,d$ = $b\,d$: bA + Ad, or nearly = $b\,d$: 2 CA. Therefore Cd : 2$b\,d$ = pC : 4 CA nearly.

119. Hence we ſee that the action on ſhort columns is much more diminiſhed by the receſs of the redundant fluid toward the circumference than that on long columns. Therefore, any external electric force which tends to ſend fluid along this canal, and from thence to ſpread it over the plate, will ſend into the plate a greater quantity of fluid than if the fluid remained ultimately in a ſtate of uniform diſtribution over its ſurface; and that the odds will be greater when the canal is ſhort.

120 Equivalent centre of action.

Laſtly, on this ſubject. If KL be taken equal to AP, or PL be equal to KI, the repulſion which all the fluid in the plate, collected in K, would exert on the fluid in the canal CL, is equal to the repulſion which the ſame fluid, conſtipated in the circumference, would exert on the column CP. For we have ſeen that the action of a particle in A, on the whole column PC, when eſtimated in the direction PC, is $\frac{y-r}{yr}$; and it is well known that the action of a particle in K for the column CL is $\frac{1}{\text{KC}}-\frac{1}{\text{KL}}$, or $\frac{1}{r}-\frac{1}{y}, = \frac{y-r}{yr}$. Therefore the action of the whole fluid, collected in the circumference, on the column CP, is equal to that of the ſame fluid, collected in K, on the columns CL.

121. *Cor.* 1. If the column CP is very long in proportion to AC or KC, the actions of the fluids in theſe two different ſituations are very nearly the ſame. The action of the fluid collected in K exceeds its action when collected in A only by its action on the ſmall and remote column LP. The action of all the fluid collected at K on the column CP, is eaſily had by taking Cl = KP. It is equal to the action of the ſame fluid placed in A on the column Cl.

Cor. 2. The action of all the fluid uniformly ſpread, exerted on the column CP, is to the action of the ſame fluid collected in K, exerted on the column CL, as 2 IK to CD. 122.

123. If the column CP is very great in proportion to AC, the half breadth of the plate, the action in the firſt caſe is very nearly double of the action in the other caſe, and is exactly in this proportion if CP is of infinite extent.

124 Action of a ſpherical ſurface, or ſhell, or ſolid, on the ſame canal.

Cor. 3. If CNO be a ſpherical ſurface or ſhell of the ſame thickneſs and diameter as the plate Aa, and containing redundant fluid of the ſame uniform denſity, the action of this fluid on the column CL is double of the action of the fluid uniformly ſpread over the plate on the column CP, and quadruple of the action of the fluid collected in the circumference: for the action is the ſame as if all were collected in the centre K, and the ſurface of the ſphere is four times that of the plate, and therefore they are as IK to 2 CD.

Let us now conſider the comparative actions of different plates or ſpheres on the canals.

125 Action of two plates, or two ſpheres, are as their diameters, when the canals are infinitely long.

If two circular plates, DE, de (fig. 25.), or two ſpherical ſhells, ABO, $a\,b\,o$, of equal diameters and thickneſs with the plates, and containing redundant fluid of equal denſity, communicate with infinitely extended ſtraight canals OP, $o\,p$, paſſing through their centres perpendicular to their ſurfaces, alſo containing fluid uniformly diſtributed and of equal denſity—the repulſions will be as the diameters. For the repulſion of the ſpherical ſurfaces is the ſame as if all the fluid were collected at their centres; and the repulſion of the fluid uniformly ſpread over the ſurfaces of the plates is double of its repulſion if collected at the centres of theſe ſpheres; it follows, that the repulſions of the plates are proportional to thoſe of the ſpheres. But becauſe the repulſion of a plate whoſe radius is r was ſhewn to be $= 2a\times\overline{r+x-y}$, and when the column is infinitely extended, x is equal to y, and $\overline{r+x-y} = r$, it follows, that the repulſions of the plates are as $2a\times$R and $2a\times r$, or proportional to their diameters. Therefore the repulſions of the ſpheres are in the ſame proportion.

126. *Cor.* 1. If the canals are very long in proportion to the diameters of the plates or ſpheres, the repulſions are nearly in the ſame proportion.

127 The proportion of the greateſt action is diminiſhed if the canals are ſhort.

Cor. 2. But as the lengths of the canals diminiſh, the repulſions approach to equality; for it was ſhewn, that when the canal was very ſmall, the repulſion was to that for an infinite column as the length of the canal to the radius of the plate. Therefore if the radius of the greater plate be (for example) double of that of the ſmaller, and the little column be $\frac{1}{10}$th of the radius, it will be $\frac{1}{10}$th of the radius of the ſmaller plate. Now $\frac{1}{10}$th of half the repulſion is equal to $\frac{1}{10}$th of the double repulſion. Alſo, in the caſe of the ſpheres, the repulſion of a particle at the ſurface is as the quantity of fluid directly, and as the ſquare of the radius inverſely; but when the denſity is the ſame in both ſhells, the quantity is as the ſurface, or as the ſquare of the radius. Therefore the repulſions are equal.

Cor. 3. If the denſity of the fluid in two ſpherical ſhells be inverſely as the diameters, the repulſions for an

128
Actions of two ſpheres are equal if the denſity be inverſely as the diameters;

infinitely extended column of fluid are equal; for each repels as if all the fluid was collected in the centre. Therefore, if the denſity, and conſequently the quantity, be varied in any proportion, the repulſion will vary in the ſame proportion. The repulſions will now be as $CO \times \frac{1}{CO}$ to $co \times \frac{1}{co}$, or in the ratio of equality.

129
Or if the quantity of redundant fluid be as the diameters.

Cor. 4. When the quantities of redundant fluid in two ſpheres are proportional to their diameters, their repulſions for an infinitely extended canal are equal: for if this redundant fluid is conſtipated in the ſurfaces of the ſpheres, as it always will be when they conſiſt of conducting matter, the denſities are as the diameters inverſely, becauſe the ſurfaces are as the ſquares of the diameters. Therefore, by the laſt corollary their actions on an infinitely extended canal are equal. But in ſpheres of nonconducting matter it may be differently diſpoſed, in concentric ſhells of uniform denſity. This makes no change in the action on the fluid that is without the ſphere, becauſe each ſhell acts on it as if it were all collected in the centre. Therefore the repulſions are ſtill equal.

130
Two ſpheres overcharged in this proportion are in equilibrio if communicating by a very long canal.

Cor. 5. Two overcharged ſpheres, or ſpherical ſhells, OAB, *oab* (fig. 26.), communicating by an infinitely extended canal of conducting matter, contain quantities of redundant fluid proportional to their diameters; for their actions on the fluid in the interjacent canal muſt be in equilibrio, and therefore equal. This will be the caſe only when the quantities of fluid are in the proportion of their diameters.

When the canals are very long in proportion to the diameters of the ſpheres, the proportion of the quantities of redundant fluid will not greatly differ from that of the diameters.

131.

Cor. 6. When the ſpheres of conducting matter are thus in equilibrio, the preſſures of the fluid on their ſurfaces are inverſely as their diameters; for the repulſion of a particle at the ſurface is the ſame with the tendency of that particle from the centre of the ſphere, the actions being mutual. Now this is proportional to the quantity of redundant fluid directly, and to the ſquare of the diſtance from the centre inverſely, that is, to the diameter directly, and to the ſquare of the diameter inverſely, that is, to the diameter inverſely.

Tendency of the fluid to eſcape is inverſely as the diameter.

Hence it follows, that the tendency to eſcape from the ſpheres is inverſely as the diameter, all other circumſtances being the ſame: for in as far as the eſcape proceeds from mere electric repulſion, it muſt follow this proportion. But there are evident proofs of the co-operation of other phyſical cauſes. We obſerve chemical compoſitions and decompoſitions accompanying the eſcape of electric fluid, and its influx into bodies: we are ignorant how far, and in what manner, theſe operations are affected by diſtance. Boſcovich ſhews moſt convincingly, that the action of a particle (of whatever order of compoſition), on external atoms and particles, is ſurpriſingly changed by a change in the diſtance and arrangement of its component atoms. A conſtipation, therefore, to a certain determined degree and lineal magnitude, may be neceſſary for giving occaſion to ſome of thoſe chemical operations that accompany, and perhaps occaſion, the eſcape of the electric fluid. If this be the caſe (and it is *demonſtrable* to be poſſible, if the operations of Nature be owing to attractions and repulſions), the eſcape *muſt* be deſultory. It is actually ſo; and this confirms the opinion.

The public is indebted to Mr Cavendiſh for the preceding theorems on the action of ſpheres and circular plates. He has given them in a more abſtract and general form, applicable to any law of electric action which experience may warrant. We have accommodated them to the inverſe duplicate ratio of the diſtances, as a point ſufficiently eſtabliſhed; and we hope that we have rendered them more ſimple and perſpicuous. We have availed ourſelves of Mr Coulomb's demonſtration of the uniform denſity in the canal, without which the theorems could not have been demonſtrated. The minute quantity of the fluid in the canal can have no ſenſible effect on the diſpoſition or proportion of the fluid in the plates or ſpheres.

This propoſition agrees with hydroſtatical laws.

It may be thought that the laſt corollary, reſpecting the equilibrium of two ſpheres, is not agreeable to hydroſtatical principles, which require the equality of the two forces which balance each other at the orifices of the ſlender cylindric canal; whereas, in that corollary, the forces at the extremities of the canal are inverſely as the diameters of the ſpheres or plates. This would be a valid objection, if the compreſſing forces acted only on the extremities of the canals; but they act on every particle through their whole length. It is not, therefore, the preſſure at one end of the canal that is in equilibrio with the preſſure at the other end, by the interpoſition of the fluid. It is the preſſure at one end, together with the ſum of all the intermediate preſſures in that direction, that is in equilibrio with all the preſſure in the oppoſite direction. The preſſures at the ends are only parts of the whole oppoſite preſſures; they are the firſt in each account. In this manner a ſlender pipe, having a ball at each end, may be kept filled with mercury, while lying horizontal, if the air in each ball is of equal denſity. But if it be raiſed perpendicular to the horizon, it cannot remain filled from end to end, unleſs the air of the ball below be made ſo elaſtic by condenſation, that its preſſure on the lower orifice of the pipe exceed the preſſure of the air in the upper ball on the other orifice by a force equal to the weight of the mercury, that is, to the aggregate of the action of gravity on each particle of mercury in the pipe. Therefore the repulſions of the ſpheres that we are ſpeaking of are in equilibrio by the intervention of the fluid in the canal, in perfect conſiſtency with the laws of hydroſtatical preſſure.

Mr Cavendiſh has purſued this ſubject much farther, and has conſidered the mutual action of more than two bodies, communicating with each other by canals of moveable fluid uniformly denſe. But as we have not room for the whole of his valuable propoſitions, we ſelected thoſe which were elementary and leading theorems, or ſuch as will enable us to explain the moſt important phenomena. They are alſo ſuch, as that the attentive reader will find no difficulty in the inveſtigation of thoſe which we have omitted.

132
General propoſition with reſpect to the ſtate of communicating bodies.

Mr Cavendiſh's moſt general propoſition is as follows:

When an overcharged body communicates, by a canal of *very great* length, ſtraight or crooked, with two or more ſimilar bodies, alſo at a very great diſtance from each other, and all are in electric equilibrium, and conſequently each body overcharged in a certain determined proportion, depending on its magnitude, if any two of theſe bodies are made to communicate in the ſame manner, their degrees of electricity are ſuch, that no fluid will paſs from one to the other, their mutual actions on the fluid in this canal being alſo in equilibrio. He brings out this by induction and combination of the ſingle caſes, each of which he demonſtrates by means of the following theorem:

133 It is indifferent whether the canal be ſtraight or crooked.

The action of an overcharged ſphere ACB (fig. 25.) on the fluid in the whole of a canal df P that is oblique, tending to impel the fluids in the direction of that canal, is equal to its action on the fluid in the whole of the rectilineal canal CP. Let hi be a minute portion of the ſtraight canal, and fd the portion of the crooked canal which is equidiſtant from the centre C of the ſphere; draw the radii Cf, Cd, and the concentric arches hf, id, cutting fC in g; and draw ge perpendicular to fd; the force acting on ih, impelling it toward P, may be repreſented by hi. The ſame force acting on df, in the direction cf, muſt therefore be expreſſed by gf. This, when eſtimated in the direction of the canal df, is reduced to ef; but it is exerted on each particle of df. Now $df : gf = gf : ef$, and $df \times ef = gf^2, = gf \times hi$; therefore the whole force on df, in the direction df, is equal to the force on ih, in the direction ih. Hence the truth of the propoſition is manifeſt.

We beg the curious reader to apply this to the caſe in hand, and he will find that the moſt complicated caſes may all be reduced to the ſimple ones which we have demonſtrated to be ſtrictly true when the bodies are ſpheres or plates, and the canals infinitely long, and which are very nearly true when the canals are *very long*, and the bodies ſimilar: And we now proceed to one compound caſe more, which includes all the moſt remarkable phenomena of electricity.

134 Curious and very important caſe of four plates.

Let HK, AB, DF, and LM (fig. 27.), be four parallel and equal circular plates, two of which, HK and AB, communicate by a canal GC of indefinite extent, joining their centres, and perpendicular to their planes; let DF and LM be connected in the ſame manner, and let the two canals be in one ſtraight line; let the plate HK be overcharged, and the plate LM juſt ſaturated. It is required to determine the diſpoſition and proportion of the electric fluid in the plates which will make this condition of HK and LM poſſible and permanent, every thing being in equilibrio?

The plate HK being overcharged, and communicating with AB, AB muſt be overcharged in the ſame manner; and being alſo equal to HK, it muſt be overcharged in the ſame degree, containing an equal quantity of redundant fluid diſpoſed in the ſame manner. To ſimplify the inveſtigation, we ſhall firſt ſuppoſe that the redundant fluid is uniformly ſpread over the ſurfaces of both.

When the plates HK and AB are in this ſtate, let the plates DF and LM be brought near them, as is repreſented in the figure, CE being the diſtance of the centres of AB and DF. It is evident that the redundant fluid in AB will act on the natural moveable fluid in DF, and drive ſome of it along the canal EN, and render LM overcharged. Take off this redundant fluid in LM. This will diminiſh or annihilate the repulſion which it was beginning to exert on the canal EN; therefore more fluid will come out of DF, and again render LM overcharged. The redundant fluid in LM may again be taken off, in leſs quantity than before, as is plain. Do this repeatedly till no more can be taken off. But this will undoubtedly render DF undercharged, and it will now contain redundant matter. This will act on the fluid in the canal GC, and abſtract it from G; therefore fluid will come out of HK into AB. HK will be leſs overcharged than before, and AB will be more overcharged. But the now increaſed quantity of redundant fluid in AB will act more ſtrongly on the moveable fluid in DF, and drive more out of it. This will leave more redundant matter in it than before, and this will act as before on the fluid in the canal GC. This will go on, by repeatedly touching LM, till at laſt all is in equilibrio. Or this ultimate ſtate may be produced at once by allowing LM to communicate with the ground. And now, in this permanent ſtate of things, HK contains a certain quantity of redundant fluid; AB contains a greater quantity; DF contains redundant matter; and LM contains its natural quantity. The demand of the problem therefore is to determine the proportion of the redundant fluid in HK to that in AB, and the proportion of the redundant fluid in AB to the deficiency of fluid in DF. The dynamical conſiderations which determine theſe proportions are, *1ſt*, The repulſion of the redundant fluid in AB, for the fluid in the canal EN, muſt be preciſely equal to the attraction of the redundant matter in DF for the ſame fluid in the canal; for LM, being ſaturated, is neutral. *2d*, The repulſion of the redundant fluid in HK, for the whole fluid in the canal GC, muſt balance the exceſs of the repulſion of the redundant fluid in AB above the attraction of the redundant matter in DF for the ſame.

Let the redundant fluid in AB be $= f$.
the redundant matter in DF $= m$.
the redundant fluid in HK $= F$.

Becauſe HK and AB are equal, there can be no doubt but that the fluid in thoſe plates would be ſimilarly diſpoſed; and it is highly probable, that if AB be very near DF, the redundant fluid in AB, and the redundant matter in DF, will alſo be diſpoſed nearly in the ſame manner. This will appear plainly when we conſider with attention the forces acting between a very ſmall portion of AB and the correſponding portion of DF. The probability that this is the caſe is ſo evident, that we apprehend it unneceſſary to detail the proofs. We ſhall afterwards conſider ſome circumſtances which ſhew that the diſpoſition in the three plates will (though nearly ſimilar) be nearer to a ſtate of uniform diſtribution than if only AB and HK had been in action. Aſſuming therefore this ſimilarity of diſtribution, it follows, that their actions on the fluid in the canals will be ſimilar, and nearly proportional to their quantities.

Therefore let 1 be to n as the repulſion of the fluid in AB, for the fluid that would occupy CE, is to its repulſion for the fluid in EN or CG.

Then the action of AB on EN is $f \times \overline{n - 1}$, and the action of DF on EN is mn; therefore, becauſe the plate LM is inactive, the actions of AB and DF on EN muſt balance each other, and $f \times \overline{n - 1} = mn$, and $m = f \times \frac{n - 1}{n}$.

The

The repulſion of f for the fluid in CG is $f n$. The attraction of m for it is $m \times \overline{n-1}$; and becauſe $m = f \times \frac{n-1}{n}$, the attraction of m for the fluid in CG is $f \times \overline{\frac{n-1}{n}} \times \overline{n-1}$. Therefore the repulſion of f is to the attraction of m as $f n$ to $f \times \frac{\overline{n-1}^2}{n}$, or as $f n^2$ to $f \times \overline{n-1}^2$, or as n^2 to $\overline{n-1}^2$. Call the repulſion of f r, and the attraction of m a.

We have $r : a = n^2 : \overline{n-1}^2$

and $r : r - a = n^2 : n^2 - (n-1)^2 = n^2 : 2n - 1$.

Therefore, becauſe the repulſion of F is equal to this exceſs of r above a, we have $n^2 : 2n - 1 = f : \mathrm{F}$, and $\mathrm{F} = f\frac{2n-1}{n^2}$, or $f = \mathrm{F}\frac{n^2}{2n-1}$. Therefore, if n^2 is much greater than $2n - 1$, the quantity of redundant fluid in AB will be much greater than the quantity in HK.

135
Prodigious
ccumula-
ion of re-
dundant
luid;

Now, when the electric action is inverſely as the ſquare of the diſtance, and EC is very ſmall in compariſon with AC, we have ſeen (n° 115.) that $1 : n$ nearly $= \mathrm{CE} : \mathrm{CA}$, or that n is nearly $\frac{\mathrm{AC}}{\mathrm{EC}}$. When this is the caſe, and conſequently n is a conſiderable number, we may take the number $\frac{n^2}{2n}$ for $\frac{n^2}{2n-1}$ without any great error. In this caſe f is equal to $\mathrm{F} \times \frac{n}{2}$ very nearly. Suppoſe CA to be ſix inches, and CE to be $\frac{1}{20}$th of an inch; this will give $n = 120$, and $f = 60\,\mathrm{F}$; or, more exactly, $\mathrm{F} = \frac{n^2}{2n-1} = \frac{14{,}400}{239}$; $= 60\frac{1}{4}$. If, inſtead of the plate HK, we employ a globe of the ſame diameter, f will be but half of this quantity, or $f = \mathrm{F} \times \frac{n}{4}$ (n° 123, 124.)

136
And evacu-
ation:

It alſo appears, that when the plates AB and DF are very near to each other, and conſequently n a large number, the deficiency in DF is very nearly equal to the redundancy in AB. In the example now given, m is $\frac{59}{60}$ of f, being $= f \times \overline{n-1}$.

137
Yet no very
ſenſible ap-
pearance.

Yet this great deficiency in DF does not make it electrical on the ſide toward LM. It is juſt ſo much evacuated that a particle of fluid at its ſurface has no tendency to enter or to quit it.

Laſtly, this great quantity of fluid collected in AB does not render it more electrical than HK.

In general, things are in the condition treated of in n° 22, 23, &c.

The attentive reader will readily ſee, that this account of the apparatus of four plates is only an approximation to the condition that readily obtains under our obſervation. Our canals are not of indefinite length, nor occupied by fluid that is diſtributed with perfect uniformity; nor is the fluid uniformly ſpread over the ſurface of the plates. He will alſo ſee, that the real ſtate of things, as they occur in our experiments, tends to diminiſh the great diſproportion which this imaginary ſtatement determines. But when the canals are very long in compariſon with the diameters of the plates, and AB is very near to DF, the difference from this determination is inconſiderable. We ſhall note theſe differences when we conſider the remarkable phenomena that are explained by them.

In the mean time, we ſhall juſt mention ſome ſimple conſequences of the preſent combination of plates.

138
Method
of deſtroy-
ing this
great accu-
mulation:
1. By de-
grees;

Suppoſe AB touched by a body. Electric fluid will be communicated; but by no means all the redundant fluid contained in AB: only as much will quit it as will reduce it to a neutral ſtate, if the body which touches it communicates with the ground; that is, till the attraction in the redundant matter in DF attracts fluid on the remote ſide of AB as much as the redundant fluid left in AB repels it. When this has been done, DF is no longer neutral; for the repulſion of AB for the fluid in EN is now diminiſhed, and therefore the attraction of DF will prevail. If we now touch DF, it may again become neutral with reſpect to EN; but AB will now repel again the fluid in CG, and again be electric on that ſide by redundancy. Touching AB a ſecond time takes more fluid from it, and DF again becomes electric by deficiency, and attracts fluid on that ſide.—And thus, by repeatedly touching AB and DF alternately, the great accumulation of fluid in AB may be exhauſted, and the nearly equal deficiency in DF may be made up.

139
2. All at
once.

But this may be done in a much more expeditious way. Suppoſe a ſlender conducting canal $a\,b\,d$ brought very near to the outſides of the plates, the end a being near to A, and the end d to D. The vicinity of a to A cauſes the fluid in $a\,b$ to recede a little from a by the repulſion of the redundant fluid in AB. This will leave redundant matter in a, which will ſtrongly attract the redundant fluid from A, and a may receive a ſpark. But the conſequence, even of a nearer approach of the fluid to the outward ſurface of A, will render the correſponding part of DF more attractive, and the retiring of fluid from a along $a\,b$ will puſh ſome of its natural fluid toward d; and thus A becomes more diſpoſed to give out, and a to take it in, while d is diſpoſed to emit, and D to attract. Thus every circumſtance favours the paſſage of the whole, or almoſt the whole, redundant fluid to quit AB at A, to go along $a\,b\,d$, and to enter into DF at D.

140
The plates
ſtrongly at-
tract each
other.

It is plain that there muſt be a ſtrong tendency in the fluid in AB to go into DF, and that the plates muſt ſtrongly attract each other. A particle of fluid ſituated between them tends toward DF with a force, which is to the ſole repulſion of AB nearly as twice the redundant fluid in it to what it would contain if electrified to the ſame degree while ſtanding alone.

With this particular and remarkable caſe of induced electricity, we ſhall conclude our explanation of Mr Æpinus's Theory of Electric Attraction and Rupulſion. The reader will recollect, that we began the conſideration of the diſpoſition of the electric fluid in bodies, in order to deduce ſuch legitimate conſequences of the hypothetical law of action as we could compare with the phenomena.

141
Method of
examining
the validity
of this the-
ory.

Theſe compariſons are abundantly ſupplied by the preceding paragraphs, particularly by n° 74, 75, 76; by n° 130, and by n° 134.

Let a ſmooth metal ſphere be electrified poſitively in any manner whatever, and then touch it with a ſmall one in its natural ſtate. The redundant fluid is divided between them in a proportion which the theory determines with accuracy. By the theory alſo the redundant fluid in both acts as if collected in the centre. Therefore the proportion of the repulſions is determined. Theſe can be examined by our electrometer. But as this menſuration may be ſaid to depend on the truth of the theory, we may examine this independent of it Let the balls be equal. Then the redundant fluid is divided equally between the bodies, whatever be the law of action. Therefore obſerve the electrometer, as it is affected by the electrified body, both before and after the communication. This will give the poſitions of the electrometer which correſpond to the quantities 2 and 1.

142 Graduation of electrometer. Take off the electricity of one of the balls by touching it, and then touch the other ball with it. This will reduce to $\frac{1}{2}$ the original quantity $\frac{1}{2}$, and therefore to $\frac{1}{4}$th of the original quantity. This will determine the value of another poſition of the electrometer. In like manner, we obtain $\frac{1}{8}$th, $\frac{1}{16}$th, &c. &c. Then, by touching a ball containing 1 with a ball containing $\frac{1}{2}$, we get a poſition for $\frac{3}{1}$, $\frac{3}{2}$, $\frac{3}{8}$, &c. Proceeding in this way, we graduate our electrometer independently of all theory, and can now examine the electricity of bodies with confidence. The writer of this article took this method of examining his electrometer, not having then ſeen Mr Cavendiſh's diſſertation, which gives another mode of meaſurement. He had the ſatisfaction of obſerving, in the firſt place, that the poſitions of the inſtrument, which unqueſtionably indicated 1, $\frac{1}{2}$, $\frac{1}{4}$, &c. were preciſely thoſe which ſhould indicate them if electric repulſion be inverſely as the ſquares of the diſtances. Having thus examined the electrometer, it was eaſy to give to balls any propoſed degree of electricity, and then make a communication between balls of very different diameters. The electrometer informed us when the repeated abſtractions by a ſmall ball reduced the electricity of a large ball to $\frac{1}{2}$, $\frac{1}{4}$, &c. This ſhewed the proportion of electricity contained in balls of different diameters. This was alſo found to be ſuch as reſulted from an action in the inverſe duplicate ratio of the diſtances.

143. Long after this, Mr Cavendiſh's inveſtigation pointed out the proportion of the redundant electric fluid in balls of different ſizes joined by long wires; in n° 130, &c. theſe were examined—and found to be ſuch as were ſo indicated by the electrometer.

144. And, laſtly, the mode of accumulating great quantities of fluid by means of parallel plates, gave a third way of confronting the hypothetical law with experiment. The argument was no leſs ſatisfactory in this caſe; but the examination required attention to particulars not yet mentioned, which made the proportions between the fluid in HK and AB (fig 27.) widely different from thoſe mentioned in the preceding paragraphs. Theſe circumſtances are among the moſt curious and important in the whole ſtudy, and will be conſidered in their place.

145 The law of electric action is well determined. We reſt therefore with confidence on the truth of the law of electric action, aſſumed by us as a principle of explanation and inveſtigation. It is quite needleſs and unprofitable to give any detail of the numerous experiments in which we confronted it with the phenomena. The ſcrupulous reader will get ample ſatisfaction from the excellent experiments of Mr Coulomb with his delicate electrometer. He will find them in the Memoirs of the Academy of Sciences of Paris for 1784, 1785, 1786, and 1787. Some of them are of the ſame kind with thoſe employed by the writer of this article; others are of a different kind; and many are directed to another object, extremely curious and important in this ſtudy, namely, to diſcover how the electric fluid is diſpoſed in bodies; and a third ſet are directed to an examination of the manner in which the electric fluid is diſſipated along imperfect conductors.

But we have already drawn this article to a great length, and muſt bring it to an end, by explaining ſome very remarkable phenomena, namely, the operation of the Leyden phial, the operation of the electrophorus, and the diſſipation of electricity by ſharp points and by imperfect conductors.

146 Of the Leyden phial. The obſervations of Mr Watſon on the neceſſity of connecting the rubber of an electrical machine with the ground, might have ſuggeſted to philoſophers the doctrine of *plus* and *minus* electricity, eſpecially after the valuable diſcoveries of Mr Symmer and Cigna. A ſerious conſideration of theſe general facts would have led to the theory of coated glaſs almoſt at its firſt appearance. But the hiſtorical fact was otherwiſe; and a conſiderable time elapſed betwen the firſt experiments with charged glaſs by Kleiſt, and the clear and ſatisfactory account given by Dr Franklin, of all the eſſential parts of the apparatus, and the probable procedure of nature in the phenomenon. The impermeability of glaſs by the electric fluid, and the conſequent abſtraction of it from the one ſide while it was accumulated on the other, ſuggeſted to his acute mind the leading principle of electrical philoſophy; namely, that all the phenomena ariſe from the redundancy or deficiency of electric fluid, and that a certain quantity of it reſides naturally in all bodies in a ſtate of uniform diſtribution, and, in this ſtate, produces no ſenſible effect. This was, in his hands, the inlet to the whole ſcience; and the greateſt part of what has been ſince added is a more diſtinct explanation how the redundancy or deficiency of electric fluid produces the obſerved phenomena. Dr Franklin deduced this leading principle from obſerving, that as faſt as one ſide of a glaſs plate was electrified poſitively, the other ſide appeared negative, and that, unleſs the electricity of that ſide was communicated to other bodies, the other ſide could be no farther electrified. Having formed this opinion, the old obſervations of Watſon, Symmer, and Cigna, were explained at once, and the explanation of the Leyden phial would have come in courſe. It is for theſe reaſons, as much as for the important diſcovery of the ſameneſs of electricity and of thunder, that Dr Franklin ſtands ſo high in the rank of philoſophers, and is juſtly conſidered as the author of this department of natural ſcience. Whatever credit may be due to the chemical ſpeculations of De Luc, Wilcke, Winkler, and many others, who have attempted to aſſociate electricity with other operations of nature, by reſolving the electric fluid into its conſtituent parts, all their explanations preſuppoſe a mathematical and mechanical doctrine concerning the mode of action of the ingredients, which will either account for the total inactivity of the compound, or which will explain, in the very ſame manner, the action of the compound itſelf: yet all ſeem to

to content themſelves with a vague and indiſtinct notion of this preliminary ſtep, and have allowed themſelves to ſpeak of electrical atmoſpheres, and ſpheres of activity, and ſuch other creatures of the mind, without once taking the trouble of conſidering whether thoſe aſſumptions afforded any real explanation. How different was Newton's conduct. When he diſcovered that the planets attracted each other in the inverſe duplicate ratio of the diſtances, and that terreſtrial gravity was an inſtance of the ſame force, and that *therefore* the deflection of the earth was the effect of the accumulated weight of all its parts; he did not raſhly affirm this of the planets, till he examined what would be the effect of the accumulated attraction in the abovementioned proportion.

147. Mr Æpinus has the honour of firſt treading in the ſteps of our illuſtrious countryman; and he has done it with ſingular ſucceſs in the explanation of the phenomena of attraction and repulſion, as we have already ſeen. In no part of the ſtudy has his ſucceſs been ſo conſpicuous as in the explanation of the curious and important phenomena of the Leyden phial. It only remained for him to account for the accumulation of ſuch a prodigious quantity of this agent as was competent to the production of effects which ſeemed to exceed the ſimilar effects in other caſes, out of all proportion. Indeed, the diſproportion is ſo great, as to make them appear to be of a different and incomparable nature. Dr Wilſon's experiments in the pantheon are therefore precious, by ſhewing that nothing was wanted for the production of all the effects of the Leyden phial but a ſurface ſufficiently extenſive for containing a vaſt quantity of fluid, and ſo perfectly conducting as to admit of its ſimultaneous and rapid transference. Therefore we aſſert that one of the chief merits of Mr Æpinus's theory is the ſatisfactory explanation of the accumulation of this vaſt quantity of fluid in a ſmall ſpace. We truſt, therefore, that our readers will peruſe it with pleaſure. But we muſt here obſerve, that Mr Æpinus has not expreſsly done this in his work which we have already made ſo much uſe of, nor in any other that we know of. He has gone no farther than to point out to the mathematicians, that his hypotheſis is adequate to the accounting for any degree of accumulation whatever. This he does in that part of his work which contains the formulæ of n° 38, 39, 40, 41, &c. And he afterwards ſhews, that all the phenomena of attraction and repulſion which are obſerved in the charged jar are preciſely ſuch as are neceſſary conſequences of his theory.

148 Theory of charged glaſs completed by Mr Cavendiſh.

It is to the Hon. Mr Cavendiſh that we are indebted for the ſatisfactory, the complete (and we may call it *the popular*), explanation of all the phenomena. Forming to himſelf the ſame notion of the mechanical properties of the electric fluid with Mr Æpinus, he examined, with the patience, and much of the addreſs, of a Newton, the action of ſuch a fluid on the fluid around it, and the ſenſible effects on the bodies in which it reſided; the diſpoſition of it in a conſiderable variety of caſes; and particularly its action on the fluid contained in ſlender canals and in parallel plates;—till he arrived at a ſituation of things ſimilar to the Leyden phial. And he then pointed out the preciſe degree of accumulation that was attainable, on different ſuppoſitions concerning the law of electric action in general. We have given an abſtract of this inveſtigation accommodated to the inverſe duplicate ratio of the diſtances.

149. From this it appears (n° 135), that whatever quantity of electric fluid we can put into a circular plate 12 inches in diameter, by ſimple communication with the prime conductor of an electrical machine, we can accumulate 60 times as much in it by bringing the plate within $\frac{1}{10}$th of an inch of another equal plate which communicates with the ground; and it appears in n° 139, that all this accumulated fluid may be transferred in an inſtant to the other plate (which is ſhewn to be almoſt equally deprived of fluid), by connecting the two plates by a ſmall wire.

But as it was alſo ſhewn in that paragraph, that the force with which the accumulated fluid was attracted by the redundant matter in the other plate was exceedingly great, and conſequently its tendency to eſcape was proportionably increaſed; this accumulation cannot be obtained unleſs we can prevent this ſpontaneous transference.

150 Inexplicable by material atmoſpheres.

Here the non-conducting power of idio-electrics, without any diminution, the action of the electric fluid on fluid or matter on the other ſide of them, comes to our aid, and we at once think of interpoſing a plate of glaſs, or wax, or roſin, or any other electric, between our conducting plates. Such is the immediate ſuggeſtion of a perſon's mind who entertains the Æpinian notion of the electric fluid; and ſuch, we are convinced, is the thought of all who imagine that they underſtand the phenomena of the Leyden phial. But thoſe who attempt to explain electric action by means of what they call electric atmoſphere of variable denſity or intenſity, are not intitled to make any ſuch inference, nor to expect any ſuch phenomena as the Leyden phial exhibits. Electricity, they ſay, acts by the intervention of atmoſpheres: Therefore, whatever allows the propagation of this action (conceive it in any manner whatever), allows the propagation of theſe agents; and whatever does not conduct electric action, does not conduct the agents. Interpoſed glaſs ſhould therefore prevent all action on the other plate. This is true, even although it were poſſible (which we think it is not) to form a clear notion of the free paſſage of this material atmoſphere in an inſtant, and this without any diminution of its quantity, and conſequently of its action, by the diſplacement of ſo much of it by the ſolid matter of the body which it penetrates. Yet without this undiminiſhed action of the electrified plate on the fluid, and on the matter, beyond the glaſs, and on the canal by which its fluid may be driven off into the general maſs—no ſuch accumulation can take place; and if the phenomena of the Leyden phial are agreeable to the reſults of the Æpinian hypotheſis, all explanation by atmoſpheres muſt be abandoned. Indeed when the partiſans of the atmoſpheres attempt to explain their conceptions of them, they do not appear to differ from what are called *ſpheres of activity* (a phraſe firſt uſed by Dr Gilbert of Colcheſter, in his celebrated work *De Magnete et Corporibus Magneticis*): and ſpheres of activity will be found nothing more than a figurative expreſſion of ſome indiſtinct conception of *action in every direction*. When we uſe the words *attraction* and *repulſion*, we do not ſpeak a whit more figuratively than when we uſe the general word *action*. Theſe terms are all figurative, only *attraction* and *repulſion* have the advantage

vantage of ſpecifying the *direction* in which we conceive the *action* to be exerted.

It therefore becomes ſtill more intereſting to the philoſopher to compare the phenomena of CHARGED GLASS with the Æpinian theory. They afford an *experimentum crucis* in the queſtion about electric atmoſpheres.

151 Phenomena of charged glaſs explained.

Let G (fig. 28.) repreſent the end of a prime conductor, furniſhed with Henley's electrometer. Let AB repreſent a round plate of tinfoil, paſted on a pane of glaſs which exceeds the tinfoil about two inches all round. The pane is fixed in a wooden foot, that it may ſtand upright, and be ſhifted to any diſtance from the conductor. DF repreſents another plate of the ſame dimenſions as AB, in the centre of which is a wire EN, having a ſmall ball on the end N, to which is attached a Canton's electrometer. This wire paſſes through the wooden ball O, faſtened to the inſulating ſtand P. The glaſs pane muſt be very clean, dry, and warm. Connect the conductor G with AB by a wire reaching to the centre C. Turn the cylinder of the electrical machine ſlowly, till the electrometer riſe to 30° or 40°, and note the number of turns. Take off the electricity; and having taken away the connecting wire GC, turn the machine again till the electrometer riſe to the ſame height. The difference in the number of turns will give ſome notion of the expenditure of fluid neceſſary for electrifying the plate of tinfoil alone. This will be found to be very trifling when the electricity is in ſo moderate a degree. It is proper, however, to keep to this moderate degree of electrification, becauſe when it is much higher, the diſſipation from the edges of the plate is very great. Replace the wire, and again raiſe the electrometer to 30°. Now bring forward the plate DF, keeping it duly oppoſite and parallel to AB, and taking care not to touch it. It will produce no ſenſible change on the poſition of the electrometer till it come within four or three inches of the glaſs pane; and even when we bring it much nearer (if a ſpark do not fly from the glaſs pane to DF), the electrometer HG will ſink but two or three degrees, and the electrometer at N will be little affected. Now remove the plate DF again to the diſtance of two or three feet, and attach to its ball N a bit of chain, or ſilver or gold thread, which will trail on the table. Again, raiſe the electrometer to 30°, and bring DF gradually forward to AB. The electrometer HG will gradually fall down, but will riſe to its former height, if DF be withdrawn to its firſt ſituation. It is ſcarcely neceſſary to ſhew the conformity of this to the theory contained in n° 134, 135, &c. As the plate DF approaches, the redundant fluid in AB acts on the fluid in DF, and drives it to the remote end of the wire EN, as was ſhewn by the divergency of the balls at N; and then an accumulation begins in AB, and the electrometer HG falls in the ſame manner as if part of the fluid in the prime conductor were communicated to AB. When DF communicates with the ground, the electrometer at N cannot ſhew any electricity, but much more fluid is now driven out of DF, in proportion as it is brought nearer to AB. Inſtead of connecting AB immediately with the prime conductor, let the wire GC have a plate at the end G, of the ſame dimenſions as AB, having an electrometer attached to the ſide next to AB. Let this apparatus of two plates be electrified anyhow, and note the divergency of the electrometer at H, before DF, communicating with the ground, is brought near it, and then attend to the changes. We ſhall find the divergency of this electrometer correſpond with the diſtance of DF very nearly as the theory requires.

152 State of the coatings.

While the plates AB and DF are near each other, eſpecially when DF communicates with the ground, if we hang a pith-ball between them by a ſilk thread, it will be ſtrongly attracted by the plate which is neareſt to it, whether DF or AB; and having touched it, it will be briſkly repelled, and attracted by the glaſs pane, which will repel it after contact, to be again attracted and repelled by DF; and thus bandied between the plates till all electricity diſappear in both, the electrometer attached to H deſcending gradually all the while.

153. As all theſe phenomena are more remarkable in proportion as the plates are brought nearer, they are moſt of all when DF is applied cloſe to the glaſs pane. And if, in this ſituation, we take any accurate method for meaſuring the intenſity of the electricity in the plate HG, before the approach of DF, we ſhall find the diminution, occaſioned by its coming into full contact with the pane, conſiderably greater than what is pointed out in n° 135. When we employed plates of 12 inches diameter, paſted on a pane one fortieth of an inch in thickneſs, we found the diminution not leſs than 199 parts of 200; and we found that it required at leaſt 200 times the revolution of the cylinder to raiſe the electrometer to the ſame height as before. This compariſon is not ſuſceptible of great accuracy, by reaſon of many circumſtances, which will occur to an electrician. But in all the trials we have made, we are certain that the accumulation greatly exceeded that pointed out by the Æpinian theory as improved by Mr Cavendiſh. And we muſt here obſerve, that we found this ſuperiority more remarkable in ſome kinds of glaſs than others, and more remarkable in ſome other idioelectrics. We think that, in general, it was moſt remarkable in the coarſe kinds of glaſs, provided they were uniformly tranſparent. We found it moſt remarkable in ſome common glaſs which had exfoliated greatly by the weather; but we alſo found that ſuch glaſſes were very apt to be burſt by the charge. The hardeſt and beſt London crown-glaſs ſeemed to accumulate leſs than any other; and a coloured glaſs, which when viewed by reflection ſeemed quite opake, but appeared brown by tranſmitted light, admitted an accumulation *greatly* exceeding all that we have tried; but it could not be charged much higher without the certainty of being burſt. This diverſity in the accumulation, which may be made in different kinds of glaſs, hinders us from comparing the *abſolute* accumulations aſſigned by the theory with thoſe which experiment gives us. But though we cannot make this compariſon, we can make others which are equally ſatisfactory. We can diſcover what proportion there is between the accumulation in glaſs of the ſame kind, as it may differ in thickneſs and in extent of ſurface. Uſing mirror glaſs, which is of uniform and meaſurable thickneſs, and very flat plates, which come into accurate or equable contact—we found that the accumulation is inverſely as the thickneſs of the plates; but with this exception, that when two plates were uſed inſtead of a plate of double thickneſs, the diminution by the increaſe of thickneſs was not nearly in the proportion of this increaſe. Inſtead

ſtead of being reduced to one half, it was more than two-thirds; and in the kind called Dutch plate, the diminution was inconſiderable.

154
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The experiments with the Dutch and other double plates, ſuggeſted another inſtructive and pretty experiment. Obſerving theſe plates to cohere with conſiderable force, it was thought worth while to meaſure it; which was attempted in this manner: Two very flat braſs plates AB, DF (fig. 29.) furniſhed with wires and balls, were ſuſpended. about three inches aſunder, by ſilk threads, as repreſented in the figure. At G was attached a very fine ſilver wire, which hung very looſe between it and the prime conductor, without coming near the table. Another was attached to N, which touched the table. A plate of mirror glaſs was ſet between them, as ſhewn by QR. When this apparatus was electrified, the threads of ſuſpenſion immediately began to deviate from the perpendicular, and the plates to approach the glaſs pane and each other. The pane was carefully ſhifted, ſo as to be kept in the exact middle between them. This reſult ſhewed very plainly the preſſure of the fluid on one of the plates, and the mutual attraction of the redundant matter and redundant fluid. This increaſed as the accumulation increaſed; and it was attempted to compare the attraction with the accumulation, by comparing the deviation of the ſuſpending threads with that of the electrometer attached to the prime conductor; but we could not reconcile the ſeries (which, however, was extremely regular) with the law of electric action. This harmony was probably diſturbed by the force employed in raiſing the ſilver wires. When more flexible ſilver threads were uſed, much was loſt by diſſipation from the roughneſs of the thread. We did not think of employing a fine flaxen thread moiſtened: but, indeed, an agreement was hardly to be expected; becauſe theory teaches us, that the diſtribution of the redundant fluid in AB will be extremely different from the diſtribution of the redundant matter in DF, till the plates come very near each other. The accumulation in AB depends greatly on the law of diſtribution, being leſs (with any degree of redundancy) when the fluid is denſer near the centre of the plate. Other circumſtances concurred to diſturb this trial; but the theory was abundantly confirmed by the experiment, which ſhewed the ſtrong attraction ariſing from the accumulation. This was ſo great, that although the plates were only three inches in diameter, and the glaſs pane was $\frac{1}{12}$ of an inch thick, and the threads deviated about 18 degrees from the perpendicular—it required above an ounce weight, hung on the wire EN, to ſeparate the plates from the glaſs.

155
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ow it is
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The experienced electrician need not be told, that by bringing the two ends of a bent wire in contact with the two plates (firſt touching DF with it) diſcharges the apparatus, and cauſes the plates to drop off from the pane. But he may farther obſerve, that if there be attached to each end of the diſcharging wire a downy feather, and if he firſt bring the end near the plate DF, and obſerve the feather to be not at all, or but a very little, affected, and if he then bend round the other end toward the plate AB, *both feathers* will immediately ſtretch out their fibres to the plates, and cling faſt to them, long before the diſcharging ſpark is ſeen. This is a fine proof of the proceſs of diſcharge, which begins by the induction of electricity on the ends of the diſcharging wire; firſt, negative electricity on the end that approaches A, and, in the ſame inſtant, oppoſite electricities at D and the adjoining end of the wire.

156
Beautiful and inſtructive experiment by Profeſſor Richmann.

The following obſervation of Profeſſor Richmann of St Peterſburgh (the gentleman who fell a ſacrifice to electrical ſtudies by a thunder ſtroke from his apparatus) is extremely inſtructive and amuſing. Let a glaſs pane be coated on both ſides, and furniſhed with a ſmall electrometer attached to the coatings. It is repreſented as if ſeen edgewiſe in fig. 30. Let it be charged poſitively (that is, by redundancy) by the coating AB, while DF communicates with the ground. The electrometer A a will ſtand out from the plate, and D d will hang down cloſe by its coating, as long as DF communicates with the ground. But as the electricity gradually diſſipates by communication to the contiguous air, the ball a will gradually, but very ſlowly, fall down. We may judge of the intenſity of the remaining electricity by the deviation of the electrometer, and we may conceive this deviation divided into degrees, indicating not angles, but intenſities, which we conceive as proportional to the redundancy or deficiency which occaſion them.

If we take away the communication with the ground, we ſhall obſerve the ball a fall down very ſpeedily, and then more ſlowly, till it reach about half of its firſt elevation. The ball d will at the ſame time riſe to nearly the ſame height; the angle between the two electrometers continuing nearly the ſame as at firſt. When a has ceaſed to riſe, both balls will very ſlowly deſcend, till the charge is loſt by diſſipation. If we touch DF during this deſcent, d will immediately fall down, and a will as ſuddenly riſe nearly as much; the angle between the electrometers continuing nearly the ſame. Remove the finger from DF, and a will fall, and d will riſe, to nearly their former places; and the ſlow deſcent of both will again continue. The ſame thing will happen if we touch AB; a will fall down cloſe to the plate, and d will riſe, &c. And this alternate touching of the coatings may be repeated ſome hundreds of times before the plate be diſcharged. If we ſuſpend a crooked wire $v\ m\ u$, having two pith balls v and u from an inſulated point m above the plate, it will vibrate with great rapidity, the balls ſtriking the coatings alternately; and thus reſtoring the equilibrium by ſteps. Each ſtroke is accompanied by a ſpark.

Theory of it.

All theſe phenomena are not only conſequences of the theory, but their meaſures agree preciſely with the computations deduced from the formulæ in nº 22, 23, 24, accommodated to the caſe by means of nº 135 and 136, as we have verified by repeated trials. But it would occupy much room to trace the agreement here, and would fatigue ſuch readers as are not familiarly converſant with fluxionary calculations. The inquiſitive reader will get full conviction by peruſing Epinus's Eſſay, Appendix i. A very diſtinct notion may be conceived of the whole proceſs, by ſuppoſing that in a minute AB loſes $\frac{1}{10}$th of the unbalanced redundancy actually in it, and conſequently diminiſhes as much in its action. It will be proved afterwards, that the diſſipations in equal times are really in proportion to the ſuperficial repulſions then exerted. We may alſo ſuppoſe, that the action of the redundant fluid, or redundant matter, in either coating, on the external fluid contiguous to it, is to its action on the fluid contiguous to the

the other coating in the conſtant proportion of 10 to 9. We ſelect this proportion for the ſimplicity of the computation. Then the difference of theſe actions is always $\frac{1}{10}$th of the full action on the fluid contiguous to it. This is alſo an exact ſuppoſition in ſome particular caſe, depending on the breadth of the coating and the thickneſs of the pane.

Now, let the primitive unbalanced repulſion between AB and the contiguous fluid of the electrometer be 100, while DF communicates with the ground. The ball *a* will ſtand at 100; the ball *d* will hang touching DF. Then *a*, by loſing $\frac{1}{10}$th, retains only 90, and would ſink to 90°: But as this deſtroys the equilibrium on the other ſide, fluid will enter into DF, ſo as to reduce the deficiency $\frac{1}{10}$th. Therefore nine degrees of fluid will enter; and its action on *a* will be the ſame as if $\frac{9}{10}$ths of 9, or 8,1 had been reſtored to AB. Therefore *a* will riſe from 90 to 98,1; or it will ſink in one minute from 100 to 98,1.

But if we have cut off the communication of DF with the ground, this quantity of fluid cannot come into DF; and the quantity which really comes into it from the air will be to that which eſcapes from A as the attraction on the ſide of DF to the repulſion on the ſide of AB. By the diminution of the repulſion $\frac{1}{10}$th, and the want of 9 degrees of fluid in DF to balance it, DF acquires an attraction for fluid which may be called 9. Therefore, ſince $\frac{1}{10}$th of the primitive repulſion of AB has diſſipated 10 meaſures of fluid in the minute, the attraction of DF will cauſe it to acquire $\frac{1}{10}$th of 9, or 0,9, from the air in the ſame minute. At the end of the minute, therefore, there remains an unbalanced attraction for fluid = 8,1; and conſequently an unbalanced repulſion between the redundant matter in DF, and that in the ball *d*. Therefore *d* will riſe to 8,1. But *a* cannot now be at 98,1; becauſe DF has not acquired 9 meaſures of fluid, but only $\frac{9}{10}$ths of one meaſure. Therefore *a*, inſtead of riſing from 90 to 98,1, will only riſe to 90 + $\frac{9}{10}$ths × $\frac{9}{10}$ths; that is, to 90,81.

At the cloſe of the minute, therefore, *a* is at 90,81, and *d* is at 8,1, and their diſtance is 98,91. In the next minute, AB will loſe $\frac{1}{10}$th of the remaining unbalanced electricity of that ſide, and DF will now acquire a greater proportion than before; becauſe its former unbalanced attraction gets an addition equal to $\frac{9}{10}$ths of the loſs of AB. This will make a larger compenſation in the action on *a*, and *a* will not fall ſo much as before. And becauſe in the ſucceeding minutes the attraction of DF for fluid is increaſing, and the repulſion of AB is diminiſhing, the compenſation in the action on *a*, by the increaſed attraction of DF, continues to increaſe, and the deſcent of *a* grows continually ſlower; conſequently a time muſt come, when the repulſion of AB for fluid is to the attraction of DF for it, nearly in the proportion of 10 to 9. When this ſtate obtains, *d* will riſe no more; becauſe the receipt of fluid by DF, being now $\frac{9}{10}$ths of the loſs by AB, it will exactly compenſate the additional attraction of DF for fluid, occaſioned by that loſs. The next loſs by AB not being ſo great, and the next receipt by DF continuing the ſame, by reaſon of its undiminiſhed attraction, there will be a greater compenſation in the action on *a*, which will prevent its deſcending ſo faſt; and there will be more than a compenſation for the additional attraction of DF for fluid: that is, the fluid which has now come into DF will render it, and alſo the ball *d*, leſs negative than before; and therefore they will not repel ſo ſtrongly. Therefore *d* muſt now deſcend. It is evident, that ſimilar reaſons will ſtill ſubſiſt for the ſlow deſcent of *a*, and the ſlower deſcent of *d*, till all redundancy and deficiency are at an end.

This maximum of the elevation of *d* happens when *a* has deſcended about one half of its elevation; that is, when the unbalanced repulſion of AB is reduced to about one-half. For if one-half of the unbalanced fluid be really taken out of AB, and if DF can get no ſupply whatever, it muſt acquire an attraction correſponding to $\frac{9}{10}$ths of this; and if the ſupply by the air be now opened to it, things will go on in the way already deſcribed, till all is diſcharged.

This account of the proceſs is only an approximation; becauſe we have ſuppoſed the changes to happen in a deſultory manner, as in the popular way of explaining the acceleration of gravity. The riſe of *d* is not at an end till the attraction of DF for fluid is to the repulſion of AB as 19 to 20.

But if we interrupt this progreſs in any period of it, by touching DF, we immediately render it neutral, and *d* falls quite down, in conſequence of receiving a complete ſupply of fluid. But this muſt change the ſtate of AB, and cauſe it to riſe $\frac{9}{10}$ths of the deſcent of *d*. As *a* and *d* were nearly at an equal height before DF was touched, it is plain that *a* will riſe to nearly twice its preſent height; after which, the ſame ſeries of phenomena will be repeated as ſoon as the finger is removed from DF.

If, inſtead of touching DF, we touch AB, the ſame things muſt happen; *a* muſt fall down, and *d* muſt riſe to nearly twice its preſent height, and all will go on as before, after removing the finger. Laſtly, if inſtead of allowing either ſide to touch the *ground* alternately, we only touch it with a *ſmall inſulated body*, ſuch as the wire with the balls *v* and *u*, the ball attached to the ſide touched ſinks, till the electricity is ſhared between the coating and the wire with balls. The ball attached to the other coating riſes $\frac{9}{10}$ths of the ſinking of the firſt ball. The crooked wire ball is now repelled by the coating which it touched, and the other ball is brought near to the other coating, and muſt be attracted by it, becauſe the electricities are oppoſite. This operation evidently tends to transfer the redundant fluid *by degrees* to the ſide where it is deficient. It needs no explanation. We ſhall only mention a thing which we have always obſerved, without being able to account for it. The vibration of the wire acquires a certain rapidity, which continues for a long while, and ſuddenly accelerates greatly, and immediately afterwards ceaſes altogether.

This pretty experiment of Profeſſor Richmann will be found very inſtructive; and will enable us to underſtand the operation of the electrophorus, and to ſee the great miſtake of thoſe who ſay that it is perfectly ſimilar to a diſcharged glaſs plate.

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Electric action *e diſtanti* demonſtrated.

Thus, then, we ſee, that all the claſſes of phenomena, connected with attraction and repulſion, are preciſely ſuch as would reſult from the action of a fluid ſo conſtituted. The complete undiminiſhed action of the cauſe of thoſe phenomena on the other ſide of the interpoſed non-conductor of that cauſe is demonſtrated, and all

all explanation by the mechanical action of material elaſtic atmoſpheres of variable denſity muſt be abandoned, and the infinitely ſimpler explanation by the attractive and repulſive forces of the fluid itſelf muſt be preferred.

So happily does the Franklinian theory of poſitive and negative electricity explain the phenomena, when a ſuitable notion is formed of the manner of action of this fluid. We cannot but think that this is attained, when, to the general doctrine of Æpinus, we add the ſpecification of the law of action, ſo fully verified by the experiments of Mr Coulomb, which are in the hands of the public, and are of that ſimple nature that any careful experimenter can convince himſelf of their accuracy (See n° 144.) We may therefore proceed with ſome confidence, and apply this doctrine even to caſes where experiment does not offer itſelf for proof.

158
Franklin miſtaken in ſuppoſing that a charged plate contains its natural quantity of fluid.

Dr Franklin affirms that electric fluid cannot be thrown into one ſide of the coated pane unleſs it be abſtracted from the other; and that therefore the charged glaſs contains no more than it did before charging. We indeed find that we cannot *charge* the inſide, if the outſide do not communicate with the ground. He proves it alſo by ſaying, that if a perſon, when inſulated, diſcharges a glaſs through his own body, he is not found electrified: And he infers, as a neceſſary conſequence of this, that a ſeries of any number of jars may be charged by the ſame turns of a machine, if we make the outſide of the firſt communicate with the inſide of the ſecond, and the outſide of the ſecond with the inſide of the third; and ſo on; and the outſide of the laſt communicate with the ground. Having made the trial, and having found that more turns of the machine were neceſſary, he attributes this to diſſipation into the air by the communication. But our theory teaches us otherwiſe. We learn from it, that the redundant matter in the plate DF is leſs than the redundant fluid in AB, in the proportion of $n - 1$ to n; and therefore the redundant fluid in the overcharged ſide of the next plate is no greater. The charge or redundancy in the mth jar of the ſeries will therefore be $\left.\overline{\frac{n - 1}{n}}\right|^{m}$. Thus, if n, or the charge of the firſt jar, be 60, the charge of the 10th jar will be nearly 51. Although a coated plate cannot be *charged* unleſs one of the coatings communicate with the ground, it may be *electrified* as much as one of the coatings can be alone. And this is ſeen in our attempt to charge it: For as ſoon as we attempt to electrify one ſide, the other is electrified alſo; for it gives a ſpark which no unelectrified body will do. Alſo, when we diſcharge a jar by an inſulated diſcharger, we always leave it electrical in the ſame way with the body from which it was charged. If a man is not found electrified after having diſcharged a jar through his own body, it is owing to the great ſurface of his body, which reduces the ſimple electrification of a ſide of the jar to a very inſignificant and inſenſible quantity.

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iſtake of ilcke's.

Wilcke (and we believe Franklin before him) maintains, that when the jar has been charged, by connecting one ſide with the prime conductor, and the other with the rubber, it is neutral and inactive on both ſides. But this is not ſo; and a ſlight reflection might have convinced them that it cannot be ſo: if it were, the jar could not be diſcharged. Each ſide, while connected with the machine, muſt be in the condition of the part with which it is connected, and in a diſpoſition to take or give. If the trial be carefully made, it will be found to be *equally active* on both ſides; and the diſcharging rod, having down on its ends, will ſhew this in an unequivocal manner, and ſhew that its condition differs in this reſpect from that of a jar charged in the ordinary way. It is in the maximum ſtate of Richmann's plate, deſcribed in n° 156. when d riſes no more.

160
Charge one jar by the diſcharge of another.

In diſcharging a jar A, if inſtead of the outſide communicating with the inſide by a wire, we make it communicate with the inſide of a ſecond jar B, while the outſide of B is made to communicate with the inſide of A, we ſhall find be charged by the diſcharge of A; and that the diſcharge of A is not complete, the charge 2^2 always remaining, whatever may have been the magnitude of n.

161
Important inference.

We may infer from this experiment, that when a ſhock is given to a number of perſons a, b, c, &c. we are not to conclude, that the fluid which comes into the deficient ſide of the jar is the ſame which came out of the redundant ſide. The whole, or perhaps only a part, of the moveable fluid in the perſon a goes into b, replacing as much as has paſſed from b into c, &c. Indeed, where the canal is a ſlender wire, we may grant that great part of the individual particles of fluid which were accumulated on the inſide of the jar have gone into the outſide. Perhaps the quantity transferred, even in what we call *a very great diſcharge*, may be but a ſmall proportion of what naturally belongs to a body. This may be the reaſon why a charge will not melt more than a certain length of wire. Mr Cavendiſh aſcribes this to the greater obſtruction in a longer wire; but this does not appear ſo probable. A greater obſtruction would occaſion a longer delay of the transference; and therefore the action of the ſame quantity would be longer continued. He proves, that a metal wire conducts many hundred times faſter than water; yet, when water is diſſipated by a diſcharge, it is found to have actually conducted a *much greater* proportion of the whole charge. We aſcribe it chiefly to this, that, in a ſhort wire, the quantity transferred exceeds the whole quantity belonging to the wire.

162
Leyden phial like a coated pane.

It is ſurely needleſs to prove that the theory of the Leyden phial is the ſame with that of the coated pane. The only difference is, that we are not ſo able to tell the diſpoſition of the accumulated fluid, and the evacuated matter, in every figure. When the phial is of a globular form, and of uniform thickneſs, with an exceedingly ſmall neck, we then knew the diſpoſition more accurately than in a plate. The redundant fluid is then uniformly diſtributed. If we could inſure the uniformity of thickneſs, ſuch a phial would be an excellent UNIT for meaſuring all other charges by; but we can neither inſure this (by the manner of working glaſs), nor meaſure its want of uniformity: whereas we can have mirror plate made of preciſely equal thickneſs, and meaſure it. This, therefore muſt be taken as our unit.

163
Excellent method for verifying the theory.

And here we remark, that this gives us the moſt perfect of all methods for comparing our theory with experiment. We muſt take two plates, of the ſame glaſs and the ſame thickneſs, but of different dimenſions of coated ſurface. We muſt charge both by very long conducting wires on both ſides, and then meaſure

how

how often the charge of the one is contained in the other. Mr Cavendiſh has given an unexceptionable method of doing this independent of all theory. As it applies equally to jars, however irregular, we ſhall take it altogether.

Meaſure of a charge

When a jar is charged, obſerve the electrometer connected with it, and immediately communicate the charge to another equal jar (the perfect equality being previouſly aſcertained by the methods, which will appear immediately). Again note the electrometer. This will give the elevation, which indicates one-half, independent of all theory. Now electrify a jar, or a row of equal jars, to the ſame degree with the firſt, and communicate the charge to a coated mirror plate, diſcharging the plate after each communication, till the electrometer reaches the degree which indicates one-half. This ſhews how often the charge of the plate is contained in that of the jar or row of jars.

Let the charge of the plate be to that of the jars as x to 1. Then, by each communication, the electricity is diminiſhed in the proportion of $\overline{1 + x}$ to 1. If m communications have been made, it will be reduced in the proportion of $\overline{1 + x}^m$ to 1. Therefore $\overline{1 + x}^m = 2$, and $1 + x = \sqrt[m]{2}$, and $x = \sqrt[m]{2} - 1$.

When x is ſmall in proportion to 1, we ſhall be very near the truth, by multiplying the number of communications by 1,444, and ſubtracting 0,5 from the product. The remainder ſhews how often the charge of the plate is contained in that of the jars, or $\frac{1}{x}$.

Thus may the perfect equality of two jars be aſcertained; and the one which exceeds, on trial, may be reduced to equality by cutting off a little of the coating. An electrician ſhould have a pair of ſmall jars or phials ſo adjuſted. It will ſerve to diſcover in a minute or two the mark of one-half electricity for any electrometer, and for any degree; as alſo for meaſuring jars, batteries, ſhocks, &c. much more accurately than any other method: becauſe ſuch phials, conſtructed as we ſhall deſcribe immediately, may be made ſo neutral, and ſo retentive, that the quantity which diſſipates during the handling becomes quite inſignificant in proportion to the quantity remaining; whereas, in all experiments with electrometers, conſtructed with the moſt curious attention, the diſſipations are great in proportion to the whole, and are capricious.

164. It was chiefly by this method that the writer of this article, having read Mr Cavendiſh's paper, compared the meaſures given by experiment with thoſe which reſult from an action in the inverſe duplicate ratio of the diſtance. When the charges were moderate, the coincidence was perfect; when the charges were great, the large plates contained a little more. This is plainly owing to their being leſs diſpoſed to diſſipate from the edges.

165

Maxims for conſtructing jars, batteries, &c.

We may now follow with ſome confidence the practical maxims deducible from the theory for the conſtruction of this accumulating apparatus. The theory preſcribes a very conducting coating, in cloſe and uninterrupted contact: It preſcribes an extenſive ſurface, and a thin plate of idio-electric ſubſtance. Accordingly all theſe are in fact attended by a more powerful effect. Metal is found to be far preferable to water, which was firſt employed, having been ſuggeſted by the original experiments of Gray, Kleiſt, and Cunæus. A continuous plating is preſcribed, in preference to ſome methods commonly practiſed; ſuch as filling the jar with braſs duſt, or gold leaf, or covering its ſurface with filings ſtuck on with gum water, or coating the inſide with an amalgam of mercury and tin. This laſt appears, by reflection from the outſide, to give a very continuous coating; but if we hold the jar between the eye and the light, we may perceive that it is only like the covering with a cobweb. Yet there are caſes where theſe imperfect coatings only are practicable, and ſome rare ones where they are preferable.

Hint for medical exhibition of electricity.

In the medical exhibition of electricity, where the purpoſe intended is ſuppoſed to require the transfuſion of a great quantity of the electric fluid, any thing that can diminiſh the irritating ſmartneſs of the ſpark is deſirable. This is greatly effected by thoſe imperfect coatings. Small ſhocks, which convey the ſame quantity of fluid with the ſharp pungent and alarming ſpark from a large ſurface, are quite ſoft and inoffenſive, greatly reſembling the ſpaſmodic quivering, ſometimes felt in the lip or eye-lid, and will not alarm the moſt fearful patient.

166

How to prevent the burſting of jars by high charges,

Cloſe contact of the metallic coating is obſerved to increaſe the effect of the charge. But it is alſo found that it greatly increaſes the riſk of burſting the glaſs by ſpontaneous diſcharge through its ſubſtance. An experienced electrician (we think it is Mr Brookes of Norwich) ſays, that ſince he has employed paper covered with tinfoil, with the paper next the glaſs, inſtead of the foil itſelf, he has never had a jar burſt; whereas the accident had been very frequent before. The theory juſtifies this obſervation. Paper is an imperfect conductor, even when ſoaked with flour paſte; and the transfuſion, though rapid, is not inſtantaneous nor deſultory, but begins faintly, and ſwells to a maximum. It operates on the glaſs, like gradual warming, inſtead of the ſudden application of great heat.

167

Very curious obſervation by Mr Cuthbertſon.

Mr Cuthbertſon, an excellent artiſt in all electrical apparatus, and inventor of the beſt air-pump, has made a curious obſervation on this ſubject. He ſays that he has uniformly obſerved, that jars take a much greater charge (nearly one-third), if the inſide be conſiderably damped, by blowing into it with a tube reaching to the bottom (*Nicholſon's Journal*, March 1799).—We muſt acknowledge, that we can form no diſtinct conception of what Mr Cuthbertſon calls *an undulation of the elaſtic atmoſphere*. We do not know whether he means that the atmoſphere is actually undulating as water, or as air in the production of ſound, its parts being in a reciprocating motion; or whether he only means that this atmoſphere conſiſts of quieſcent ſtrata, alternately denſer and rarer. Nor can we form any notion how either of theſe undulations contributes to the exploſion, or prevents it. We are really but very imperfectly acquainted with that part of the ſcience which ſhould determine the preciſe accumulation that produces the deſultory transference. We mentioned one neceſſary conſequence of the action inverſely as the ſquare of the diſtance, which has ſome relation to this queſtion, *viz.* that a particle, making part of a ſpherical ſurface, is twice as much repelled when it has juſt quitted the ſurface, as when it made part of it, provided its place be immediately ſupplied. And another circumſtance has been frequently mentioned, *viz.* that a greater, and perhaps much greater, force is neceſſary for enabling a particle

particle of fluid to quit the laſt ſeries of particles of the ſolid matter than for producing almoſt any conſtipation. But we are not certain that theſe circumſtances are of ſufficient influence to explain the whole of the event. *Valeant quantum valere poſſint.* Yet we are of opinion that Mr Cuthbertſon has aſſigned the true cauſe, namely, the imperfect coating of the inſide of the glaſs. When we come to the explanation of the eſcape of electricity along imperfect conductors, we hope that it will appear, that the diſpoſition to eſcape muſt be greatly diminiſhed by a charge, which diſpoſes the fluid ſo, that in no place the conſtipation is remarkably greater than in another part very near it, and the denſity changes everywhere ſlowly.

168 Beſt forms for jars, &c.

With reſpect to the form of the coated glaſs, the theory preſcribes that which will occaſion ſuch a diſtribution of the electric fluid as ſhall make its repulſion for the fluid in the canal which connects it with the prime conductor as little as poſſible. In this reſpect it would ſeem that a plate is the beſt, and a globe the worſt: but if both are very thin, the difference cannot be conſiderable. Our experience, however, ſeems to indicate the oppoſite maxim as the moſt proper. We have uniformly found a globe to be far preferable to a plate of the ſame thickneſs, and that a plate was generally the weakeſt form. It muſt be owned that we have not yet been able to aſcertain by the theory what is the exact diſtribution of the redundant fluid in a plate. In a ſphere it muſt be uniformly ſpread over the ſurface. We muſt alſo aſcribe part of the inferiority of the plate to its greater tendency to diſſipation from the edges. If a plate be coated in a ſtar-like form, with ſlender projecting points, we ſhall obſerve them luminous in the dark, almoſt at the beginning of the accumulation; and the plate will diſcharge itſelf by theſe points, over the uncoated part, before it has attained any conſiderable ſtrength. Thoſe forms are leaſt expoſed to this deterioration which have the leaſt circumference to the ſame quantity of ſurface. We have always found that a ſquare coating will not receive a more powerful charge without exploding than a circular one of the ſame breadth, although it contains a fourth more ſurface; and this although any viſible eſcape from the angles be prevented by covering the outline with ſealing wax. Of all forms, therefore, a globe, with a very narrow, but long neck, is the moſt retentive. But it is very difficult to coat the inſide of ſuch a veſſel. The balloons uſed in chemical diſtillations make excellent jars, and can be eaſily coated internally when the neck will admit the hand. The thinneſt of tinfoil may be uſed, by firſt paſting it on paper, and then applying it either with the foil or the paper next the glaſs. It ſhould be cut into guſſets, as in the covering of terreſtrial globes; and they ſhould be put on overlapping about half an inch. The middle of the bottom is then coated with a circular piece. The great bottles for holding the mineral acids are alſo good jars, but inferior to the balloons, becauſe they are very thick in the bottom, and for ſome diſtance from it. A box of balloons contains more effective ſurface than an equal box of jars of the ſame diameter and height of coating.

169 Compendious battery.

The moſt compendious battery may be made in the following manner: Chooſe ſome very flat and thin panes of the beſt crown glaſs, coat a circle (*a b c d*), (fig. 31.) in the middle of both ſurfaces, ſo as to leave a ſufficient border uncoated for preventing a ſpontaneous diſcharge; let each of them have a narrow ſlip of tinfoil *a* reaching from the coating to the edge on one ſide, and a ſimilar ſlip *c* leading to the oppoſite edge on the other ſide. Lay them on each other, ſo that the ſlips of two adjoining plates may coincide. Connect all the ends of theſe ſlips on one ſide together by a ſlip of the ſame foil, or a wire which touches them all. Then, connecting one of theſe collecting ſlips with the prime conductor, and the other with the ground, we may charge and diſcharge the whole together. If the panes be round, or exact ſquares, we may employ as few of them together as we pleaſe, by ſetting the whole in an open frame, like an old-faſhioned plate-warmer; and then turning the ſet which we would employ together at right angles to the reſt. This evidently detaches the two parcels from each other. This battery may be varied in many ways; and if the whole is always to be employed together, we may make it extremely retentive, by covering the uncoated border of the plate with melted pitch, and, while it is ſoft, preſſing down its neighbour on it till the metallic coatings touch. For greater variability this may be done in parcels of the whole.

170 Another.

On the ſame principle, a moſt compendious battery may be made by alternate layers of tinfoil and hard varniſh, or by coating plates of very clear and dry Muſcovy glaſs. But theſe muſt be uſed with caution, leſt they be burſt by a ſpontaneous diſcharge; in which caſe we cannot diſcover where the flaw has happened. They make a ſurpriſing accumulation, without ſhewing any vivid electricity.

171 Portable jar.

We have made a very fine electric phial for carrying about, by forming tin-plate (iron plate tinned) into ſomewhat of a phial ſhape, with a long neck. We then covered this with a coating of fine ſealing wax, about $\frac{1}{10}$th of an inch thick, quite to the end of the neck, and coated the ſealing wax, all but the neck, with tinfoil. It is plain that the ſealing wax is the coated idio-electric, and that the tin-plate phial ſerves for an inner coating and wire. The diſſipation is almoſt nothing if the neck be very ſmall; and it only requires a little caution to avoid burſting by too high a charge. Even this may be prevented by coating the ſealing wax ſo near to the end of the neck, that a ſpontaneous diſcharge muſt happen before the accumulation is too great.

172 Importance of a cloſe diſcharge.

It is well known that the diſcharge happens when the diſcharging balls are at a conſiderable diſtance from each other; therefore only ſo much is diſcharged as correſponds to that diſtance. This is one cauſe of the reſiduum of a diſcharge which ſometimes is pretty conſiderable. Some experiments require the very utmoſt force of the charge. It is therefore proper to make the diſcharge as cloſe and abrupt as poſſible. But the moſt rapid approach that we can make of the diſcharger is nothing in compariſon with the velocity with which the fluid ſeems to fly off, and will therefore have but ſmall influence in making a more inſtantaneous and complete diſcharge. Theory points out the following method: Let a very thick plate of glaſs (half an inch), of ſeveral inches diameter, be put between the diſcharging balls, which ſhould, in this caſe, be ſmall, and let theſe balls be ſtrongly preſſed againſt it by a ſpring. While the charge is going on, a very ſmall part of the glaſs plate, round

round the points of contact, will receive a weak and uſeleſs charge; but this will not hinder the battery from acquiring the ſame intenſity of charge. When this is completed, let the intervening glaſs plate be briſkly withdrawn. The diſcharge will begin with an intenſity which is unattainable in the ordinary manner of proceeding.

173 Lateral exploſion. Much has been ſaid of the lateral exploſion. It appears, that in ſome of the prodigious transferences of electricity that have taken place in the diſcharge of great ſurfaces through wires barely ſufficient to conduct them, flaſhes of light are thrown off laterally; but the moſt delicate electrometer, it is ſaid, is not affected. The fact is not accurately narrated; we have always obſerved a very delicate electrometer to be affected. The paſſage of ſuch a quantity of fluid is almoſt equivalent to the co-exiſtence of it in any given ſection of the wire; but it remains there for ſo ſhort a time, that, acting as an accelerating force, it cannot produce a very ſenſible motion. It is like the diſcharging a piſtol ball through a ſheet of paper hanging looſely. It goes through it without very ſenſibly agitating it.

174 Propoſal for diſcovering which is redundant electricity. It has ſometimes appeared to us probable that, by means of this lateral exploſion, the direction of the current may be diſcovered. Let the jar *a b* (fig. 32.) be diſcharged by a wire *a c d e b*, interrupted at *c d* by the coating of a very thin plate of talc; let the coating alſo be very thin. There muſt be *ſome* obſtruction to the motion, which muſt cauſe the fluid to preſs on the ſides or ſurfaces of the coating, juſt as the obſtruction to the motion of water in a pipe (ariſing from friction, or even from material obſtacles in the pipe) cauſes the water to preſs on the ſides of the pipe. Therefore if a wire κ ε connect the other coating with the ground, we ſhould expect that fluid will be expelled along this wire, and a charge be given to the plate of talc. Now whether the courſe in this apparatus be from *b* to *a*, or from *a* to *b*, if any charge be acquired by *c d*, it will *probably* be poſitive in *c d*, and negative in κ δ; for it is electric fluid that is ſuppoſed to paſs: therefore we ſhould always have one ſpecies of electricity, whether *a* has been charged by glaſs or by ſealing wax; and this ſpecies will indicate which is poſitive. We have ſaid "*probably*"—for it is not impoſſible that it may be otherwiſe. If the abſtraction at *d* be ſuppoſed more powerful than the ſupplying force at *c*, the ſame obſtruction may perhaps keep the plate *c d* in an *abſorbing* ſtate, juſt as water deſcending in a vertical pipe, into which it is preſſed by a very ſmall head of water in the ciſtern, inſtead of preſſing the ſides of the pipe, rather draws them inwards, as is well known. This ſeems, at any rate, an intereſting experiment; for we muſt acknowledge, that there ſtill hangs a myſterious curtain before a theory which deduces ſo much from the preſence of a ſubſtance which we have never been able to exhibit alone, and where we do not know when it abounds and when it is deficient. It is like the phlogiſton of Stahl, or the caloric of Lavoiſier. It will be proper to uſe the thinneſt plate of talc to be charged, and to connect it with another coated plate of half the diameter, or leſs, in order to increaſe the accumulation. It ſeems by no means a deſperate caſe.

The theory of coated glaſs now explained, might have been treated with more preciſion, and the formulæ deduced in the beginning of this article might have been employed for ſtating the ſum total of the acting forces, and thus demonſtrating with preciſion the truth of the general reſult; and indeed it was with ſuch a view that they were premiſed: but they would have been conſiderably complicated in the preſent caſe; for however thin we ſuppoſe the tinfoil coatings to be, it is evident from nº 92, &c. that each coating will conſiſt of three ſtrata; of which the two outermoſt are active, and muſt have their forces ſtated, and the ſtatement of the force of each ſtratum would have conſiſted of three terms. This would have been very embarraſſing to ſome readers; and the force of the concluſion would not, after all, have been much more convincing than we hope the above more looſe and popular account has been.

175 Does the charge reſide in the coatings or in the glaſs? We have hitherto conſidered the non-electric coatings only, and have not attended to what may chance to obtain in the ſubſtance of the coated electrics themſelves. May not part, at leaſt, of the redundant fluid be lodged in one ſuperficial ſtratum of the glaſs? or, if it do not penetrate it, may it not adhere to the ſurface, and drive off from the other ſurface, or ſtratum, a part of what naturally adheres to it? Till Dr Franklin's notions on the ſubject became prevalent, no perſon doubted this. The electric was ſuppoſed to contain or to accumulate in its ſurface all the electricity that we know. But the firſt ſuggeſtion of Dr Franklin's experiments certainly was, that the electric plate or veſſel acted merely as an obſtacle, preventing the fluid from flying from the body where it was redundant to that where it was deficient. It is therefore an important queſtion in the ſcience, whether the glaſs or electric concerned in theſe phenomena ſerve any other purpoſe beſides the mere prevention of the redundant fluid from flying to the negative plate?

176 It is in the glaſs. Now it appears, at the very firſt, that this is the caſe. For if a glaſs be coated only on one ſide, and be electrified on that ſide, we obtain a ſtrong ſpark from the other ſide by bringing the knuckle near it: and this may be obtained for ſome time from one ſpot of that ſurface; and after this we get no more from that ſpot, but get ſparks, with the ſame vivacity, and in the ſame number, from any other ſpot that is oppoſite to the coating on the other ſide. In this manner we can obtain a ſucceſſion of ſparks from every inch of ſurface oppoſite to the coating, and from no other part. But what puts this queſtion beyond all doubt, is, that if we now lay a metal coating on the ſurface from which the ſparks have been drawn in this manner, and make a communication between the two metallic coatings, by means of a bent wire, we obtain a perfect diſcharge. To complete the proof, we need only obſerve that this experiment ſucceeds whether the glaſs has been electrified by excited glaſs or by excited ſealing-wax. Therefore the coated ſurface may receive the electric fluid by the coating, as we ſee plainly that it is abſtracted by the coating. The uſe of the coatings may be nothing more than to act as conductors to every part of the ſurface of the electric. None of theſe thoughts eſcaped the penetrating and ſagacious mind of Dr Franklin. He immediately put it to the teſt of experiment; and, laying a moveable metallic coating on both ſurfaces, he found the glaſs charge perfectly well. He lifted off the coatings; which operation was accompanied by flaſhes

flaſhes of light between the metallic coverings and the glaſs from which he ſeparated them. Having removed the coatings, he applied others, completed the circle, and obtained a perfect diſcharge, not diſtinguiſhable from what he would have obtained from the firſt coatings.

177 Charged glaſs acquires redundant and deficient ſtrata.

Thus it was demonſtrated, that the glaſs plate itſelf acquired by charging a redundant ſtratum on one ſide, and a deficient ſtratum on the other ſide; and we now ſee, at once, the reaſon why the accumulation turns out greater than what is determined by the theory. The diſtance between the redundant and deficient ſtratum is leſs than the thickneſs of the glaſs; and this, perhaps, is an unknown proportion.

This precious experiment of Dr Franklin was repeated by every electrician, and varied in a thouſand ways. No philoſopher has carried this reſearch farther than Beccaria; and he has given ground for a moſt important diſcovery in the mechanical theory, namely, that the charged glaſs has ſeveral ſtrata, of inconceivable thinneſs, alternately redundant and deficient in electric fluid; and that by continuing the electrification, theſe ſtrata penetrate deeper into the glaſs, and probably increaſe in number. We have not room here to give even an account of his experiments, and muſt refer the philoſophical and curious reader to that part of his valuable Treatiſe where he treats of what he calls *vindicating* or *recovering electricity;* as alſo to a paper by Mr Henly in Phil. Tranſ. for 1766, giving account of experiments on Dutch plates by Mr Lane. The general form of the experiment is this. He puts two plates together; he coats the outer ſurfaces, and charges and diſcharges them as one thick plate. Their inner touching ſurfaces are found ſtrongly electrical after the diſcharge, having oppoſite electricities, and changing theſe electricities, by repeated ſeparations and replacings, in a way ſeemingly very capricious at firſt ſight, but which the attentive reader will find to be according to fixed laws, and agreeably to the ſuppoſition that the ſtrata gradually ſhift their places within the glaſs, very much reſembling what we obſerve on a long glaſs rod which we would render electric by induction. In this caſe, as was obſerved in n° 57. there are obſerved more than one neutral point, &c.

178. Mr Cavendiſh endeavours to give us ſome notion of the diſpoſition of the fluid in the ſubſtance of the glaſs in the following manner: Having ſeparated the coated plate from the machine and from the ground, ſuppoſe a little of the redundant fluid in $B\beta\delta D$ (fig. 33.) equal to the fluid wanting in $E\varepsilon\varphi F$. If we now ſuppoſe all the redundant fluid to be lodged in $b\beta\delta d$, and $e\varepsilon\varphi f$ to hold all the redundant matter, and the two coatings to be in their natural ſtate, a particle p, placed in the middle of the ſurface bd, will be nearly as much attracted by $\varepsilon ef\varphi$ as it is repelled by $b\beta\delta d$ (exactly ſo if the plates were infinitely extended); and if the coating be removed, keeping parallel and oppoſite to the ſurface that it quits, there will be very little, if any, tendency to fly from the glaſs to the coating: there will rather be ſome diſpoſition in the fluid to quit the coating and fly to the glaſs; becauſe the repulſion of $b\beta\delta d$ is more diminiſhed than the attraction of $\varepsilon ef\varphi$. (n° 42.) But the difference will be very ſmall indeed. (*N. B.* the reſult would be very different if electric action followed a different law. Were it as $\frac{1}{d^3}$, the coating would be much overcharged; and were it as $\frac{1}{d}$, it would be very much undercharged). Now the fact is, that when the coating is carefully removed, it is poſſeſſed of very little electricity, not more than may reaſonably be ſuppoſed to run into it by bringing away one part before another. It is impoſſible to keep it mathematically parallel.

Hence we may conclude that the greateſt part of the redundant fluid is lodged in the glaſs if the plates be thin, and the redundant fluid bear but a ſmall proportion to the natural quantity. Similar reaſoning ſhews that the greateſt part of the deficiency is in the other ſide of the glaſs; and that therefore the coatings are very nearly in their natural ſtate, and merely ſerve the purpoſe of conducting.

We have employed coatings of conſiderable thickneſs, having holes through them, oppoſite to which was ſome gold leaf of the heavieſt ſort, and almoſt free of cracks. We have examined the ſtate of the bottom of thoſe pits in Mr Coulomb's manner, and always found them void of electricity.

179 Conjecture about the burſting of jars.

Thus we learn that glaſs, and probably all other electrics, acquire redundant and deficient ſtrata as well as the moſt perfect conductors, at the ſame time that they may be impervious to the fluid; and we get ſome mode of conceiving how the rupture happens by a ſtrong charge. This may very probably happen when the ſtrata have formed, in alternate order, ſo deep in the glaſs, that a ſtratum, in which the fluid is crowded cloſe together, may become contiguous to one deprived altogether of fluid. We cannot, however, ſay with confidence, what *ſhould* be the effect of this ſtate of things; or of one conſtipated ſtratum coming in contact with another.

This view of the condition of charged glaſs explains (we think) ſeveral phenomena which ſeem not well underſtood by electricians.

180 Several phenomena explained.

The reſiduum of a diſcharge is frequently owing to a charge extending beyond the coating, where the action is conſiderably irregular, or different from what it would be if the plates were infinitely extended. This *outline* charge is taken up by the coated part after a very little while, and may again be diſcharged. But it alſo frequently ariſes from another ſtratum (much thinner, as it will always be) than the exterior one, coming to the ſurface ſome time after the firſt diſcharge, and being now in a condition for being diſcharged. It explains the ſparkling that is perceived *in ſucceſſion* between the parts of a jar that is coated in ſpots, during the charge, and the very ſenſible reſiduum of the charge of ſuch a veſſel. It explains the phenomena of Beccaria's *Electricitas Vindex* (ſee ELECTRICITY, *Encycl.* n° 48.), and the great difference that may be found in the different kinds of glaſs in this reſpect. It explains the great difference between the ſenſation occaſioned by a ſpark from a perfectly conducting ſurface of conſiderable extent, and that occaſioned by a ſhock, which conveys the ſame quantity of fluid accumulated in a ſmall ſurface of glaſs. The diſcharge of the firſt is almoſt inſtantaneous, while that of the laſt requires a ſmall moment of time, and is therefore leſs deſultory

and

and abrupt. The one is pungent and ſtartling; but the other is ſofter in the firſt inſtant, and ſwells to a maximum. Therefore, in the medical employment of electricity, when the purpoſe is to be affected by the transfuſion of a great quantity of electric fluid, we ſhould recommend very ſmall ſhocks from a very large ſurface of coated glaſs, very faintly electrified, in place of ſtrong ſparks. Patients of irritable conſtitutions are frequently alarmed by the quickneſs and pungency of ſtrong ſparks: but if the balls of Lane's ſhock-meaſurer be ſet ſo cloſe as to give four or five ſhocks in each turn of a ſeven inch cylinder, the ſhocks are not even diſagreeable. The balls ſhould be made of fine cupelled ſilver: in which caſe, the ſurface will never be hurt by the greateſt diſcharge; whereas the diſcharge of four ſquare feet of coated glaſs will raiſe ſuch a roughneſs on the ſurface of braſs as will cauſe it to ſputter, and deſtroy entirely the regularity of the expenditure of fluid. The ſame conſideration ſhould make us prefer a jar coated entirely with amalgam. This cob-web coating gives a greater ſoftneſs to the ſhock. Laſtly, we ſee why a powerful and permanent electricity was not produced in the tube filled with melted ſealing wax, and treated as mentioned in n° 101. The redundancy and deficiency intended to be produced could only be ſuperficial. And becauſe the wax cooled by degrees from the ſurface to the axis, and the wax is a conductor while liquid, it muſt have taken a charge at laſt; and therefore muſt appear but faintly electrical.

181. This account of the ſtate of charged glaſs promiſes us ſome aſſiſtance in our attempts to conceive what paſſes in the excitation of glaſs by friction. It appears from Beccaria's experiments, that the redundant fluid is lodged in the ſame manner in both caſes; for by rubbing one ſide of a glaſs tumbler, while points were preſented to the oppoſite ſurface, and were connected with a wire that communicated with the ground, he gave it a powerful charge.

182
The quantity of fluid in a body may be exceeding great.

It is obſerved, that when the laminæ of a piece of Muſcovy glaſs are ſeparated, by pulling them aſunder without inſerting any inſtrument between them, they are electrical when ſeparated; one being poſitive, and the other negative. Muſt we not conclude from this, that when conjoined they were in the ſtate of charged glaſs? If we take this view of it, a body may contain a prodigious quantity of electric fluid without exhibiting any appearance of it. Mr Nicholſon found, by a very fair computation from his experiments, that a cubic inch of talc, when ſplit into plates of 0,011 of an inch in thickneſs, and coated with gold leaf, gave a ſhock equal to the emptying 45 conductors, each ſeven inches in diameter and three feet long, electrified ſo that each gave a ſpark at nine inches diſtance. Now, the whole of this was moveable fluid, and no more than what the talc contains when unelectrified: for no more comes into the poſitive ſide than goes out of the negative ſide. Nay, there is no probability that the quantity moveable in our experiments bears a conſiderable proportion to the natural quantity. The quantity of moveable fluid in a man's body is therefore very great: and Lord Mahon is well authoriſed to ſay, that the ſudden diſplacing of this quantity in a *returning ſtroke*, which has been occaſioned by a diſcharge of a cloud in a very diſtant place, is fully adequate to the production of the moſt violent effects. But his Lordſhip has not attended to the circumſtance, that no ſuch diſplacement can happen. The accumulation that can be made in the human body is only ſuperficial; and therefore, altho' the whole fluid of a man's body may change its place, it will not change it with the rapidity that ſeems neceſſary for the violent effects of electricity, except in the very points of communication with the ſurrounding bodies.

183. We have now ſeen in what ſenſe the idio-electrics may be ſaid to be impervious to the electric fluid. It is moved in them only to very ſmall and imperceptible diſtances. When a conſiderable ſtratum is diſcharged, the fluid does not come from the extremity of it to the point of diſcharge through the glaſs, but through the coating. And when alternate ſtrata of redundant fluid and redundant matter are formed, the particles in each ſhift their places very little, moving perpendicularly to the ſtratum.

184
The impermeability of electrics denied by ſome.

Even this degree of obſtruction has been denied by ſome very active electricians, who have multiplied experiments to prove that the fluid paſſes freely through glaſs, and that the theory of coated electrics is totally different from what Franklin imagines. Mr Lyons of Dover has publiſhed a numerous liſt of ſingular experiments, which he has made with this view, with much trouble, and no ſmall expence. They may all be reduced to this: A wire is brought from the outſide of a phial, charged by the knob, and terminates in a ſharp point at a ſmall diſtance from a thin glaſs plate (it is commonly introduced into a glaſs tube, having a ball at the end, and the point of the wire reaches to the centre of the ball); and another wire is connected with the diſcharging rod, and alſo comes very near (and frequently cloſe) to the other ſide of the glaſs, oppoſite to the pointed wire. With this apparatus he obtains a diſcharge; and therefore ſays that the glaſs is permeable to electricity. But he does not narrate all the circumſtances of the experiment. We have repeated all of them that have any real difference (for moſt of them are the ſame fact in different forms), and we have obtained diſcharges: But they were all very incomplete, except when the glaſs was perforated, which happened very frequently. The diſcharge was never made with a full, bright, undivided ſpark, and loud ſnap; but with ſputtering, and trains of ſparks, continued for a very ſenſible time; and the phial was never deprived of a conſiderable part of its charge: and (which Mr Lyons has taken no notice of) the glaſs is found to be charged, negative on the ſide connected with the poſitive ſide of the phial, and poſitive on the other. This charge was communicated to the glaſs over a pretty conſiderable ſurface round the points immediately oppoſite to the wires. This is quite conformable to the experiments of Dr Franklin and Beccaria, who charged a tumbler by graſping it with the hand, and preſenting the inſide to a point electrified by the prime conductor. The whole experiment is analogous to the one narrated in n° 176.

185
Bars touched like magnets for electricity.

We may conclude our obſervations on coated glaſs with mentioning a curious experiment. A flat ſtick of fine ſealing wax, warmed till it bent pretty readily, was rendered permanently electrical, with a poſitive and negative pole, in a manner analogous to the double touch of magnets. A ſmall jar was taken, having a hemiſphere on the end of its inſide wire, and another on the end

end

end of a ſtiff wire projecting from the outer coating, and then turned up parallel to the inſide wire; ſo that the two hemiſpheres ſtood equally high, and about three inches aſunder. This jar was electrified ſo weakly, as to run no riſk of a ſpontaneous diſcharge. The flat faces of the two hemiſpheres were now applied to the flat ſide of the ſealing wax, and were moved to and fro along it, overpaſſing both ends about an inch with each hemiſphere. The experiment was very troubleſome; for the phial often diſcharged itſelf along the ſurface of the ſealing wax, and all was to begin again. But, by continuing this operation till the ſealing wax grew quite cold and hard, it acquired a very ſenſible electriciſm, which laſted ſeveral weeks when kept with care; but ſtill it was not much more ſenſible than that of the ſealing wax, which congealed between two globes oppoſitely electrified.

186 ectro- iorus. After this application of the theory to the phenomena of coated glaſs, it will not be neceſſary to employ much time in its application to the electrophorus. The general propoſitions from n° 14. to 25. and their companions in n° 38—43, will enable us to ſtate with preciſion (when combined with the law of electric action) the actions of every part of this apparatus; and conſiderable aſſiſtance will be derived from a careful conſideration of our analyſis of Profeſſor Richmann's experiment in n° 156. But we muſt content ourſelves with a general, popular view of theſe particulars, which may be ſufficient for making us underſtand what will be the *kind*, and ſomewhat of the *intenſity*, of the action of its different parts.

The electrophorus conſiſts of three parts. The chief part is the cake ABCD (fig. 34.) of ſome electric; ſuch as gum lac, ſealing wax, pitch, or other reſinous compoſition. This is melted on ſome conducting plate, DCFE, and allowed to congeal; in which ſtate it is found to be negatively electric. Another conducting plate GHBA is laid on it, and may be raiſed up by ſilk lines, or any inſulating handle. We ſhall call ABCD the CAKE, DCFE the SOLE, and GHBA the COVER.

The general appearances not having been ſo ſcientifically claſſed in the article ELECTRICITY as could be wiſhed, we ſhall here narrate them, very briefly, in a way more ſuited to our purpoſe. In comparing the theory with obſervation, it will be proper to make all the three parts of conſiderable thickneſs, and of no great breadth. Although this diminiſhes greatly the moſt remarkable of the actions, it leaves them ſufficiently vivid, and it greatly increaſes the ſmaller changes which are inſtructive in the compariſon. The general facts are,

enome- thereof. 1. If the ſole has been inſulated during the congelation of the electric, till all is cold and hard, the whole is found negatively electric, and the finger draws a ſpark from any part of it, eſpecially from the ſole. If allowed to remain in this ſituation, its electricity grows gradually weaker, and at laſt diſappears: but it may be excited again by rubbing the cake with dry warm flannel, or, which is the beſt, with dry and warm cat or hare fur. If the cover be now ſet on the cake by its inſulating handle, but without touching the cover, and again ſeparated from the cake, no electricity whatever is obſerved in the cover.

2. But if it be touched while on the cake, a ſharp pungent ſpark is obtained from it; and if, at the ſame time, the ſole be touched with the thumb, a very ſenſible ſhock is felt in the finger and thumb.

3. After this, the electrophorus appears quite inactive, and is ſaid to be *dead*; neither ſole nor cover giving any ſign of electricity. But,

4. When the cover is raiſed to ſome diſtance from the cake (keeping it parallel therewith), if it be touched while in this ſituation, a ſmart ſpark flies, to ſome diſtance, between it and the finger, more remarkably from the upper ſide, and ſtill more from its edge, which will even throw off ſparks into the air, if it be not rounded off. As this diminiſhes the deſired effects, it is proper to have the edge ſo rounded. This ſpark is not ſo ſharp as the former, and reſembles that from any electrified conductor.

5. The electricity of the cover, while thus raiſed, is of the oppoſite kind to that of the cake, or is poſitive.

6. The electricity of the cover while lying on the cake is the ſame with that of the cake, or negative.

7. The appearances n° 2, 3, 4, may be repeated for a very long time without any ſenſible diminution of their vivacity. The inſtrument has been known to retain its power undiminiſhed even for months. This makes it a ſort of magazine of electricity, and we can take off the electricity of the cake and of the cover as charges for ſeparate jars, the cover, when raiſed, charging like the prime conductor of an ordinary electrical machine; and, when ſet on the cake, charging it like the rubber. This cauſed the inventor, Mr Volta, to give it the name of ELECTROPHORUS.

8. If the ſole be inſulated before putting on the cover, the ſpark obtained from the cover is not of that cutting kind it was before: but the ſame ſhock will be felt if both cake and cover be touched together.

9. If the cover be again raiſed to a conſiderable height, the ſole will be found electrical, and its electricity is that of the cake, and oppoſite to that of the cover.

10. After touching both cover and ſole, if the cover be raiſed and again ſet down, without touching it while aloft, the whole is again inactive.

11. If both cover and ſole be made inactive when joined, they ſhew oppoſite electricities when ſeparated, the ſole having the electricity of the cake.

12. If both cover and ſole be made inactive when ſeparate, they both ſhew the oppoſite to the electricity of the cake when joined.

187 Diſpoſition of the fluid. Let us now attend to the diſpoſition of the electrical fluid in the different parts of the inſtrument in their various ſituations, and to the forces which operate mutually between them. *N. B.* Experiments for examining this inſtrument are beſt made by ſetting the three plates vertically, ſupported on glaſs ſtalks, with leaden feet, to ſteady them. A very ſmall electrometer may be attached to the outer ſurfaces of the cover and ſole.

If the extent of the plates were incomparably greater than their thickneſs, we may infer from n° 92, &c. that the redundant fluid and matter would be diſpoſed in parallel ſtrata, and that the actions would be the ſame at all diſtances. But ſince this is not the caſe, the diſpoſition of the fluid will be ſomewhat different; and whatever it is, the action of any ſtratum will be diminiſhed by an increaſe of diſtance. The following deſcription cannot be very different from the truth:

I. The cake grows negative by cooling; and if it

188 Explanation of the *primitive ſtate.* were alone, it would have a negative ſuperficial ſtratum on both ſides, of greater thickneſs near the edges; and the fluid would probably grow denſer by degrees to the middle, where it would have its natural denſity. This diſpoſition may be inferred from n° 92, 93, and 98. But it cools in conjunction with the ſole, and the attraction of the redundant matter in the cake; for the moveable fluid in the ſole diſturbs its uniform diffuſion in the ſole, and cauſes it to approach the cake. And becauſe this, in all probability, happens while the cake is ſtill a conductor, the diſpoſition of its fluid will be different from that deſcribed above, and the final diſpoſition of the fluid in the cake and ſole will reſemble that deſcribed in n° 95, where the plates E and A repreſent the cake and ſole. But becauſe we do not know preciſely the gradation of denſity, and aim only at general notions at preſent, it will be ſufficient to conſider the cake and ſole as divided into two ſtrata only; one redundant in fluid, and the other deficient, neglecting the neutral ſtratum that is interpoſed between them in each. The cake, then, conſiſts of a ſtratum $ABbaA$ containing redundant matter, and a ſtratum $abCD$ containing redundant fluid: and the ſole has a ſtratum $DCnm$ containing redundant fluid, namely, all that belongs naturally to the ſpace DCFE, and a ſtratum $mnFE$ containing redundant matter. This may be called the PRIMITIVE STATE of the cake and ſole; and if once charged by communication with unelectrified bodies, it can never be recovered again without ſome new excitement.

189 *Common ſtate.* II. If the ſole be touched by any body communicating with the ground, fluid will come in, till the repulſion of the redundant fluid in the ſole for a ſuperficial particle y is equal to the attraction of the redundant matter in the cake for the ſame particle. What has been ſaid concerning infinitely extended plates rendered neutral on one ſide, may ſuffice to give us a notion of the preſent diſpoſition of the fluid in the ſole. The under ſurface will be neutral, and the fluid will increaſe in denſity toward the ſurface DC. The ſole contains more than its natural quantity of fluid, but is neutral by the balance of oppoſite forces. Let it now be inſulated. This diſpoſition of fluid may be called the *common ſtate* of the electrophorus.

190. III. Let the cover GHBA be laid on it. The particle z, at the upper ſurface of the cover, muſt be more attracted by the redundant matter in the ſtratum $ABba$ than it is repelled by the redundant fluid in the remoter ſtrata; for the fluid in the cake is leſs than what belongs to it in its natural ſtate, and therefore z is attracted by the cake. The redundant fluid which has come into the remote ſide of the ſole is leſs than what would ſaturate the redundant matter of the cake, becauſe it only balances the exceſs of the remote action of this matter above the nearer action of the compreſſed fluid in the ſole; and this ſmaller quantity of redundant fluid acts on z at a greater diſtance than that of the redundant matter in the cake. On the whole, therefore, the particle z, lying immediately within the ſurface GH, is attracted; therefore ſome will move toward the cake, and its natural ſtate of uniform diffuſion through the cover will be changed into a violent ſtate, in which it will be compreſſed on the ſurface AB, being abſtracted from the ſurface GH. It will now have a ſtratum $GgpH$, containing redundant matter, and another $gpBA$, containing redundant fluid. But this will diſturb the arrrangement which had taken place in the ſole, and had rendered it neutral on the under ſurface. We do not attend to the fluid in the cake, but conſider it as immoveable; for any motion which it can get will be ſo ſmall, that the variations of its action will be altogether inſignificant. The particle y, ſituated in that ſurface, will be more repelled by the compreſſed fluid in the ſtratum $gpCA$ than it is attracted by the equivalent, but more remote redundant matter in $GHpg$. Fluid is therefore diſpoſed to quit the ſurface EF, and the ſole appears poſitively electric; very little indeed, if the cover be thin. All this may be obſerved by attaching a ſmall Canton's electrometer to the lower ſurface of the ſole, or by touching the ſole with the electrometer of fig. 8. and then trying its electricity by rubbed wax or glaſs.

191. IV. A particle of fluid z, placed immediately without the ſurface GH, will be more attracted by the deficient ſtratum $GHpg$ and by $ABba$ than it is repelled by the redundant ſtrata beyond them, and the cover muſt be ſenſibly negative. This is the common ſtate of the whole inſtrument after ſetting on the cover. It is ſlightly poſitive on the lower ſurface of the ſole, and much more ſenſibly negative on the upper ſurface of the cover. A ſmart ſpark will therefore be ſeen between it and the finger, fluid will enter, till the attraction of the redundant matter in $ABba$ is balanced by the repulſion of the redundant fluid in DCFE.

192 *Dead ſtate.* V. A ſpark will now be obtained from the ſole, becauſe it was faintly poſitive before, and there has been added the action of the fluid which has entered into the cover. The fluid in the ſole is therefore diſpoſed to fly to any body preſented to it. But when this has happened, the equilibrium at the ſurface GH is deſtroyed. and that ſurface again becomes negative, and will attract fluid, although the cover already contains more than its natural quantity. A ſmall ſpark will therefore be ſeen between the cover and any conducting body preſented to it. By touching it, the neutrality or equilibrium is reſtored at GH; but it is deſtroyed again at EF, which will again give a poſitive ſpark, which, in its turn, again leaves GH negative. This will go on for ever, in a ſeries of communications continually diminiſhing, ſo as ſoon to become inſenſible, if the three parts of the electrophorus be thin. This makes it proper to make them otherwiſe, if the inſtrument be intended for illuſtrating the theory.

At laſt the equilibrium is completed at the ſurfaces GH and EF, and both are neutral in relation to ſurrounding bodies, although both the cover and ſole contain more than their natural ſhare of electric fluid. We may call this the NEUTRAL or DEAD ſtate of the electrophorus.

193 *Charged ſtate.* This ſtate may be produced at once, inſtead of doing it by theſe alternate touches of GH and EF. If we touch at once both theſe ſurfaces, we have a bright, pungent ſpark, and a ſmall ſhock. If this be the object of the experiment, the ſtate N° IV. which gives occaſion to it, may be called the CHARGED ſtate of the electrophorus.

When the inſtrument has thus been rendered neutral in relation to ſurrounding bodies, it is plain that it may continue in this ſtate for any length of time without any diminution of its capability of producing the other phenomena,

phenomena, provided only that no fluid paſs from the cover to the cake. We do not *fully* underſtand what prevents this communication, nor indeed what prevents the rapid eſcape from an overcharged body into the air. This cauſe, whatever it be, operates here; and the beſt way of preventing the diſſipation, or the abſorption by the cake, is to keep the electrophorus with its cover on. It will come into this neutral ſtate by diſſipation from the ſole, and abſorption by the cover, in no very long time; and after this, will remain neutral, retaining its power with great obſtinacy, eſpecially if the cake and plates are very thin.

194 Charging or ive ſtate. VI. If the cover be now removed to a diſtance, both parts of the apparatus will ſhew ſtrong marks of electricity. The cover contains much redundant fluid, and muſt appear ſtrongly poſitive, and will give a bright ſpark, which may be employed for any purpoſe. It may be employed for charging a jar poſitively by the knob, if we juſt touch the cover with the knob. The ſole will attract fluid, or be negative, although it contain more than its natural quantity of fluid, and it will take a ſpark. The ſole therefore, in the abſence of the cover, may be employed to charge a jar negatively by the knob. By touching it with the finger, or with the knob of a jar held in the hand, it is reduced to the common ſtate deſcribed in N° II.; and now all the former experiments may be repeated. We may call this the ACTIVE or the CHARGING ſtate.

lectrophorus not magazine electricity, but a llecting achine. This ſtate of the apparatus has cauſed it to get the name *Electrophorus*. Volta, its undoubted inventor, called it *Electroforo perpetuo*; for it *appears*, as has been already obſerved, to contain a magazine of electricity. The cover, when removed, will charge a jar held in the hand poſitively; and having done this ſervice, it will charge a jar negatively when again ſet on the cake. The ſole, in the abſence of the cover, will charge a third jar negatively; and then, when the cover, after being touched, is ſet down again, it will charge a fourth jar poſitively. It will not be difficult to contrive a ſimple mechaniſm, connected with the motion of the cover, which ſhall connect the joined parts with two jars, and ſhall connect them, when ſeperated, with two others; and thus charge all the four with great expedition. All this is done without any new excitation of the electrophorus. But it is by no means a *magazine* of electricity which it gradually expends: it is a COLLECTOR of electricity from the ſurrounding bodies, which it afterwards imparts to others, and may be employed to diſcharge jars in the ſame gradual manner as to charge them.

195. VII. If the electrophorus is not inſulated, a ſhock may ſtill be obtained, by firſt touching the ſole, and then, without removing the finger, touching the cover: but this will not be ſo ſmart as when the negative cover is touched at the ſame time that we touch the ſole, more highly poſitive than when it communicates with the ground. The difference muſt, however, be almoſt imperceptible when the pieces are thin.

196. VII. If the electrophorus is not inſulated, the cover, when put on, will give a ſpark in the manner already mentioned, and it will be ſomewhat ſtronger than when it is inſulated; becauſe the fluid is allowed to eſcape from the ſole, and does not obſtruct the entry into the cover. If we then, without removing the finger from the cover, touch the ſole, nothing is felt; but if we firſt touch the ſole, and, without removing the finger from it, touch the cover, we obtain a ſhock. This is evident from the theory. By this ſeries of alternate touches, the period of the electrophorus is completed. The electrophorus is charged, or rendered neutral, by touching the plates when joined; then, by touching both when ſeparated, the whole is reduced to the common ſtate. When ſeparated, from being in the neutral ſtate, they have oppoſite electricities, the ſole ſhewing that of the cake. When brought together, each in the common ſtate, they have oppoſite electricities, the cover ſhewing that of the cake.

197 How it may be recreated. IX. When, by long expoſure to the air without its cover, the electrophorus has loſt its virtue, it may be brought again into an active ſtate in a variety of ways. Its ſurface may be rendered negative by friction with dry cat or hare ſkin, or warm flannel. It may be rendered negative by ſetting on it a jar charged negatively on the inſide, and then touching the knob with any thing communicating with the ground. This is the moſt expeditious method, and will give it a high degree of excitation, if the jar be of ſize, and if the electrophorus be covered with a plate of tinfoil which comes into contact all over its ſurface. This however requires the previous charging of the jar; therefore it will be as expeditious and effectual to connect this ſurface with the rubber of an electrical machine. We had almoſt forgotten to remark, that the effects of bringing the cover edgewiſe to the cake follow clearly from the theory, as will appear to the attentive reader without further explanation.

198 It is not ſimilar to a charged pane. The electrophorus has been compared to a charged plate of coated glaſs. It is true that it *may be brought* into an external ſtate which very much reſembles a charged pane; namely, when the cover, in its natural ſtate, is ſet on the electrophorus in its natural ſtate: and accordingly it gives a ſhock, and the two exterior ſurfaces become neutral; but the internal conſtitution, and the acting forces, are totally and *eſſentially* different. The two coatings of the pane would not, when ſeparated, exhibit the appearances of the electrophorus; nor, when touched in their disjoined ſtate, will they pruduce the ſame effects when joined. In the operation of coated glaſs, the conſtant or invariable part, the glaſs is not the *agent*, it is merely the *occaſion* of the action, by *allowing* the accumulation. In the electrophorus, the electric, which is the conſtant invariable part, is the *agent producing* the accumulation. The electrophorus is an original, and a very ingenious and curious electrical machine. Nothing has ſo much contributed to ſpread ſome general, though ſlight, acquaintance with the mechanical principles of electricity. The numerous dabblers in natural knowledge had been diverted from ſcientific purſuit by the variety of the ſingular and amuſing effects of electricity, and had really attained very little connected knowledge. The effects of the electrophorus *forced* this knowledge on them; becauſe no uſe can be made of it without a pretty clear conception of the diſpoſition of the electricity, and the kind and intenſity of the actions. It is therefore moſt ungrateful in the experimenters who have attained better views, to attempt to rob Mr Volta of the real merit of diſcovery, by ſhewing that its effects are ſimilar to thoſe of Mr Symmer's ſtockings, or of Cigna's plates, or of Franklin's charged or diſcharged glaſs panes. And the attempt

tempt deſtroys itſelf: for it ſhews the ignorance or inattention of its author; for the ſimilarity is not real, as will appear clear to any perſon who will examine things minutely and ſcientifically, proceeding in this examination on ſuppoſitions ſimilar to thoſe which we employed in the analyſis of Richmann's experiment. It was indeed in ſubſerviency to this examination that we entered into the detail of that experiment, it being a ſimpler caſe. The accurate examination of Richmann's experiment requires the fluxionary calculus in its refined form. In the preſent queſtion five acting ſtrata are to be conſidered, which renders the formulæ very complicated, and indeed intractable, unleſs we make the plates extremely thin; which, fortunately, is the beſt form of the inſtrument. We have completed this mathematical analyſis; and the popular view here given is the reſult of that computation.

199 *Condenſator of electricity.* The electricians are no leſs obliged to Mr Volta for another machine, or inſtrument, from which the ſtudy of Nature's operations has derived, or may derive, immenſe advantages. We mean the CONDENSER or COLLECTOR of electricity. We refer to the article ELECTRICITY in the *Encyclopædia* for a deſcription of the inſtrument, and ſome account of its effects and properties. The general effect is to render ſenſible an accumulation or deficiency of electric fluid ſo ſlight that it will not affect the moſt delicate electrometer; and it produces (at leaſt in the opinion of Mr Volta) this effect, by employing for the ſole of an electrophorus a body which is an imperfect conductor, ſuch as a plate of well dried marble, or well dried, but not baked, wood; or even a conducting body, covered with a bit of dry taffety or other ſilk. Mr Volta, Cavallo, and others, who have written a great deal on the ſubject, have attempted to ſhew how theſe ſubſtances are preferable (and they certainly are preferable in a high degree) to more perfect inſulators: but not having taken pains to form preciſe notions of the diſpoſition and action of the electric fluid in the ſituations afforded by the inſtrument, their reaſonings have not been very clear. We think that an adequate conception of the eſſentials of the propoſed inſtrument may be acquired by means of the following conſiderations:

200. Furniſh the cover of an electrophorus with a graduated electrometer, which indicates the proportional *degrees of electricity*; electrify it poſitively to any degree, ſuppoſe ſix, while held in the hand, at ſome diſtance, right over a metal plate lying on a wine glaſs as an inſulating ſtand, but communicating with the ground by a wire. Bring it gradually down toward the plate. Theory teaches, and we know it by experiment, that the electrometer will gradually ſubſide, and perhaps will reach to 2° before the electricity is communicated in a ſpark. Stop it before this happens. In this ſtate the attraction of the lying plate produces a compenſation of four degrees of the mutual repulſion of the parts of the cover, by conſtipating the fluid on its under ſurface, and forming a deficient ſtratum above. This needs no farther explanation after what has been ſaid on the charging of coated glaſs plates. Now we can ſuppoſe that the eſcape of the fluid from this body into the air begins as ſoon as electrified to the degree 6, and that it will fly to the lying plate with the degree 2, if brought nearer. If we can prevent this communication to the lying plate, by interpoſing an electric, we may electrify the cover again, while ſo near the metal plate, to the degree 6, before it will ſtream off into the air. If it be now removed from the lying plate, the fluid would raiſe the electrometer to 10, did it not immediately ſtream off; and an electric excitement of any kind which could only raiſe this body to the degree 6 by its intenſity, will, by this apparatus, raiſe it to the degree 10, if only copious enough in extent. If we do the ſame thing when the wire is taken away which connects the lying plate with the ground, we know that the ſame diminution of the electricity of the other plate cannot be produced by bringing it down into the neighbourhood of the lying plate (ſee nº 134, &c. 151, &c.)

Theory thereof. Here we ſee the whole theory of Mr Volta's condenſer. He ſeems to have obſcured his conceptions of it by having his thoughts running upon the electrophorus lately invented by him, and is led into fruitleſs attempts to explain the advantages of the imperfect conductor above the perfect inſulator. But the apparatus is altogether different from an electrophorus, and is more analogous in its operations to a coated plate not charged nor inſulated on the oppoſite ſide; and ſuch a coated plate lying on a table is a complete condenſer, if the upper coating be of the ſame ſize with the plate of the condenſer. All the directions given by Mr Volta for the preparation of the imperfect conductors ſhew, that the effect produced is to make them as perfect conductors as poſſible for any degree of electricity that exceeds a certain ſmall intenſity, but ſuch as ſhall not ſuffer this very weak electricity to clear the firſt ſtep of the conduit. The marble muſt be thoroughly dried, and even heated in an oven, and either uſed in this warm ſtate, or varniſhed, ſo as to prevent the reabſorption of moiſture. We know that marble of ſlender dimenſions, ſo as to be completely dried throughout, will not conduct till it has again become moiſt. A thick piece of marble is rendered ſo, ſuperficially only, and ſtill conducts internally. It is then in the beſt poſſible ſtate. The ſame may be ſaid of dry unbaked wood. Varniſhing the upper ſurface of a piece of marble or wood is equivalent to laying a thin glaſs plate on it. Now this method, or covering the top of the marble, or of a book, or even the table, with a piece of clean dry ſilk, makes them all the moſt perfect condenſators. This juſt view of the matter has great advantages. It takes away the myſterious indiſtinctneſs and obſcurity which kept the inſtrument a quackiſh tool, incapable of improvement. We can now make one incomparably better and more ſimple than any propoſed by the very ingenious inventor. We need only the ſimple moveable plate. Let this be varniſhed on the under ſide with a moderately thick coat of the pureſt and hardeſt *vernis de Martin*, or coach-painters varniſh; and we have a complete condenſator by laying this on a table. If it be connected by a wire with the ſubſtance in which the weak and imperceptible electricity is excited, it will be raiſed (provided there be enough of it of that ſmall intenſity) in the proportion of the thickneſs of the varniſh to the fourth part of the diameter of the plate. This degree of condenſation will be procured by detaching the connecting wire from the inſulating handle of the condenſer, and then raiſing the condenſer from the table. It will then give ſparks, though the original electricity could not ſenſibly affect a flaxen fibre.

It muſt be particularly noted, that it can produce this condenſation only when there is fluid to condenſe; that is, only when the weak electricity is diffuſed over a greater ſpace than the plate of the condenſer. In this way it is a moſt excellent collector of the weak atmoſpheric electricity, and of all diffuſed electricity. But to derive the ſame advantage from it *in many very intereſting caſes*, ſuch as the inquiry into the electricity excited in many operations of Nature on ſmall quantities of matter, we muſt have condenſers of various ſizes, ſome not larger than a ſilver penny. To conſtruct theſe in perfection, we muſt uſe the pureſt and hardeſt varniſh, of a kind not apt to crack, and highly coercive. This requires experiment to diſcover it. Spirit varniſhes are the moſt coercive; but by their difference of contraction by cold from that of metals, they ſoon appear froſty, and when viewed through a lens, they appear all ſhivered: They are then uſeleſs. Oil varniſhes have the requiſite toughneſs, but are much inferior in coercion. We have found amber varniſh inferior to copal varniſh in this reſpect, contrary to our expectation. On the whole, we ſhould prefer the fineſt coach-painters varniſh, new from the ſhop, into which a pencil has never been dipped: and we muſt be particularly careful to clear our pencils of moiſture and all conducting matter, which never fails to taint the varniſh. We ſcarcely need remark, that the coat of varniſh on theſe ſmall condenſers ſhould be very thin, otherwiſe we loſe all the advantage of their ſmallneſs.

201 avallo's nprovement hereof. Mr Cavallo has ingeniouſly improved Volta's condenſer by connecting the moveable plate, after removal, with a ſmaller condenſer. The effect of this is evident from nº 130. But the ſame thing would have been generally obtained by uſing the ſmall condenſer at firſt, or by uſing a ſtill thinner coat of varniſh.

202. It will readily occur to the reader, that this inſtrument is not inſtantaneous in its operation, and that the application muſt be continued for ſome time, in order to collect the minute electricity which may be excited in the operations of nature. He will alſo be careful that the experiment be ſo conducted that no uſeleſs accumulation is made anywhere elſe. When we expect electricity from any chemical mixture, it never ſhould be made in a glaſs veſſel, for this will take a charge, and thus may abſorb the whole excited electricity, accumulating it in a neutral or inſenſible ſtate. Let the mixture be made in veſſels of a conducting ſubſtance, inſulated with as little contact as poſſible with the inſulating ſupport; for here will alſo be ſomething like a charge. Suſpend it by ſilk threads, or let it reſt on the tops of three glaſs rods, &c.

203 ennet's *ubler* of lectricity. After this account of the Leyden phial, electrophorus, and condenſer, it is ſurely unneceſſary to employ any time in explaining Mr Bennet's moſt ingenious and uſeful inſtrument called the *doubler of electricity*. The explanation offers itſelf ſpontaneouſly to any perſon who underſtands what has been ſaid already. Mr Cavallo has with induſtry ſearched out all its imperfections, and has done ſomething to remove them, by ſeveral very ingenious conſtructions, minutely deſcribed in his Treatiſe on Electricity. Mr Bennet's original inſtrument may be freed, we imagine, as far as ſeems poſſible, by uſing a plate of air as the intermedium between the three plates of the doubler. Stick on one of the plates three very ſmall ſpherules made from a capillary tube of glaſs, or from a thread of ſealing wax. The other plate being laid on them, reſts on mere points, and can ſcarcely receive any friction which will diſturb the experiment. Mr Nicholſon's beautiful mechaniſm for expediting the multiplication, has the inconveniency of bringing the plates towards each other edgewiſe, which will bring on a ſpark or communication ſooner than may be deſired: but this is no inconvenience whatever in any philoſophical reſearch; becauſe, before this happens, the electricity has become very diſtinguiſhable as to its kind, and the degree of multiplication is little more than an amuſement. The ſpark may even ſerve to give an indication of the original intenſity, by means of the number of turns neceſſary for producing it. If the fine wires, which form the alternate connections in ſo ingenious a manner, could be tipped with little balls to prevent the diſſipation, it would be a great improvement indeed. An alternate motion, like that of a pump-handle, might be adopted with advantage. This would allow the plates to approach each other face to face, and admit a greater multiplication, if thought neceſſary.

204 Diſſipation of electricity from ſharp points. One of the moſt remarkable facts in electricity is the rapid diſſipation by ſharp points, and the impoſſibility of making any conſiderable accumulation in a body which has any ſuch, projecting beyond other parts of its ſurface. The diſſipation is attended with many remarkable circumſtances, which have greatly the appearance of the actual eſcape of ſome material ſubſtance. A ſtream of wind blows from ſuch a point, and quickly electrifies the air of a room to ſuch a degree, that an electrometer in the fartheſt corner of the room is affected by it. This diſſipation in a dark place is, in many inſtances, accompanied by a bright train of light diverging from the point like a firework. Dr Franklin therefore was very anxious to reconcile this appearance with his theory of plus and minus electricity, but does not expreſs himſelf well ſatisfied with any explanation which had occurred to him. From the beginning, he ſaw that he could not conſider the ſtream of wind as a proof of the eſcape of the electric fluid, becauſe the ſame ſtream is obſerved to iſſue from a ſharp negative point; which, according to his theory, is not diſperſing, but abſorbing it. Mr Cavendiſh has, in our opinion, given the firſt ſatisfactory account of this phenomenon.

205. To ſee this in its full force, the phenomenon itſelf muſt be carefully obſerved. The ſtream of wind is plainly produced by the eſcape of ſomething from the point itſelf, which hurries the air along with it; and this draws along with it a great deal of the ſurrounding air, eſpecially from behind, in the ſame manner as the very ſlender thread of air from a blow-pipe hurries along with it the ſurrounding air and flame from a conſiderable ſurface on all ſides. It is in this manner that it gathers the whole of a large flame into one maſs, and, at laſt, into a very point. If the ſmoke of a little roſin thrown on a bit of live coal be made to riſe quietly round a point projecting from an electrified body, continually ſupplied from an electrical machine, the vortices of this ſmoke may be obſerved to curl in from all ſides, along the wire, forming a current of which the wire is the axis, and it goes off completely by the point. But if the wire be made to paſs through a cork fixed in the bottom of a wide glaſs tube, and if its point project not beyond the mouth of the tube,

the afflux of the air from behind is prevented, and we have no ſtream; but if the cork be removed, and the wire ſtill occupy the axis of the tube, but without touching the ſides, we have the ſtream very diſtinctly; and ſmoke which riſes round the far end of the tube is drawn into it, and goes of at the point of the wire. Now it is of importance to obſerve, that whatever prevents the formation of this ſtream of wind prevents the diſſipation of electricity (for we ſhall not ſay eſcape of electric fluid) from the point. If the point project a quarter of an inch beyond the tube, or if the tube be open behind, the ſtream is ſtrong, and the diſſipation ſo rapid, that even a very good machine is not able to raiſe a Henly's electrometer, ſtanding on the conductor, a very few degrees. If the tube be ſlipped forward, ſo that the point is juſt even with its mouth, the diſſipation of electricity is next to nothing, and does not exceed what might be produced by ſuch air as can be collected by a ſuperficial point. If the tube be made to advance half an inch beyond the point which it ſurrounds, the diſſipation becomes inſenſible. All theſe facts put it beyond a doubt that the air is the cauſe, or, at leaſt, the occaſion of the diſſipation, and carries the electricity off with it, in this manner rendering electrical the whole air of a room. The problem is reduced to explain how the air contiguous to a ſharp electrified point is electrified and thrown off.

Theory of it. It was demonſtrated in n° 130, that two ſpheres, connected by an infinitely extended, but ſlender conducting canal, are in electrical equilibrium, if their ſurfaces contain fluid in the proportion of their diameters. In this caſe, the ſuperficial denſity of the fluid and its tendency to eſcape are inverſely as the diameters (n° 130). Now if, in imagination, we gradually diminiſh the diameter of one of the ſpheres, the tendency to eſcape will increaſe in a greater proportion than any that we can name We know, that when the prime conductor of a powerful table-machine has a wire of a few inches in length projecting from its end, and terminating in a ball of half an inch in diameter, we cannot electrify it beyond a certain degree; for when arrived at this degree, the electricity flies off in ſucceſſive burſts from this ball. Being much more overcharged than any other part of the body, the air ſurrounding the ball becomes more overcharged by communication, and is repelled, and its place ſupplied by other air, not ſo much overcharged, which ſurrounded the other parts of the body, and is preſſed forwards into this ſpace by the general repulſion of the conductor and the confining preſſure of the atmoſphere; otherwiſe, being alſo overcharged, it would have no tendency to come to this place. Half a turn of the cylinder is ſufficient to accumulate to a degree ſufficient for producing one of theſe exploſions, and we have two of them for every turn of the cylinder, A point may be compared to an incomparably ſmaller ball. The conſtipation of the fluid, and its tendency to eſcape, muſt be greater in the ſame unmeaſurable proportion. This denſity and mutual repulſion cannot be diminiſhed, and muſt even be increaſed, by the matter of the wire forming a cone of which the point is the apex; therefore, if there were no other cauſe, we muſt ſee that it is almoſt impoſſible to confine a collection of particles, mutually repelling, and conſtipated, as theſe are in a fine point.

206 Electricity unites chemically with air. But the chief cauſe ſeems to be a certain chemical union which takes place between the electric fluid and a correſponding ingredient of the air. In this ſtate of conſtipation, almoſt completely ſurrounded by the air, the little maſs of fluid muſt attract and be attracted with very great force, and more readily overcome the force which keeps the electrified fluid attached to the laſt ſeries of particles of the wire. It unites with the air, rendering it electric in the higheſt degree of redundancy. It is therefore ſtrongly repelled by the maſs of conſtipated fluid which ſucceeds it within the point. Thus is the electrified air continually thrown off, in a ſtate of electrification, that muſt rapidly diminiſh the electricity of the conductor. Hence the uninterrupted flow, without noiſe or much light, when the point is made very fine. When the point is blunt, a little accumulation is neceſſary before it attains the degree neceſſary for even this minute exploſion; but this is ſoon done, and theſe little exploſions ſucceed each other rapidly, accompanied by a ſputtering noiſe, and trains of bright ſparks. The noiſe is undoubtedly owing to the atoms of the highly electrified fluid. Theſe are, in all probability, rarefied of a ſudden, in the act of electrification, and immediately collapſe again in the act of chemical union, which cauſes a ſonorous agitation of the air. This electrified air is thus thrown off, and its place is immediately ſupplied by air from behind, not yet electrified, and therefore ſtrongly drawn forward to the point, from which they are thrown off in their turn. This rapid expanſion and ſubſequent collapſing of the air is verified by the experiments of Mr Kinnerſly, related by Dr Franklin, and is ſeen in numberleſs experiments made with other views in later times, and not attended to. Perhaps it is produced by the great heat which accompanies, or is generated in the transference of electricity; and it is of the ſame kind with what occaſions the burſting of ſtones, ſplitting of trees, exploding of metals, &c. by electricity. The expanſion is either inconſiderable, or it is ſucceſſively produced in very ſmall portions of the ſubſtance expanded; for when metal is exploded in cloſe veſſels, or under water, there is but a minute portion of gazeous matter produced; and in the diſſipation by a very fine point, ſufficiently great to give full employment to a powerful machine, the ſtream of wind is but very faint, and nine-tenths of this has been dragged along by the really electrified thread of wind in the middle.

From a collation of all the appearances of electricity, we muſt form the ſame conception of the forces which operate round a point that is negatively electrified, not diſperſing, but drawing in electric fluid. It is more completely undercharged than any other part of a body, and attracts the fluid in the ſurrounding air, and the air in which it is retained, with incomparably greater force. It therefore deprives the contiguous air of its fluid, and then repels it, and then produces a ſtream like the overcharged point.

207. If a conducting body be brought near to any part of an overcharged body, the fronting part of the firſt is rendered undercharged; and this increaſes the charge of the oppoſite part of the overcharged body. It becomes more overcharged in that part, and ſooner attains that degree of conſtipation that enables the fluid to quit the ſuperficial ſeries of particles, and to electrify ſtrongly the contiguous air. The exploſion is therefore made in this part in preference to any other; and the

the air thus exploded is ſtrongly attracted by the fronting part of the other body, and muſt fly thither in preference to any other point. If, moreover, the fronting part of A be prominent or pointed, this effect will be produced in a ſuperior degree; and the current of electrified air, which will begin very early, will increaſe this diſpoſition to transference in this way by rarefying the air; a change which the whole courſe of electric phenomena ſhews to be highly favourable to this transference, although we cannot perhaps form any very adequate notion how it contributes to this effect. This ſeems to be the reaſon why a great exploſion and ſnap, with a copious transference of electricity, is generally preceded by a hiſſing noiſe like the ruſhing of wind, which ſwells to a maximum in the loud ſnap itſelf.

208. If two prominences, preciſely ſimilar, and electrified in the contrary way to the ſame degree, are preſented to each other, we cannot ſay from which the current ſhould take its commencement, or whether it ſhould not equally begin from both, and a general diſperſion of air laterally be the effect; but ſuch a ſituation is barely poſſible, and muſt be infinitely rare. The current will begin from the ſide which has ſome ſuperiority of propelling force. We are diſpoſed to think that this current of material electrified ſubſtance muſt ſuffer great change during its paſſage, by mixing with the current in an oppoſite electrical ſtate coming from the other body. Any little maſs of the one current muſt ſtrongly attract a contiguous maſs of the other, and certain changes ſhould ſurely ariſe from this mixture. Theſe may, in their turn, make a great change in the *mechanical* motions of the air; and, inſtead of producing a *quaqua verſum* diſperſion of air from between the bodies, as ſhould reſult from the meeting of oppoſite ſtreams, it may even produce a collapſing of the air by the mutual ſtrong attractions of the little maſſes. Many valuable experiments offer themſelves to the curious inquirer. Two little balls may be thus preſented to each other, and a ſmoke may be made with roſin to occupy the interval between them. Motions may be obſerved which have certain analogies that would afford uſeful information to the mechanical inquirer. There muſt be ſomething of this mixture of currents in all ſuch transferences, and the moſt minute differences in the condition of a little parcel of the air may greatly affect the future motions. The moſt promiſing form of ſuch experiment would be to uſe two points of the ſame ſubſtance, ſhape, and ſize, and electrified to the ſame degree in oppoſite ſenſes.

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After all care has been taken to inſure ſimilarity, there remains one eſſential difference, that *the one current is redundant in electric fluid, and the other deficient*. This circumſtance *muſt* produce characteriſtic differences of appearance. And are there not ſuch differences? Is not the pencil and the ſtar of light a characteriſtic difference? And does not this well-ſupported fact greatly corroborate the opinion of Dr Franklin, that the electric phenomena reſult from the redundancy and deficiency of *one* ſubſtance, and not from two diſtinct ſubſtances operating in a ſimilar manner? For the diſtinction in appearance is a mechanical diſtinction. Motion, direction, velocity, are perceivable in it. Locomotive forces are concerned in it; but they are ſo implicated with forces which probably reſemble chemical affinities, hardly operating beyond contact, that to extricate their effects from the complicated phenomenon ſeems a deſperate problem. There is ſome hitherto inexplicable chemical compoſition and decompoſition taking place in the transference of electricity. Of this a numerous train of obſervations made ſince the dawn of the pneumatic chemiſtry leaves us no room to doubt. The emerſion or production of light and heat is a remarkable ſign and proof. Now *this takes place along the whole path of transference*; therefore the proceſs is by no means completed at the point from which the active cauſe proceeds; and although there be certain appearances that are pretty regular, they are ſtill mixed with others of the moſt capricious anomaly. The zigzag form of the moſt condenſed ſpark, totally unlike, by its ſharp angles, to any motions producible by accelerating forces, which motions are, without exception, curvilineal, makes us doubt exceedingly whether the luminous lines which we obſerve are ſucceſſive appearances of the ſame matter in different places, or whether they be not rather ſimultaneous, or nearly ſimultaneous, coruſcations of different parcels of matter in different places, indicating chemical compoſitions taking place almoſt at once; and this becomes more probable, when we reflect on what has been ſaid already of the jumbling of oppoſite currents; ſuch mixtures ſhould be expected. We have ſeen a darted flaſh of lightning which reached (in a direction nearly parallel to the horizon) above three miles from right to left; and it ſeemed to us *to be co-exiſtent*; we could not ſay at which end it began. The thunder began with a loud crack, and continued with a moſt irregular rumbling noiſe about 15 ſeconds, and ſeemed equal on both hands. We imagine that it was really a ſimultaneous ſnap, in the whole extent of the ſpark, but of different ſtrength in different places; different portions of the ſonorous agitation were propagated to the ear in ſucceſſion by the ſonorous undulations of air, cauſing it to ſeem a lengthened ſound. Such would be the appearance to a perſon ſtanding at one end of a long line of ſoldiers who diſcharge their firelocks at one inſtant. It will ſeem a running fire, of different ſtrength in different parts of the line, if the muſkets have been unequally loaded. It is inconceivable that this long zigzag ſpark can mark the track of an individual maſs of electrified air. The velocity and momentum would be enormous, and would ſweep off every thing in its way, and its path could not be angular. The ſame muſt be aſſerted of the ſtreams of light in our experiments. The velocity is ſo unmeaſurable that we cannot tell its direction. There may be very little local motion, juſt as in the propagation of ſound, or of a wave on the ſurface of water. That particular change of mutual ſituation among the adjoining atoms which occaſions chemical ſolution or precipitation may be produced in an inſtant, over a great extent, as we know that a parcel of iron filings, lying at random on the ſurface of quickſilver, will, in one inſtant, be arranged in a certain manner by the mere neighbourhood of a magnet. Is not this like the ſimultaneous precipitation of water along the whole path of a diſcharge?

But ſtill there muſt be ſome cauſe which gives theſe ſimultaneous coruſcations a ſituation with reſpect to each other, that has a certain regularity. Now the luminous *trains* (for they are not uniform *lines* of light) of almoſt continuous ſparks which are arranged between a poſitive and a negative point, ſeem to us to indicate emanation from the poſitive, and reception by the negative point. The general line has a conſiderable reſemblance to the path of a body projected from the poſitive point, repelled by it, and attracted by the negative point. This will appear to the mechanician on a very little reflection. If the curve were completely viſible, it would ſomewhat reſemble thoſe drawn between P and N in fig. 35. PABN overpaſſes the point N, and comes to it from behind; P *a b* N lies within the other, and arrives in a direction nearly perpendicular to the axis; P α BN deſcribes a ſtraight line, and arrives in the direction PN. As the chemical compoſition advances, the light is diſengaged or produced, and therefore the appearances are more rare as we advance farther in the direction in which they are produced; and there would perhaps be no appearance at all at the point where the motion ends, were it not that the few remaining parcels, where the compoſitions or decompoſitions have not been completed, are crowded together at the negative point, *incomparably* more than in any other part of the track. We think that theſe conſiderations offer ſome explanation of the appearance of the pencil and ſtar, which are ſo uniformly characteriſtic of the poſitive and negative electricities; but we ſee many grounds of uncertainty and doubt, and offer it with due diffidence.

210 Lichtenberg's electric writing affords diſtinctive marks of + and —

The curious figures obſerved by Mr Lichtenberg, formed by the duſt which ſettles on a line drawn on the face of a mirror by the poſitive and by the negative knobs of a charged jar, are alſo uniformly characteriſtic of the two electricities. Theſe are mechanical diſtinctions, indicating certain differences of accelerating forces. We muſt refer the curious reader to Lichtenberg's Diſſertations in the *Gottingen Commentaries*; to the *Publication of the Haarlem Society*; to the *Gotha Magazine*; to *Diſſertations by Spath* at Altdorff, and other German writers.

211 Diſſipation of electricity into the air is proportional to the denſity.

It only remains for us to take notice of the general laws of the diſſipation of electricity into the air, and along imperfect inſulators. On this ſubject we have ſome valuable experiments of Mr Coulomb, publiſhed in the Memoirs of the Academy of Sciences of Paris for 1785.

Theſe experiments were made with the aſſiſtance of an electrometer of a particular conſtruction, which ſhall be deſcribed under the article ELECTROMETER.

The general reſult of Mr Coulomb's experiments was, that the momentary diſſipation of moderate degrees of electricity is proportional to the degree of electricity at the moment. He found that the diſſipation is not ſenſibly affected by the ſtate of the barometer or thermometer; nor is there any ſenſible difference in bodies of different ſizes or different ſubſtances, or even different figures, provided that the electricity is very weak.

212. But he found the diſſipation greatly affected by the different ſtates of humidity of the air. Sauſſure's hygrometer has its ſcale diſtinctly related to the quantity of water diſſolved in a cubic foot of the air. The following little Table ſhews an evident relation to this in the diſſipation of electricity:

Hygrometer.	Grains water in cubic foot.	Diſſipation per minute.
69	6,197	$\frac{1}{60}$
75	7,295	$\frac{1}{41}$
80	8,045	$\frac{1}{29}$
87	9,221	$\frac{1}{14}$

Hence it follows, that the diſſipation is very nearly in the triplicate ratio of the moiſture of the air. Thus if

$$\frac{60}{41} \text{ be conſidered as } = \left.\overline{\frac{7,197}{6,180}}\right|^{m} \text{ we have } m = 2,764$$

$$\frac{60}{29} \;\ldots\ldots\; = \left.\overline{\frac{8,045}{6,180}}\right|^{m} \text{ gives } \quad m = 2,76$$

$$\frac{60}{14} \;\ldots\ldots\; = \left.\overline{\frac{9,220}{6,180}}\right|^{m} \text{ gives } \quad m = 3,61$$

Hence, at a medium, $m = 3,40$.

We ſhould have obſerved, that the ingenious author took care to ſeparate this diſſipation by immediate contact with the air, from what was occaſioned by the imperfect inſulation afforded by the ſupports.

213 Diminution of repulſion is double of the diſſipation.

It muſt alſo be remarked here, that the immediate object of obſervation in the experiments is the diminution of repulſion. This is found to be, in any given ſtate of the air, a certain proportion of the whole repulſion at the moment of diminution: but this is double of the proportion of the denſity of the electric fluid: for it muſt be recollected, that the repulſions by which we judge of the diſſipation are mutual, exerted by every particle of fluid in the ball *t* of Coulomb's electrometer, on every particle in the ball *a*. It is therefore proportional to the electric denſity of each; and therefore, during the whole diſſipation, the denſities retain their primitive proportion; therefore, the diminution of the repulſion being as the diminution of the products of the denſities, it is as the diminution of the ſquares of either. If therefore the denſity be repreſented by d, the mutual repulſion is repreſentable by d^2, and its momentary diminution by the fluxion of d^2; that is, by $2\dot{d}d$, or $2\dot{d} \times d$. Now $2\dot{d} \times d$ is to d^2 as $2\dot{d}$ is to d; and therefore the diminution of repulſion obſerved in our experiment bears to the whole repulſion twice as great a proportion as the diminution of denſity, or the quantity of fluid diſſipated bears to the whole quantity at the moment. For example, if we obſerve the repulſion diminiſhed $\frac{1}{40}$, we conclude that $\frac{1}{80}$ of the fluid has eſcaped.

214. Mr Coulomb has not examined the proportion between the diſſipations from bodies of different ſizes. A great and a ſmall ſphere, communicating by a very long canal, have ſuperficial denſities, and tendencies to eſcape, inverſely proportional to the diameters. A body of twice the diameter has four times the ſurface; and tho' the tendency to eſcape be twice as ſmall, the ſurface is four times as great. Perhaps the greater ſurface may compenſate for the ſmaller denſity, and the quantity of fluid actually gone off may be greater in a large ſphere. This may be made the ſubject of trial.

215 Diſſipation depends on the ſtate of the air.

It muſt be kept in mind, that the law of diſſipation aſcertained by theſe experiments, relates to one given ſtate of the air, and that it does not follow that in another ſtate, containing perhaps the ſame quantity of water, the diſſipation ſhall be the ſame. The air is ſuch a hetea heterogeneous and variable compound, that it may have very different affinities with the electric fluid. Mr Coulomb thought that he ſhould infer from his numerous experiments, that the diſſipation did not increaſe in the ratio of the cube of the water diſſolved in the air, unleſs it was nearly as much as it could diſſolve in that temperature This indeed is conformable to general obſervation: for air is thought dry when it dries quickly any thing expoſed to it; that is, when not nearly ſaturated with moiſture. Now it is well known, that what is thought dry air is favourable to electricity.

216 Diſſipation by imperfect inſulators.

The diſſipation along imperfect inſulators is brought about in a way ſomewhat different from the manner of its eſcaping by electrifying the contiguous air and going off with it. It ſeems to be chiefly, if not ſolely, along the ſurface of the inſulating ſupport that the electricity is diffuſed, and that the diffuſion is produced there chiefly by the moiſture which adheres to it. It is not very eaſy to form a clear notion of the manner, but Mr Coulomb's explanation ſeems as ſatisfactory as any we have ſeen.

Procedure thereof.

Water adheres to all bodies, ſticking to their ſurfaces. This adheſion prevents it from going off when electrified; and it is therefore ſuſceptible of a higher degree of electrification. If we ſuppoſe that the particles of moiſture are uniformly diſpoſed along the ſurface, leaving ſpaces between them, the electricity communicated to one particle muſt attain a certain denſity before it can fly acroſs the inſulating interval to the next. Therefore, when ſuch an imperfect conductor is electrified at one end, the electricity, in paſſing to the other, will be weakened at every ſtep. If we take three adjacent particles *a*, *b*, *c*, of this conducting matter, we learn, from nº 105, that the motion of *b* is ſenſibly affected only by the difference of *a* and *c*; and therefore that the paſſage of electricity from *b* to *c* requires that this difference be ſuperior or equal to the force neceſſary for clearing this coercive interval. Let a particle paſs over. The electric denſity of the particle *b* of conducting matter is diminiſhed, while the denſity of the particle on the other ſide of *a* remains as before. Therefore ſome will paſs from *a* to *b*, and from the particle preceding *a* to *a*; and ſo on, till we come to the electrified end of this imperfect inſulator. It is plain from this conſideration, that we muſt arrive at laſt at a particle beyond *c*, where the whole repulſion of the preceding particle is juſt ſufficient to clear this interval. Some will come over, whoſe repulſion, now acting in the oppoſite direction, will hinder any fluid from ſupplying its place in the particle which it has quitted. Here the transference will ſtop, and beyond this the inſulation is complete. There is therefore a mathematical relation between the inſulating power and the length of the canal, which may be aſcertained by our theory; and thus another opportunity obtained for comparing it with obſervation. That this inveſtigation may be as ſimple as poſſible, we may take a very probable caſe, namely, where the inſulating, or, to name it more graphically, the coercive, interval is equal in every part of the canal.

217 Theory thereof.

Let R be the coercive power of the inſulator; that is, let R be the force neceſſary for clearing the coercive interval. Let a ball C (fig. 36.) be ſuſpended by a ſilk thread AB, and let C repreſent the quantity of its redundant fluid; and let the denſity in the different points of the canal be as the ordinates AD, P*d*, &c. of ſome curve line D*d*B, which cuts the axis in B where the thread begins to inſulate completely. Let P*p* be an element of the axis. Draw the ordinate *pf*, the tangent *df*F, and the normal *d*E, and *fe* perpendicular to P*d*. Let AC be = *r*, AP = *x*, P*d* = *y*. Then P*p* = $\dot{x}$, and *de* = $-\dot{y}$. We have ſeen that the only ſenſible action on the particle of fluid in P is $-\frac{y\dot{y}}{\dot{x}}$ (ſee nº 105), when the action of the redundant fluid in the globe on the particle P, having the denſity *y*, is repreſented by $\frac{Cy}{(r+x)^2}$. Therefore we have $\frac{y\dot{y}}{\dot{x}} =$ R, the coercive power of the thread. This is ſuppoſed to be conſtant. Therefore $\frac{Pd \times de}{Pp}$ is equal to ſome conſtant line R. But P*p*, or *fe* : *de* = P*d* : PE. Therefore the ſubnormal PE is a conſtant line. But this is the property of the parabola alone; and the curve of denſity D*d*B is a parabola, of which the parameter is 2 PE, or 2 R.

218 Variation of denſity in the inſulator.

Cor. 1. The denſities in different points of an imperfect inſulator are as the ſquare roots of their diſtance from the point of complete inſulation: For $Pd^2 : AD^2 = BP : BA$.

219 Length neceſſary for inſulation ÷ denſity².

2. The length of canal required for inſulating different denſities of electricity are as the ſquares of the denſities. For $AB = \frac{AD^2}{2PE}$; and PE has been ſhewn to be a conſtant quantity. Indeed we ſee in the demonſtration, that BP would inſulate a ball, whoſe electric denſity is P*d*, and $BA : BP = AD^2 : Pd^2$.

220 Alſo ÷ $\frac{1}{\text{coercion}}$.

3. The length neceſſary for inſulation is inverſely as the coercive force of the canal, and may be repreſented generally by $\frac{D^2}{R}$. For AB is $= \frac{DA^2}{2PE} = \frac{D^2}{2R}$.

Mr Coulomb has verified theſe concluſions by a very ſatisfactory ſeries of experiments, by the aſſiſtance of his delicate electrometer, which is admirably ſuited for this trial. The ſubject is ſo intereſting to every zealous ſtudent of electricity, that Mr Canton, Dr B. Wilſon, Mr Waitz, Wilcke, and others, have made experiments for eſtabliſhing ſome meaſure of the conducting powers of different ſubſtances. It was one of the firſt things that made the writer of this article ſuppoſe that electric action was in the inverſe duplicate ratio of the diſtances: for, as early as 1763, he had found that the lengths of capillary tubes neceſſary for inſulation were as the ſquares of the repulſions of the ball which they inſulated. The mode of reaſoning offers of itſelf, and the fluxionary expreſſion of the inſulating power, *viz.* $\frac{d\dot{d}}{\dot{x}}$ led immediately to a force proportional to $\frac{1}{x^2}$. Numerous experiments were made, which we do not give here, becauſe the public are already poſſeſſed of thoſe of Mr Coulomb.

Explanation of the efficacy of Volta's *condenſer*.

This diſcuſſion explains, in a ſatisfactory manner, the operation of the condenſer, as deſcribed by Mr Volta. The weak degrees of electricity, which are rendered ſufficiently ſenſible by the inſulation of the plate of dry marble, are completely inſulated by the perhaps thin ſtratum that has been ſufficiently dried, while the reſt conducts with an efficacy ſufficient for permitting the accumulation.

221. When we reflect on the theory now delivered, we ſee that the formulæ determine the diſtribution of the fluid along an imperfect conductor in a certain manner, on the ſuppoſition that a *certain determinate* doſe has been imparted to the ball: Becauſe this doſe, by diffuſing itſelf from particle to particle of the conducting matter, will diffuſe itſelf all the way to B, in ſuch a manner that the repulſion ſhall everywhere be in equilibrio with the *maximum* of the coercive force of the inſulating interval. But it muſt be farther noticed, that this reſiſtance is not *active*, but coercitive, and we may compare it to friction or viſcidity. Any repulſion of electric fluid, which falls ſhort of this, will not diſturb the ſtability of the fluid ſpread along the canal, according to any law whatever. So that if AD repreſent the electric denſity of the globe, and remain conſtant, any curve of denſity will anſwer, if $\frac{d\dot{d}}{x}$ be everywhere leſs than R. It is therefore an indeterminate problem to aſſign, in general, the diſpoſition of fluid in the canal. The denſity is as the ordinates of a parabola only on the ſuppoſition that the maximum of R is everywhere the ſame. And, in this caſe, the diſtances AB is a minimum: for, in other caſes of denſity, we muſt have $\frac{d\dot{d}}{\dot{x}}$ leſs than R. If, therefore, we vary a ſingle element of the curve D d B, in order that the ſtability of the fluid may not be diſturbed, having $\dot{d}$ conſtant, we muſt neceſſarily have $\dot{x}$ larger, that $\frac{d\dot{d}}{\dot{x}}$ may ſtill be leſs than R; that is, we muſt lengthen the axis.

We ſee alſo, that to aſcertain the diſtribution in a conducting canal is a determinate problem; whereas, in imperfect conductors, it is indeterminate, but limited by the ſtate of the fluid, when it is ſo diſpoſed that in every point the action of the fluid is in equilibrio with the maximum of reſiſtance. This conſideration will be applied to a valuable purpoſe in the article MAGNETISM.

222 Explanation of a curious and important fact; and method of increaſing a charge.

This doctrine gives, in our opinion, a very ſatisfactory explanation of the curious obſervations of Mr Brookes and Mr Cuthbertſon, mentioned in nº 167. namely, that damping the inſide of a coated jar diminiſhes the riſk of exploſion, and enables it to hold a higher charge. We learn here, that there is no denſity ſo great but that the leaſt imperfect conductor will inſulate it, if long enough; and that the coercive quality of an imperfect conductor may be conceived ſo conſtituted from A towards B, that the denſities ſhall diminiſh in any ratio that we pleaſe, ſo that the variation of denſity (the cauſe of motion) may everywhere, even to the inſulating point B, be very ſmall. However great the conſtipation at the edge of the metallic coating may be, an imperfect conductor may be continued outward from that edge, and may be ſo conſtituted, that the conſtipation ſhall diminiſh by ſuch gentle gradations, that an exploſion ſhall be impoſſible. An uniform dampneſs will not do this, but it will diminiſh the abruptneſs of the variation of denſity. The ſtate of denſity beyond the edge of the coating of a charged jar, very clean and dry, may be repreſented by the parabolic arch D i a. This may be changed by damping, or properly dirtying (to uſe Mr Brookes's phraſe), to D f B; which is evidently preferable. We think it by no means difficult to contrive ſuch a continuation of imperfectly conducting coating. Thus, if gold leaf can be ground to an impalpable powder, it may be mixed with an oil varniſh in various proportions. Zones of this gold varniſh may be drawn parallel to the edge of the coating, decreaſing in metal as they recede from the edge. By ſuch contrivances it may be poſſible to increaſe the retentive power to a great degree.

223 Cautions in deducing meaſures from experiments.

This doctrine farther teaches us, that many precautions muſt be taken when we are making experiments from which meaſures are to be deduced; and it points them out to the mathematician. In particular, when bodies, ſupported by inſulators, are electrified to a high degree, the ſupports may receive a quantity of fluid, which may greatly diſturb the reſults; and this quantity, by exerting but a weak action on the parts of the canal, may continue for a very long time, and not be removed but with great difficulty. In ſuch caſes, it will be neceſſary to uſe new ſupports in every experiment. Not knowing, or not attending to this circumſtance, many erroneous opinions have been formed in ſome delicate departments of electrical reſearch.

Mr Coulomb's experiments on this ſubject are chiefly valuable for having ſtated the relation between the intenſity of the electricity, or, as he expreſſes it, the electric denſity, and the lengths of ſupport neceſſary for the complete inſulation. But, as the abſolute intenſities have all been meaſured by his electrometer, and he has not given its particular ſcale, we cannot make much uſe of them till this be done by ſome electrician.

224 Inſulating powers of various ſubſtances.

Mr Coulomb found that a thread of gum lac was the moſt perfect of all inſulators, and is not leſs than ten times better than a ſilk thread as dry as it can be made, if we meaſure its excellence by its ſhortneſs. In a conſiderable number of experiments, he found that a thread of gum lac, of 1,5 inches long, inſulated as well as a fine ſilk thread of 15 inches. When the thread of ſilk was dipped in fine ſealing-wax, it was equal to the pure lac, if ſix inches long, or four times its length. If we meaſure their excellence by the intenſities with which they inſulate, lac is three times better than the dry thread, and twice as good as the thread dipped in ſealing-wax: ſo that a fibre of ſilk, even when included in the lac, diminiſhes its inſulating power. We alſo learn that the diſſipation along theſe ſubſtances is not entirely owing to moiſture condenſed or adherent on their ſurfaces, but to a ſmall degree of conducting power. We have repeated many of theſe experiments, and find that the conducting power of ſilk thread depends greatly on its colour. When of a brilliant white, or if black, its conducting power ſeems to be the greateſt, and a high golden yellow, or a nut brown, ſeemed to be the beſt inſulators; doubtleſs the dyeing drug is as much concerned as the fibre.

Glaſs, even in its dryeſt ſtate, and in ſituations where moiſture could have no acceſs to it, *viz.* in veſſels containing cauſtic alkali dried by red heat, or holding freſh made quicklime, appeared in our experiments to be conſiderably better than ſilk; and where drawn into a ſlender thread, and covered with gum lac (melted), inſulated when three times the length of a thread of lac; but we found at the ſame time, that extreme fineneſs was neceſſary, and that it diſſipated in proportion to the ſquare of its diameter. It was remarkably hurt by having a bore, however fine, unleſs the bore could alſo

be

be coated with lac. Human hair, when completely freed from every thing that water could waſh out of it, and then dried by lime, and coated with lac, was equal to ſilk. Fir, and cedar, and larch, and the roſe-tree, when ſplit into filaments, and firſt dried by lime, and afterwards baked in an oven which juſt made paper become faintly brown, ſeemed hardly inferior to gum lac.

The *white woods*, as they are called, and mahogany, were much inferior. Fir baked, and coated with melted lac, ſeems therefore the beſt ſupport when ſtrength is required. The lac may be rendered leſs brittle by a minute portion of pure turpentine, which has been cleared of water by a little boiling, without ſenſibly increaſing its conducting power. Lac, or ſealing wax, diſſolved in ſpirits, is far inferior to its liquid ſtate by heat.

Theſe obſervations may be of uſe for the conſtruction of electrical machines of other electrics than glaſs.

General reflections.

We have now given a compariſon of the hypotheſis of Mr Æpinus with the chief facts obſerved in electricity, diverſified by every circumſtance that ſeemed likely to influence the reſult, or which is of importance to be known. We truſt that the reader will agree with us in ſaying that the agreement is as complete as can be expected in a theory of this kind; and that the application not only ſeems to explain the phenomena, but is practically uſeful for directing us to the procedures which are likely to produce the effect we wiſh. Thus, ſhould our phyſiological opinions ſuggeſt that copious transference of fluid is proper, our hypotheſis points out the moſt effectual and the moſt convenient methods for producing it. We learn how to conſtipate the fluid in a quieſcent ſtate, or how to abſtract as much of it as poſſible from any part of a patient; we can do this even in the internal parts of the body. We had once an opportunity of ſeeing what we thought the cure of a paralyſis of the gullet. Electricity was tried, firſt in the way of ſparks, and then ſmall ſhocks taken acroſs the trachea. Theſe could not be tolerated by the patient. The ſurgeon wiſhed to give a ſhock to the œſophagus without affecting the trachea. We recommended a leaden piſtol bullet at the end of a ſtrong wire, the whole dipped in melted ſealing wax. This was introduced a little way, we think not more than three inches, into the gullet, which the palſy permitted. A very ſlight charge was given to it in a few ſeconds; and the firſt ſhock produced a convulſion in the muſcle, and the ſecond removed the diſorder completely. Here the ball formed the inner, and the gullet the outer, coating of the Leyden phial.

The theory of Æpinus is only a hypotheſis.

Notwithſtanding the flattering teſtimony given by the great conformity of this doctrine with the phenomena, we ſtill chooſe to preſent it under the title of a hypotheſis. We have never ſeen the electric fluid in a ſeparate ſtate; nor have we been able to ſay in what caſes it abounds, or when it is deficient. After what we have ſeen in the late experiments of that philanthropic philoſopher Count Rumford on the production of heat by friction, we think that we cannot be too cautious on what grounds we admit inviſible agents to perform the operations of Nature. We think that all muſt acknowledge that thoſe experiments tend very much to ſtagger our belief in the exiſtence of a fluid *ſui generis*, a fire, heat, caloric, or what we pleaſe to call it; and all will acknowledge, that no better proofs can be urged for the exiſtence of an electric fluid.

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The reality of an electric fluid is denied.

Accordingly, many acute and ingenious perſons have rejected the notion of the exiſtence of an electric fluid and have attempted to ſhew that the phenomena proceed, not from the preſence of a peculiar *ſubſtance*, but from peculiar *modes*; as we know that ſound, and ſome concomitant motions and other mechanical appearances, are the reſults of the elaſtic undulations of air; and as Lord Bacon and others have explained the effects of fire by elaſtic undulations of the integrant particles of tangible matter.

Requiſites for a juſt theory.

We have ſeen nothing, however, of this kind that appears to give any explanation of the motions, preſſures, and other mechanical appearances of electricity. We peremptorily require, that every doctrine which claims the name of an explanation, ſhall be perfectly conſiſtent with the acknowledged laws of mechaniſm; and that the explanation ſhall conſiſt in pointing out thoſe mechanical laws of which the facts in electricity are particular inſtances. It is no difficult matter to preſent an intricate or complex phenomenon to our view, in ſuch a form that it ſhall have ſome reſemblance to ſome other complex phyſical fact, more familiar, perhaps, but not better underſtood. The ſpecious appearance of ſimilarity, and the more familiar acquaintance with the other phenomenon, diſpoſe us to conſider the compariſon as a ſort of explanation, or, at leaſt, an illuſtration, and to have a ſort of indolent acquieſcence in it as a theory.

But this will not do in the preſent queſtion: For we have here ſelected a particular circumſtance, the obſerved motions occaſioned by electricity, and called *attractions* and *repulſions*—a circumſtance which admits of the moſt accurate examination and compariſon with any explanation that is attempted. In ſuch a caſe, a vague picture would ſpeedily vaniſh into air, and prove to be nothing but figurative expreſſions.

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No advantage is gained by the hypotheſis of two fluids.

Many philoſophers, and among them ſome reſpectable mathematicians, have ſupported the doctrine of Du Fay, Symmer, Cigna, &c. who employ two fluids as agents in all electrical operations. It muſt be granted that there are ſome appearances, where the explanation by means of two fluids ſeems, at firſt ſight, more palpable and eaſier conceived. But whenever we attempt to obtain *meaſures*, and to ſay what will be the preciſe kind and degree of the action, we find ourſelves obliged to aſſign to the particles of thoſe fluids actuating mechanical forces preciſely equivalent to thoſe aſſigned by Æpinus to his ſingle fluid. Then we have to add ſome myſterious unexplained connections, both with each other and with the other particles of tangible matter. If we except Mr Prevoſt, in his *Eſſai ſur les Forces Magnetiques et Electriques*, we do not recollect an author who has ventured to ſubject his ſyſtem to ſtrict examination, by pointing out to us the laws of action according to which he conceives the particles influence each other. We ſhall have a proper opportunity, in the article Magnetism, to give this author's theory the attention it really merits. We venture to ſay, that all the chemical theories of electricity labour under theſe inconveniences, and have acquired their influence merely from the inattention of their partiſans

tiſans to the laws of mechanical motion, and require, in order to reconcile them with theſe laws, the adoption of powers ſimilar to Æpinus's attractions and repulſions. Slight reſemblances to phenomena, which ſtand equally in need of explanation, have contented the partiſans of ſuch theories, and figurative language and metaphorical conceptions have taken place of preciſe diſcuſſion. It would be endleſs to examine them all.

227 Hypotheſis of Profeſſor Ruſſel.

The moſt ſpecious of any that we know was publicly read in the univerſity of Edinburgh by the late Mr James Ruſſel, Profeſſor of natural philoſophy; a perſon of the moſt acute diſcernment, and an excellent reaſoner. It was delivered to his pupils, not as a *theory*, but as a *conjecture*, founded on Lord Kames's theory of ſpontaneous evaporation, which had obtained a very general reception; a conjecture, ſaid the Profeſſor, founded on ſuch reſemblances as made a ſimilarity of operation very probable, and was an incitement and direction to the philoſopher to a proper train of experimental diſcuſſion. We ſay this on the authority of his pupils in the years 1767, 1768, and 1769, and of ſome notes in his own hand-writing now in our poſſeſſion.

Mr Ruſſel conſidered the electrical phenomena as the reſults of the action of a ſubſtance which may be called the *electrical fluid*, which is connected with bodies by attractive and repulſive forces acting at a diſtance, and diminiſhing as the diſtance increaſes.

Mr Ruſſel ſpeaks of the electric fluid as a compound of ſeveral others; and, particularly, as containing elementary fire, and deriving from it a great elaſticity, or mutual repulſion of its particles. This, however, is different from the elaſticity or mutual repulſion of the particles of air, becauſe it acts at a diſtance; whereas the particles of air act only on the adjoining particles. By this conſtitution, bodies containing more electric fluid than the ſpaces around them repel each other.

The particles of this electric fluid attract the particles of other bodies with a force which diminiſhes by diſtance.

The characteriſtic ingredient of this fluid is *ELECTRICITY properly ſo called*. This is united with the elaſtic fluid by chemical affinity, which Mr Ruſſel calls *elective attraction*, a term introduced into chemiſtry by Dr Cullen and Dr Black. This extends to all diſtances, but not preciſely by the ſame law as the mutual repulſion of the particles of the other fluid, and in general, it repreſſes the repulſions of that fluid while in this ſtate of compoſition. This *electricity*, moreover, attracts the particles of other bodies, but with certain elections. Non-electric or conducting bodies are attracted by it at all diſtances, but electrics act on it only at very ſmall and inſenſible diſtances. At ſuch diſtances its particles alſo attract each other.

By this conſtitution, the compound electric fluid repels its own particles at all conſiderable diſtances, but attracts at very ſmall diſtances. It attracts conducting bodies at all diſtances, but non-conductors only at very ſmall diſtances. The phenomena of light and heat are conſidered as marks of partial decompoſition, and as proofs of the preſence of elementary fire in the compound: the ſmell peculiar to electricity, and the effect on the organ of taſte, are proofs of decompoſition and of the complex nature of the fluid.

Bodies (conductors) containing electric fluid, repel each other at conſiderable diſtances, but, if forced very near, attract each other. Electrics can contain it only in conſequence of the *electricity* in the compound. Part of this electricity muſt be attached to the ſurface in a non-elaſtic ſtate; becauſe when it is brought ſo near as to be attracted, its particles are within the ſpheres of each other's action, and this redoubled attraction overcomes the repulſion occaſioned by its union with the other ingredient; and the electric fluid is partly decompoſed, and the *electricity*, properly ſo called, adheres to the ſurface of the electric, *as the water of damp air adheres to a cold pane of glaſs in our windows*. Alſo, by this conſtitution, electric fluid may appear in two ſtates; elaſtic, like air, when entire; and unelaſtic, like water, when partly decompoſed by the attraction of electrics.

Electricity may be forced into this unelaſtic union by various means; by friction, which forces the electric fluid contained in the air into cloſe contact, and thus occaſions this decompoſition of the fluid and the union of its *electricity* with the ſurface. This operation is compared by Mr Ruſſel to the forcible wetting of ſome powders, ſuch as lycoperdon, which cannot be wetted without ſome difficulty and mechanical compreſſion; after which it adheres to water ſtrongly. It may be thus united in ſome natural operations, as is obſerved in the melting and freezing of ſome ſubſtances in contact with electrics; and it may be thus forced into union by means of metallic coatings, into which the electric fluid is forced by an artful employment of its mutual repulſions. This operation is compared to the condenſation of the moiſture of damp air by a cold pane of the window; and the evacuation of the other ſide of the coated pane is compared to the evaporation of the moiſture from the other ſide of the window, pane in conſequence of the heat which muſt emerge from the condenſed vapour. We find in the Profeſſor's notes above-mentioned many ſuch partial analogies, employed to ſhew the ſtudents that ſuch things are ſeen in the operations of Nature, and that his conjecture merits attention.

The intelligent reader will ſee that the general reſults of this conſtitution of the electric fluid will tally pretty well with the ordinary electrical phenomena; and, accordingly, this *conjecture* was received with great ſatisfaction. We remember the being much pleaſed with it, as we heard it applied by Mr Ruſſel's pupils, many of whom will recollect what is here put on record. But the attentive reader will alſo ſee, that all this intricate combination of different kinds of attraction and repulſion is nothing but mere accommodations, of hypothetical forces to the phenomena. How incomparably more beautiful is the ſimple hypotheſis of Æpinus, which, without any ſuch accommodations tallies ſo preciſely with all the phenomena that have yet been obſerved? Here no diſtinction of action is neceſſary, and all the varieties are conſequences of a circumſtance perfectly agreeable to general laws; namely, that the internal ſtructure of ſome ſubſtances may be ſuch as obſtructs the motion of the electric fluid through the pores—Nothing is more likely.

228 Hypotheſis of Mr de Luc.

Several years after the death of the Scotch Profeſſor in 1773, a theory very much reſembling this acquired great authority, being propoſed to the philoſophers by the celebrated naturaliſt Mr de Luc. This gentleman having long cultivated the ſtudy of meteorology with unwearied aſſiduity and great ſucceſs, and

and having been ſo familiarly converſant with expanſive fluids, and the affinities of their compounds, was diſpoſed to ſee their operations in almoſt all the changes on the ſurface of this globe. Electricity was too buſy an actor in our atmoſphere to eſcape his particular notice. While the mechanical philoſophers endeavoured to explain its effects by accelerating forces attracting and repelling, Mr de Luc endeavoured to explain them by means of the expanſive properties of aeriform fluids and gaſes, and by their chemical affinities, compoſitions, and decompoſitions. He had formed to himſelf a peculiar opinion concerning the conſtitution of our atmoſphere, and had explained the condenſation of moiſture, whether of ſteam or of damp aeriform fluids, in a way much more refined than the ſimple theory of Dr Hooke, *viz.* ſolution in air. He conſiders the compound of air and fire as the *carrier* of the water held in ſolution in damp air, and the fire as the general carrier of both the air and the moiſture. Even *fire* is conſidered by him as a *vapour*, of which *light* is the *carrier*. When this damp air or ſteam is applied to a cold ſurface, ſuch as that of a glaſs pane, it is decompoſed. The water is attracted by the pane by chemical affinity, and attaches itſelf to the ſurface. The fire, thus ſet at liberty, acts on the pane in another way, producing the equilibrium of temperature, and the expanſion of the pane. Acting in the ſame manner on the moiſture which chances to adhere to the other ſide, in a proportion ſuited to its temperature, it deſtroys their union, enters into chemical combination with the moiſture, and fits it for uniting with the air on the other ſide, or carries it off. Having read Mr Volta's theory of *electric influences*, by which that philoſopher was enabled to give a ſcientific narration and arrangement of the phenomena of the *electrophorus* newly invented by himſelf, and which is called an explanation of thoſe phenomena, Mr de Luc imagined that he ſaw a cloſe analogy between thoſe *influences* on the plates of the electrophorus and the *hygroſcopic* phenomena of the condenſation and evaporation of moiſture. In ſhort, he was ſtruck with the reſemblance between the condenſation of moiſture on one ſide of a glaſs pane, and its evaporation from the other; and the accumulation of electric fluid on one ſide of a coated pane, and the abſtraction of it from the other. Subſequent examination pointed out to him the ſame analogy between all other *hygroſcopic* and *electric* phenomena.

He therefore immediately formed a ſimilar opinion concerning the electric operations. It may be expreſſed briefly as follows:

229. The electrical phenomena are the operations of an expanſive ſubſtance, called the *electric fluid*. This conſiſts of two parts: 1. *Electric matter*, which is the gravitating part of the compound; and *electric deferent fluid*, or *carrying fluid*, by which alone the electric matter ſeems to be carried from one body to another. The reſemblance between the hygroſcopic and electrical phenomena are affirmed to be *.

1. As watery vapour or ſteam is compoſed of fire, the deferent fluid, and water, the gravitating part, ſo *electric fluid* is compoſed of the *electric deferent fluid*, and *electric matter*.

2. As *vapours* are partly decompoſed when too denſe for their temperature, and then their *deferent fluid* becomes free, and ſhews itſelf as *fire*; ſo *electric fluid* that is too denſe is decompoſed, and its *deferent fluid* manifeſts itſelf in the *phoſphoric* and *fiery* phenomena of *electricity*.

3. As *fire* quits the *water* of *vapour*, to unite itſelf with a body leſs warm; ſo the *electric deferent* quits the *electric matter*, in part, to go to other bodies which have proportionally leſs of it.

In this analogy, however, there is a diſtinction. *Fire*, in quitting the *water* in *vapour*, remains actuated by nothing but its expanſive force; remains free, and extends itſelf till the equilibrium of temperature is reſtored; but the *electric deferent*, when diſengaged from *electric matter*, in order to reſtore its peculiar equilibrium, is actuated by *tendencies* to diſtinct bodies, and acts by this *tendency* in thus reſtoring the *electric equilibrium*; and it is only in conſequence of this *tendency* that it quitted the *electric matter*. This *tendency* is then directed to ſome body in the vicinity.

4. As the *fire* of *vapour* pervades all bodies, to reſtore the *equilibrium of temperature*, depoſiting the *water*; ſo the *electric deferent* quits the *electric matter*, to reſtore the *electric equilibrium* in an inſtant, and for this purpoſe pervades all bodies, depoſiting on them the *electric matter* which it carried, but differently, according to their natures.

5. As *fire* and *water*, while compoſing *vapour*, retain their *tendencies* and *affinities* by which they produce the *hygroſcopic* phenomena; ſo the ingredients of the *electric fluid*, even in their ſtate of union, retain their *tendencies* and *affinities*, which produce the greateſt part of the *electric phenomena*.

6. In particular, the *electric matter* retains its *tendencies* and *affinities*; and farther, the *electric affinities* are, like the *hygroſcopic*, without any choice.

Here, however, there is a farther diſtinction. The affinities of *water* reſpect only *hygroſcopic* ſubſtances; but thoſe of *electric matter* reſpect all ſubſtances, and therefore reſpect the common atmoſpheric fluids.

7. When *fire* quits the *water* of *vapour*, to form the *equilibrium of temperature*, it remains in the place where *vapour* moſt abounds, but is partly *latent*, not exerting its powers; ſo in the reſtoration of the equilibrium of the *electric deferent* among neighbouring bodies, thoſe which have proportionally moſt *electric matter* alſo retain moſt *deferent fluid*, but in a *latent* ſtate.

8. As two maſſes of *vapour* may be in *expanſive equilibrium* (which others call balancing each others elaſticity), although the *vapours* contain very different proportions of *fire* and *water*; ſo two maſſes of *electric fluid* may be in *expanſive equilibrium*, although one contains much more *electric matter* in the ſame bulk, provided that the *electric deferent* be alſo more copious.

The chief diſtinction that mingles with theſe analogies is, that the *affinity* of *water* to *hygroſcopic* ſubſtances operates only in contact, whereas *electric matter* tends to diſtant bodies; and theſe diſtances are very different in regard to different bodies.

Such is the reſemblance which has appeared ſo ſtrong to Mr de Luc. It is evidently the ſame which furniſhed the conjecture to Mr Ruſſel, and which he conſidered mechanically, in order to explain the phenomena of electric motions to ſtudents of mechanical philoſophy. The only reſemblance ſeems to us to appear in the condenſation of moiſture contained in damp air.

Mr de Luc, led by the habits of his former ſtudies, attempts,

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* See *Idées ſur la Meteorologie*, § 266. &c.

attempts to explain every thing by the relations which were moſt familiar to him, *affinities* and *expanſive forces.* Let us attend a little to the manner in which he explains one or two of the moſt general facts.

1. *The conditions of conductors and non-conductors.*

230. This diſtinction depends on the differences in the *tendency* to diſtant bodies: there are great differences in theſe diſtances according to the nature of the bodies; and from this ariſe great differences of phenomena, independent of inſulation or non-inſulation, which are only the ſenſible diſtinctions of theſe claſſes of bodies. *Electric matter* tends to *conductors* at great diſtances; but having reached them it does not adhere, and remains free to move round them, being dragged by the *deferent fluid;* but its tendency to *non-conductors* is only at ſmall and inſenſible diſtances; and having come into contact, it adheres, and can no longer be dragged by the *deferent fluid.*

Hence the operation of *conductors* and *non conductors;* and there is no other foundation for the notion of *idio-electrics* and *non-electrics*, or electrics by communication. A part of a *non-conductor* takes as much *electric matter* as it can from the ſubſtance furniſhing it; but cannot communicate it to another part, except very ſlowly; therefore, to communicate it to the whole ſurface, we muſt cover it with a conductor (Surely this is a diſtinction in the body, independent of the diſtance of mutual tendency!).

Hence, too, the property of *non-conductors* by which the electric fluid is *benumbed* (*engourdi*) or cramped; therefore we can accumulate a great deal in them; and it will remain long, being *benumbed;* and if it be determined to quit them at once, the current will be much more denſe than when quitting an equal conducting ſurface.

Since *conductors* do not fix the *electric fluid*, it *muſt circulate round them.* It is urged to this motion by its *expanſive power*, by which it would diſperſe from a body with inconceivable velocity, and perhaps the rapidity of its motion would decompoſe it, and cauſe ſome *light* to emerge; but it is at the ſame time impelled by its *tendency* to bodies. Thus, by theſe two forces, it runs to a *conducting body*, and muſt circulate round it as the planets do round the ſun. In this circulation, if it come to any great projection, it cannot follow the outline, becauſe ſo abrupt; it therefore flies off at all points and protuberances. It will be the more difficult to keep to an abrupt outline as the ſtratum in circulation is more copious or deeper, becauſe a greater maſs is with greater difficulty turned round a ſharp angle. It is more inclined to eſcape if another body be near, and it immediately becomes a ſatellite to that body.

Thus all bodies get a ſhare of electric fluid, circulating round conductors, and *benumbed* or *cramped* in *non-conductors.* Bodies of this laſt claſs receive their portion by the air as *hygroſcopic ſubſtances* receive their water by the *fire.*

All the differences in the tendencies to bodies proceed from the *electric matter.* The *deferent fluid* follows other laws; namely, 1. Its tendency to all ſubſtances is greater than that of the *electric matter* to any one. 2. The tendency (and alſo that of the *electric matter*) is always from the body which contains moſt of it to that which contains leaſt. 3. The body which contains moſt of the one alſo contains moſt of the other. 4. The *deferent fluid* has a particular affinity (chemical) with the *electric matter.* 5. All theſe tendencies are leſſened by an increaſe of diſtance. 6. The *electric matter*, when compoſing *electric fluid*, has more or leſs *expanſive force* as it is united to more or leſs *deferent fluid.*

Explanation of Charged Plates.

231. Mr de Luc ſays (§ 286.), that his SYSTEM was ſuggeſted by Volta's *Theory of Electric Influences.* Theſe (ſays he) had been pretty well generaliſed before, but with little improvement to the ſcience, till Mr Volta diſcovered a circumſtance which, in his opinion, connected by a general theory many phenomena which had formerly no obſerved relation to any thing. This was, that *when a body electrified poſitively brings a neighbouring body communicating with the ground into the negative ſtate, its own poſitive electricity is weakened while it remains in that neighbourhood, but is recovered when the other body is removed.* " Such is the diſtinguiſhing law of Mr Volta's theory, which brings all the phenomena of electric influences under his theory, beginning with thoſe of coated glaſs, which were formerly ſo obſcure, becauſe they were not referred to their true cauſe, &c.

" My SYSTEM (Mr de Luc ſays) concerning the nature of the *electric fluid* explains the laws of Mr Volta's theory; and of conſequence explains, like it, all the phenomena which it comprehends: but it reaches much farther, ſeeing that more general laws comprehend a greater number of phenomena.

" In the phenomena of coated glaſs, I plainly ſaw one of the procedures of *watery vapour.* Suppoſe a glaſs pane, moiſtened on both ſides, and having the temperature of the ſurrounding bodies. Suppoſe that warmer *vapour* comes to one ſide. It is condenſed on the ſurface; that is, it is decompoſed, the *water* adheres to the ſurface, and the *fire* penetrates the glaſs, heats it, and increaſes the evaporation from the other ſide, by entering into combination with the *water*, and carrying it off with it. More *vapour* is condenſed on the ſide A; more *fire* reaches the ſide B, and carries off more *water.* But as this happens only becauſe the *fire* alſo raiſes the *temperature* of the pane, it is evident that the condenſation on the ſide A, and the evaporation from B, muſt gradually ſlacken, and the *maximum of accumulation* in A, and of evaporation from B, will take place when the temperature of the pane is the ſame with that of the hot *vapour.*

" The electrical phenomena of coated glaſs are perfectly ſimilar. The *electric fluid* reaches the ſide A, is decompoſed, and the *electric matter* is there *benumbed* and fixed. The *deferent fluid* penetrates the pane, and carries off the *electric matter* from the ſide B. This goes on, but ſlackens; and the maximum of accumulation and evacuation obtains when the ſide A has acquired the ſame intenſity of electricity with the charging machine. More is accumulated in A than is abſtracted from B; becauſe B is farther from the ſource (he might have added, that part of the fire is expended in raiſing the temperature of the pane): but the accumulation is inactive, becauſe the *electric matter* is *benumbed* and fixed. Though the *electric matter* is much diminiſhed in B, yet the *electric fluid* in its coating has as much expanſive force as that of the ground; becauſe

becauſe it has a ſurplus of deferent fluid. The abſolute quantity of *electric matter* in both ſides is ſomewhat augmented."

132. This explanation of the Leyden phial comprehends the whole of Mr de Luc's theory; and the conſtitution of the electric fluid, and its various affinities, expanſive powers and tendencies, are all aſſigned to it in ſubſerviency to this explanation, or deduced from thoſe phenomena. As the author, in all his writings, claims ſome ſuperiority over other naturaliſts for more general and comprehenſive views, and for more ſcrupulous attention to preciſion and meaſurement, and particularly for more ſolicitude that no natural agent be omitted that has any ſhare in the procedure—he ſurely will not be offended, although we ſhould ſtate ſuch difficulties and objections as occur to us in the conſideration of this SYSTEM (as he chooſes to call it) of electricity.

We wiſh that it had been expreſſed in the plain and preciſe language of mechanical and chemical ſcience; for he reaſons entirely from the nature of expanſive forces, tendencies, and affinities. His language will appear to ſome readers, as it does to us, rather to expreſs the conduct of intelligent beings, acting with choice, and for a purpoſe, than the laws of lifeleſs matter. His account would have been leſs agreeable, it is true, but more inſtructive, and leſs apt to be miſtaken. Metaphorical language is ſeldom uſed without the riſk of metaphorical conceptions; and the reader is very apt to think that he has acquired a notion of the ſubject, while he is really thinking of a thing of a different nature. We apprehend that a great deal of this happens in this inſtance, and that when the narration is ſtripped of its figurative language, it will be found without that connection and analogy which it ſeems to poſſeſs.

We alſo wiſh that the explanation had been derived from ſome well-eſtabliſhed principle. The whole of it is *profeſſedly* founded on a reſemblance between the *phenomena* of electricity, and ſome things ſaid of watery vapour; but theſe are not the *phenomena* of watery vapour, but Mr de Luc's *hypotheſis* (he will pardon us the term, which we prefer to *ſyſtem*) concerning *watery vapours*. We do not think it philoſophical to explain one hypotheſis by another. Our illuſtrious countrymen, Bacon and Newton, diſapproved of this practice; and their rules of philoſophiſing have ſtill currency among philoſophers. Explanation, in our opinion, is the pointing out ſome acknowledged general fact in nature, and ſhewing that the particular phenomenon is an example of it. We do not ſee this in Mr de Luc's explanation; becauſe we do not ſee the *facts* in the caſe of watery vapours to which the *phenomena* of electricity are ſaid to have a reſemblance. The phenomena we mean are chiefly the *motions*, and the *transferences* of the powers producing ſuch motions; we do not ſpeak of the *light*, and ſome other phenomena, becauſe Mr de Luc does not ſpeak of them in this explanation. We ſhall even admit the *transference* as a *phenomenon*, although we do not ſee any ſubſtance transferred: but we ſee a power of producing certain motions where that power did not formerly appear; and the appearance of this power is all the authority adduced, even by Mr de Luc, for the transference. We muſt now add, that the electric phenomena, which Mr de Luc calls like the phenomena of watery vapour, are all *ſuppoſitions*; and that therefore the explanation is a ſyſtem of ſuppoſitions, *framed* ſo as to be like the ſyſtem of watery vapour. For Mr de Luc will grant, that, on the one hand, we ſee nothing like the water in the electric phenomena; and, on the other hand, there is nothing in watery vapour like the motions of the electrometers, which are the only PHENOMENA from which Mr de Luc profeſſes to reaſon.

We alſo fear that the very curious experiments of Count Rumford on the melting of ice, and the propagation of heat through liquids, will oblige Mr de Luc to change the taſks of the ingredients, both of *vapour* and of *electric* fluid. *Water*, and not *fire*, ſeems to be the *carrier* or *deferent fluid*; and we think that Franklin and Æpinus have made it highly probable that electricity, and not air, is the carrier.

We have alſo great difficulty in conceiving (indeed we cannot conceive) how the *deferent fluid*, from which the *electric matter* has been detached by its ſuperior *affinity* with the ſide A, can overcome the *ſame ſuperior affinity* of the *electric matter* with the ſide B (A), and carry it off; how the *deferent fluid* penetrates the non-conducting pane, in order to carry off the *electric matter* in the form of *fluid*; and how it cannot do this, except by means of a *conducting canal*, into which *it is expreſſly ſaid that it does not penetrate*. It muſt not be ſaid that it runs along the ſurface of this canal: for the ſmalleſt wire will be a ſufficient conductor, covered a foot thick with ſealing wax. This indeed, according to Mr de Luc, allows the deferent *fluid* to paſs; but it muſt alſo, according to him, ſtrain it pretty clear of all *electric matter*. For we cannot help thinking, that the proceſs (although purely ideal) has a cloſer reſemblance to what we ſhould obſerve in a ſtream of muddy water poured on a ſtrainer, both ſides of which are previouſly foul. If we were diſpoſed to amuſe ourſelves with a figurative hypotheſis, we could give one on the principle of filtration that is very pretty, and pat to the purpoſe, of glaſs coated, and charged and diſcharged by conducting canals.

With reſpect to the ſuggeſtion of this theory by Volta's theory of electric influences, and the ignorance of naturaliſts before that time of the true ſtate of things, we muſt obſerve, that Mr Ruſſel propoſed the ſame analogy to the conſideration of his hearers many years before; and it was very generally known. The electric influences had been fully detailed by Æpinus and Wilcke in 1759, and applied with peculiar addreſs and force of evidence by Mr Cavendiſh before 1771; and they were deſcribed nearly in the ſame way by Lane, Lichtenberg, and others.

And with reſpect to Mr Volta's general principle, which Mr de Luc prizes ſo highly, and by which he explains every thing, we muſt obſerve, that *it is not true as a phenomenon in electricity*; but, on the contrary, *the poſitive ſtate of a body is rendered ſtronger, or more remarkable, by inducing the negative ſtate on a neighbouring body*. See n° 52. and 66.—Mr Volta was miſled by the appearances of the electrophorus, which had engaged all his attention, and modelled all his notions on theſe ſubjects.
His-

(A) We may here aſk, How comes there to be ſuch a quantity of electric matter already lodged in B?—Is it benumbed? or in what ſtate is it?

His obſervations had been confined to diſks; and though theſe are excellent inſtruments for producing very ſenſible effects, they are quite unfit for examining the general nature of electric influences. Even without much knowledge of dynamics, a perſon muſt perceive that the action of their different parts on the electrometer may be very different, by reaſon of their different poſitions and diſtances from it. Beſides, the electrometers of the apparatus deſcribed by Mr de Luc in ſect. 440. &c. *did not* indicate the real condition of the diſks to which they were attached, but the condition of the remote ends of overcharged conductors of conſiderable length. Therefore, although all the electrometers fell lower when the other group of diſks was brought near, the poſitive ſtate of the neareſt diſk was greatly augmented. The moſt unexceptionable apparatus for this purpoſe would be a row of poliſhed balls on inſulating ſtands, placed in contact, the whole charged poſitive; and when another ſuch group, or a long body, is brought near, let the balls be ſeparated at once, and examined apart by a very ſmall electrometer, made in the form of our figure 8. We preſume to ſay that, if the other group is properly managed, and made to communicate thoroughly with the ground, the poſitive electricity of the balls neareſt to it will be found greatly augmented, and that every one of them will be found in that preciſe ſtate of electrification that is pointed out by the Æpinian theory. Mr de Luc has made and narrated the experiments with the diſks, and the curious figures obſerved by Lichtenbergh, with great judgment and fidelity; and they are claſſical and valuable experiments for the examination of the theory. We may here mention a very neat way of executing the apparatus of balls, which was practiſed by a young friend, who was ſo kind as to make the experiments for us, when our thoughts were turned to Mr de Luc's theory. Each ball was mounted on a ſlender glaſs rod varniſhed. The lower end of the ſtalk was fixed in a little block of wood which had a ſquare hole through it, by which it ſlided ſteadily along a horizontal bar of mahogany, ſupported at the ends about an inch from the table. The balls were made to ſeparate at once, and equally, from each other, by a chequer jointed frame, ſuch as is ſeen in the toyſhops, carrying a company of foot ſoldiers, who open and cloſe their ranks and files by pulling or puſhing the ends of the frame. Taking out the pins of the middle joints of this chequered frame-work, and widening the holes for receiving the glaſs ſtalks, it is plain that all the balls will ſeparate at once, in the very ſtate of electricity in which they were when in the neighbourhood of the non-inſulated group. This apparatus conſiſted of ſix balls. We found the ball next the other group much more ſtrongly poſitive than before bringing that group near; and it was generally the third ball which ſeemed equally electric in both ſituations. We added nine balls more, connecting the whole by a ſimilar contrivance; and found it a moſt inſtructive apparatus for the theory of the diſtribution of the electric fluid. We wiſh that it had occurred to us when the n° 62, &c. were under conſideration.

With reſpect to the condition in which the electric matter is ſaid to be lodged in the ſide A of the coated pane, where Mr de Luc ſays that it is fixed, *engourdi*, in the *non-conducting ſurface* (which condition Mr de Luc conſiders as characteriſtic of ſuch ſubſtances), we muſt ſay that the deſcription of its ſtate is by no means agreeable to what we have obſerved. The powers of this *electric matter* are no more *benumbed* or enervated (it is a very unphiloſophical phraſe), than if it were in a *conducting* body at the ſame diſtance from the oppoſite coating. If coatings be applied to a block of glaſs of two or three inches in thickneſs, and if the electrification be ſo moderate that it would not fly from the one coating to the other when the glaſs is removed—no ſenſible difference will be found between the electricity of the two coatings with or without the glaſs. The electric matter in the ſide A has not its powers *engourdi;* they are *balanced* by the powers of the ſide B.

But how will Mr de Luc explain the charging a pane negatively? How will he bring off a quantity of *electric matter*, greater (according to his own account) than what will be *benumbed* on the other ſide? Nay, we muſt aſk, where does he find it? Is there a quantity already *benumbed* there? What is to revive it?

Let us now conſider a little the conſtitution of the ingredients of this electric fluid, by which all theſe things are brought about. And in doing this, let us baniſh, when poſſible, all figurative language; and, in the preciſe and dry phraſeology of dynamics, let us ſpeak of the motion of ſingle particles of the *electric fluid*, *deferent fluid*, and *electric matter*. By *expanſive power*, muſt certainly be meant ſuch a power as that by which air, gaſes, inflamed gunpowder, ſteam, and the like, enlarge their bulk, and which is clearly manifeſted as a mechanical preſſure, by burſting veſſels, impelling bullets or piſtons, &c. as well as by the actual enlargement of the bulk of the fluid. We have no other indications of its being a *force;* and therefore our notions of its mode of acting muſt be derived ſolely from what we *underſtand* of this power in air or the other fluids. Newton's *Principia* are our authority for ſaying that all that we know of it is, that it acts as a number of corpuſcles would act, which repel each other with a force inverſely proportional to their diſtances; this action not extending beyond the adjoining corpuſcle, not even to the ſecond. We know a good deal of the propagation of preſſure and progreſſive motion through ſuch a fluid, when it is confined in a veſſel, or ſyſtem of veſſels, of any form, and ſome few ſimple circumſtances which take place in the elaſtic undulations which may be excited and propagated through it. We have but a *very indiſtinct notion* of the motions which one maſs of ſuch a fluid will produce in another maſs, when both are at liberty to expand. This is very indiſtinct; but we are certain that it will be like the motion of two maſſes of air blown or driven againſt each other. Now theſe electric fluids, by their expanſive powers, muſt act like thoſe others with which we are more familiarly acquainted. And here we venture to ſay, that the appearances in electricity are ſo far from being like theſe, that we cannot imagine any thing more remarkably different. We ſhall mention but one thing. Every mark that we have for the preſence of *electric fluid* obliges us to grant, that in an overcharged body it is crowded into the external ſurface, ſo that the quantity has little or no relation to the quantity of matter in any body, but merely to its ſurface. This is quite unlike air, or any other expanſive fluid, which is uniformly diſtributed through the whole ſpace comprehended by the ſurface which bounds it. We never ſaw any thing

like

like ſtreams of this *electric fluid*, impelling or any way acting on each other, except in the transference by ſparks; and there it was indeed like the motions of air, for it was not *electric fluid*, nor *electric matter*, but *electrified air*.

Let us next conſider the *tendencies* by which the relations of theſe expanſive fluids to other bodies are produced, and the electric motions are ſaid to be explained. We obſerve that Mr de Luc avoids the uſe of the words *attraction* and *repulſion*, ſo much employed by the Britiſh philoſophers. He conſiders theſe tendencies as determinate impulſions, and adopts the doctrine of *Le Sage of Geneva*, who has not only laid Newton under great obligations, by a mechanical explanation of gravity, but has alſo explained expanſion, elaſticity, chemical affinity, and all ſpecific tendencies, to the ſatiſfaction of the moſt eminent mathematicians. To ſuch only Mr de Luc profeſſes to addreſs himſelf, who are not contented with a doctrine which ſuppoſes bodies to act where they are not. But, unfortunately, Mr le Sage has never obliged the world with this explanation. We are not moſt eminent mathematicians; but we are able to prove, that Mr le Sage's favourite theorem, mentioned by Mr de Luc in § 157, 158, as demonſtrated by Mr Prevoſt, the editor of *Lucrece Neutonien*, is a complete dereliction of the firſt principles of Mr le Sage, and is alſo incompatible with mechanical laws. Mr de Luc ſhould have given a demonſtration of the theorem on which all his ſyſtem reſted; otherwiſe it is only reviving "*dixit philoſophus, ergo verum.*"

But let us ſee what theſe tendencies perform. Mr de Luc ſays, that the fluid, ſetting out from a body by its expanſive power, would move in a ſtraight line with inconceivable velocity, and would immediately deſert even this globe, were it not deflected by its tendency to other bodies. We do not ſee whence this immenſe velocity is derived. But let it go off; it is deflected from its rectilineal courſe by its tendency to ſome conducting body, which it reaches, but cannot, nor does not enter; and therefore *muſt continually circulate round it, as the planets circulate round the ſun*, following its outline, if not too abrupt, but flying off from all points in the direction of the axis of the point, &c. Here we are at home; for this is a plain dynamical problem of central forces. All that we ſhall ſay on this head is, that Mr de Luc has certainly not conſidered the planetary motions with attention, when he hazarded this very comprehenſive propoſition. If he will take the trouble to do this, he will ſee that every part of it is inconſiſtent with the acknowledged laws of mechaniſm, and that the motions are abſolutely impoſſible. Beſides, we know that it will not fly off from a hundred points placed together, which is a ſtill more abrupt line, if they do not project beyond the brim of a pit in which they ſtand; yet this pit only makes the outline more abrupt. We farther believe, that no perſon can form to himſelf any diſtinct notion of ſuch circulations round every conducting body; they will be more numerous, and infinitely more confuſed and jarring, than all the vortices of Des Cartes. How can ſuch motions take place round a bunch of braſs wire buried in ſealing wax? Yet he muſt grant that they really happen there; or what prevents the *electric fluid* from being *ſtrained* clear of all electric matter in paſſing through the air?

We would alſo aſk, why the tendency is always *from the body containing moſt of the fluid to that containing leaſt?* It is not enough to ſay that it is ſo: this would only be contriving a thing to ſuit a purpoſe; a reaſon ſhould be given if we pretend to explain. Now the tendency to a diſtant body *is to the matter* in that body, without any relation to the fluid in it, or in the body from which it came.

On the whole, we cannot think this theory is any thing but telling a ſtory of ideal beings, in very figurative language, which gives it ſome animation and intereſt. The different affinities, tendencies, and powers, are only ways of expreſſing certain *ſuppoſed* events, and ſuited to thoſe events: but it gives no explanation of the *obſerved mechanical phenomena* of electricity, ſhewing from acknowledged principles that they muſt be ſo.

What a difference between this laboured and intricate mechaniſm, and the ſimple, perſpicuous, and diſtinct theory of Æpinus! Even Mr Ruſſel's explanation is more intelligible, and more applicable to the *motions* which are really obſerved. That gentleman ſaw the neceſſity of conſidering them as the ſubjects of *mechanical diſcuſſion*, and that all that was wanted was to find out what law of diſtant action would tally with the phenomena. The Scotch philoſopher was careful to warn his hearers that he only propoſed a *conjecture*. The Swede calls his performance *Tentamen Theoriæ*, &c. and begins and concludes it with expreſsly ſaying, that it is only a *hypotheſis*. The Engliſh nobleman calls his diſſertation an *Attempt* to explain ſome of the phenomena, &c. None of theſe philoſophers call their works a SYSTEM, which comprehends all theories, whether that of Volta or of any other ſucceſsful inquirer.

We hope to be excuſed for treating ſo largely of this ſubject. It ſtruck us as a very proper example of the bad conſequences of indulging in figurative language. It muſt be very ſeducing, when ſo ſcrupulous and ſo eminent a philoſopher as Mr de Luc is led aſtray by it.

233. We conclude this long article by obſerving, that whatever may be the fate of Mr Æpinus's *hypothetical theory*, his claſſification of the facts, and his preciſe determination of the *mechanical phenomena* to be expected from any propoſed ſituation and condition of the ſubſtances, will ever remain, and be an unerring direction in future experiments; and the whole is an illuſtrious ſpecimen of ingenuity, addreſs, and good reaſoning. We hope to make this ſtill more evident, when we apply it to the quiet and manageable phenomena of MAGNETISM

Pondere et menſurâ.

APPENDIX;

CONTAINING AN ABSTRACT OF MR COULOMB'S EXPERIMENTS.

MR COULOMB in the *Mem. de l'Acad. de Paris* for 1786, relates ſeveral experiments made for aſcertaining the diſpoſition or diſtribution of the electric fluid in an overcharged body. Their general reſults were,

1. That the fluid is diſtributed among bodies according to their figure, without any elective affinity to any kind of ſubſtance.

For when a ball, or body of conducting matter, and of any ſhape, is electrified to any particular degree, as indicated by his electrometer, if it be touched by another equal and ſimilar body, ſimilarly ſituated in reſpect of the touching points, the electricity is always reduced to $\frac{1}{2}$.

2. In an overcharged conducting body, the fluid diffuſes itſelf entirely along the ſurface, without penetrating into the interior parts.

The conducting body AB (fig. 37.) had pits *a*, *b*, &c. made in various parts of its ſurface. They were half an inch in diameter, and ſome of them $\frac{1}{10}$th, others $\frac{2}{10}$ths, others $\frac{3}{10}$ths, &c. in depth. *c* repreſents the edge of a ſmall circle of gilt paper, $\frac{1}{7}$th of an inch in diameter, fixed perpendicularly on the end of a fine thread of gum lac. The body was electrified and touched with this little electroſcope, by ſetting it flat down on the ſurface. The circle *c* was then preſented to an electrometer which moved 90 degrees by a force not exceeding $\frac{1}{6000}$th of a French grain. When this contact was made with the even ſurface of the conductor, it was ſtrongly electrified, and particularly when it touched any eminence, or the ends of long cylinders, &c. The paper being exceedingly thin, and placed in full contact, it may be ſuppoſed to bring off with it the quantity of fluid correſponding to that part of the ſurface, or rather a greater quantity. But when it was made to touch the bottom, even of the ſhalloweſt of theſe pits, it did not affect the electrometer in the leaſt.

He demonſtrates the following elementary theorem:

The attraction or repulſion being ſuppoſed to be proportional to the inverſe of any power *m* of the diſtance; that is, being as $\frac{1}{x^m}$: if *m* be greater than 3, the action of all the maſſes of fluid which are at a finite diſtance is nothing in compariſon with the action in contact; and therefore the fluid muſt be uniformly diffuſed, in the ſame way as if each particle acted only on the adjoining particles.

But if *m* be leſs than 3, for example, if *m* be 2, as ſeems to be the caſe in electricity, the action of all the maſſes at a finite diſtance is not infinitely ſmall in compariſon with the action in contact, and the redundant fluid muſt go toward the ſurface, and no redundant fluid will be retained in the interior parts. The demonſtration is to this effect:

Let A *a* BF (fig. 38.) be a perfectly conducting body of any ſhape, and let *d a e* be a thin ſlice ſeparated from the reſt by the plane *de;* let *d c e* be preciſely equal and ſimilar to *d a e*, and let *a b c* be perpendicular to the ſeparating plane; then the action of all the particles in the thin ſlice *d a e* (when eſtimated in the direction *a b*) on the particle *b*, muſt balance the action of all the reſt of the fluid in the body; for *b* is ſuppoſed to be at reſt. Now, as the law of continuity will be obſerved in *any* diſtribution of the fluid, *through the whole body*, it is plain that, by taking *a b* ſufficiently ſmall, the difference of denſity at *a* and at *c* may be infinitely ſmall; therefore the action of the fluid in *dae* will be infinitely near to an equilibrium with the action of *d c e;* and the action of the fluid in the reſt of the body on the particle *b* will be infinitely ſmall. This cannot be, when the action of a maſs of fluid at a finite diſtance is not infinitely ſmall in compariſon with the action in contact, unleſs we ſuppoſe that the quantity of fluid at a finite diſtance is alſo infinitely ſmall, or nothing; that is, unleſs the whole redundant fluid is conſtipated on the ſurface, and the interior parts are merely ſaturated.

The preceding propoſitions are quite analogous to propoſitions in Mr Cavendiſh's diſſertation in the Philoſophical Tranſactions for 1771.

In the Memoirs of the ſame Academy for 1787, Mr Coulomb endeavours to aſcertain the denſity of the fluid in different bodies which touch each other. When the bodies do not differ extremely in magnitude, he determines this by the immediate application of them to the electrometer; but when one is extremely ſmall in compariſon with the other, he firſt determines the force of the large body, and then touches it 20 or 40 times with the ſmall one, till the force of the large body is reduced to $\frac{1}{2}$, $\frac{1}{3}$, $\frac{2}{3}$, &c. The general reſult was, that when the ſurfaces of the ſpheres had the proportion expreſſed in the firſt column of the following Table, then the denſity in the ſmall one had the proportion expreſſed by the numbers of the ſecond column, and never attained the magnitude 2.

1	1
4	1,08
16	1,3
64	1,65
Infinite	2

This is extremely different from the proportions which obtain when the two ſpheres communicate by very long ſlender canals, which he found exactly conformable to the determinations of the theory: but in Mr Coulomb's experiments the ſpheres touched each other, and had no other communication.

He then endeavours to aſcertain the denſity of the fluid in the different parts of the ſurface of theſe touching ſpheres, in order to obtain ſome experimental knowledge of the diſtribution. He touched them (while in mutual contact) with the little paper circle, and examined its electricity by his electrometer, and made his eſtimation on the ſuppoſition that it brought off one-half of the electricity of the touched part.

When the globes were equal, he found the denſity to be 0 in the point of contact, and ſcarcely ſenſible till he took the paper 30 degrees from the point of contact. From this it increaſed rapidly to 60°; ſlowly from thence to 90°; and from thence to 180° it was almoſt uniform. The denſities were nearly

0	at	0°
1	—	30
4	—	60
5	—	90
6	—	180

He alſo found, that the more the globes differed in bulk, the more is the denſity changed in the ſmall globe, and it is the more uniform in the great one, increaſing rapidly from 0, at the point of contact, to about 7°, and beyond this being ſenſibly uniform.

Hence we may conclude, that the electricity is diffuſed with almoſt perfect uniformity in a globe communicating with another at a great diſtance by a ſlender canal (as Mr Cavendiſh has demonſtrated); while, from the reaſoning employed before, it is probable that it is alſo uniformly diffuſed all along the canal; and therefore, that the quantities in two ſuch globes are very nearly as the diameters, and the denſities inverſely as the diameters, as Mr Cavendiſh demonſtrated, on the ſuppoſition that the fluid in the canal is incompreſſible.

He found that a ſmall globe, placed between two equally large ones, ſhewed electricities of the ſame kind with that of the other two, when the radius of the great

Fig. 1.

Fig. 2.

Fig. 3.

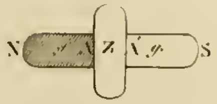
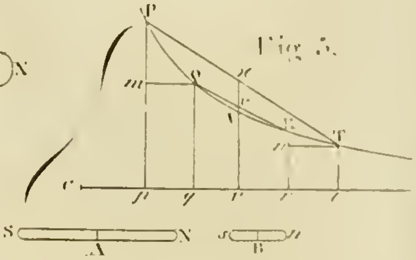


Fig. 4.

Fig. 5.



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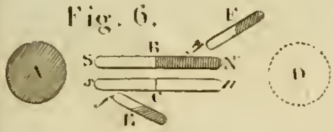

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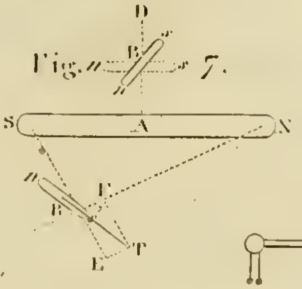
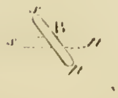



Fig. 9.

Fig. 10.

Fig. 8.

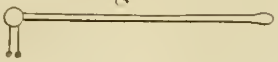


Fig. 12.

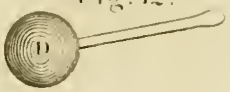


Fig. 11.

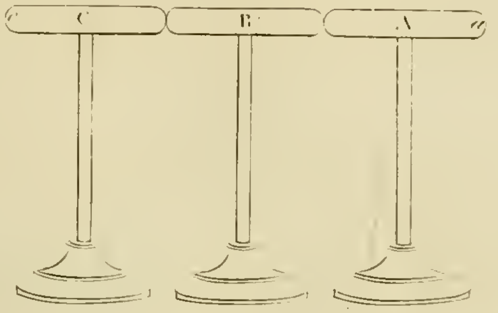
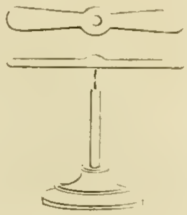


Fig. 13.



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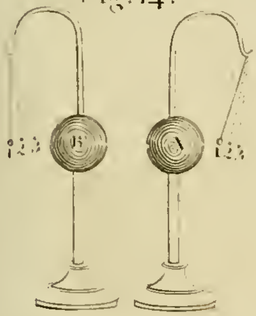
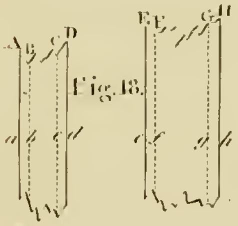


Fig. 18.



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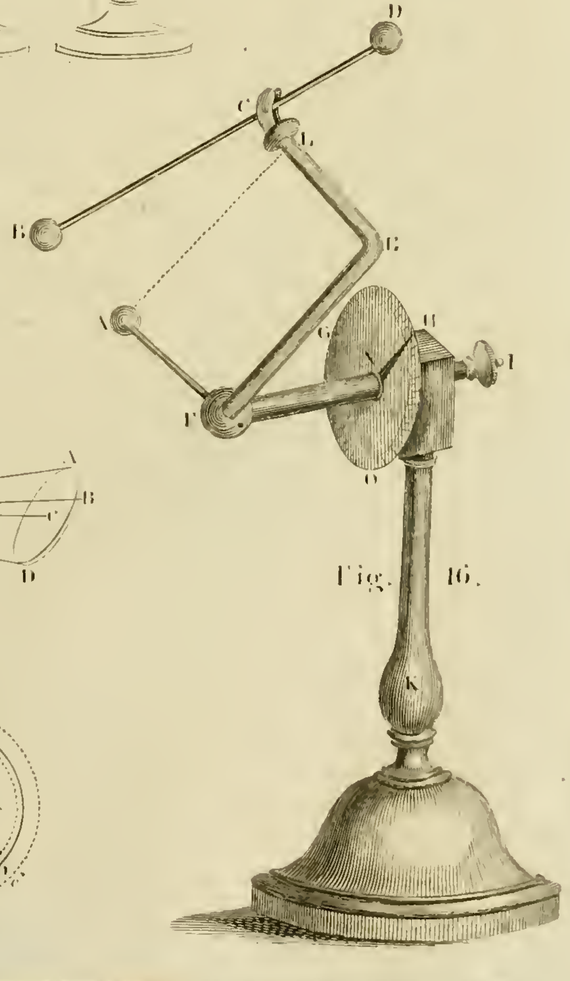
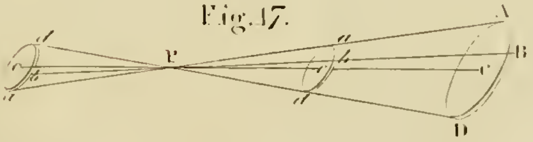


Fig. 17.



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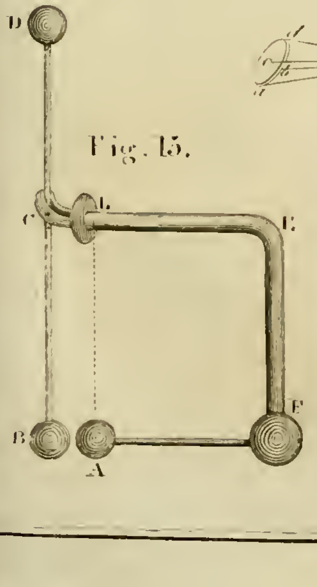

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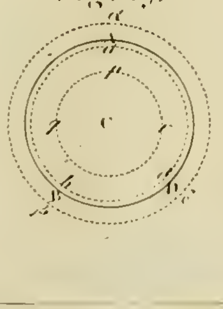


D. Lizars sculp.

Fig. 20.

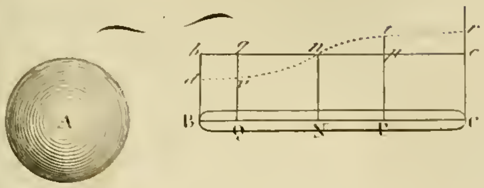


Fig. 24.

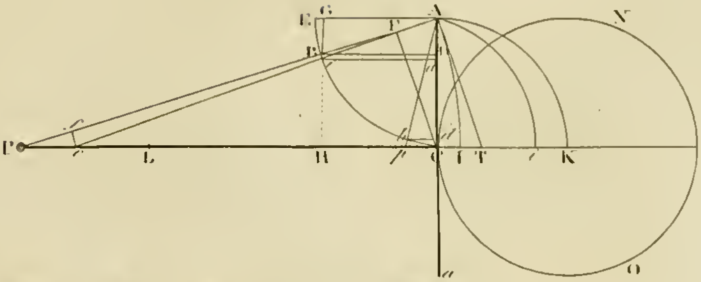
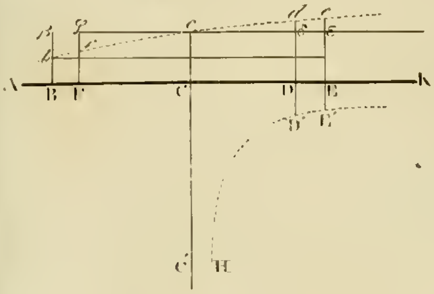


Fig. 21.



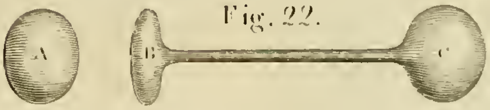


Fig. 22.

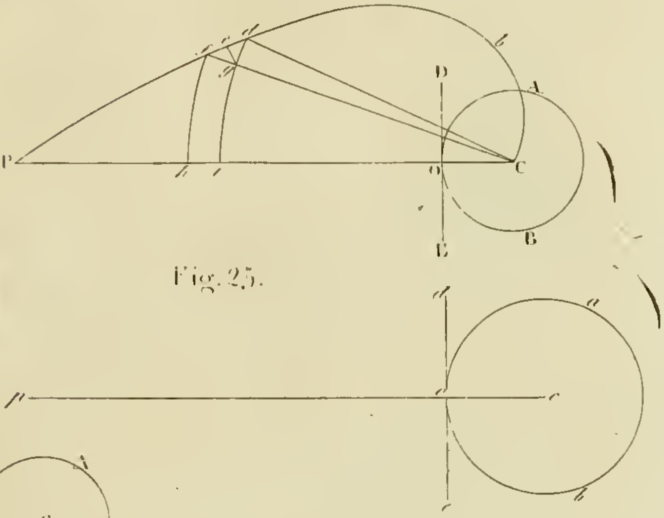


Fig. 25.

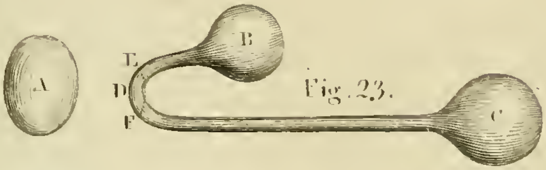


Fig. 23.

Fig. 26.

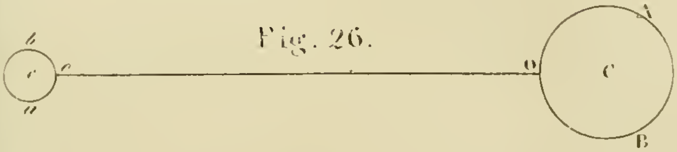
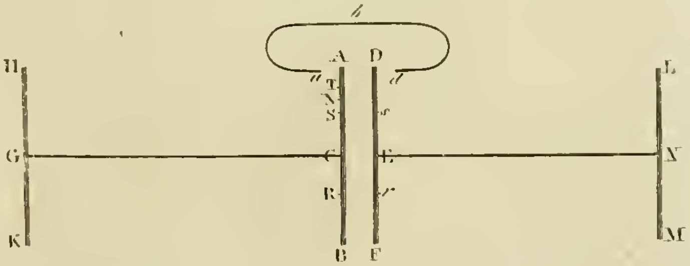


Fig. 27.



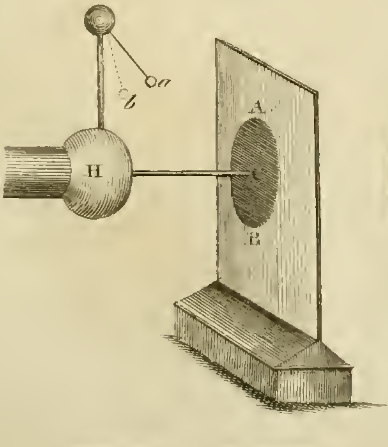
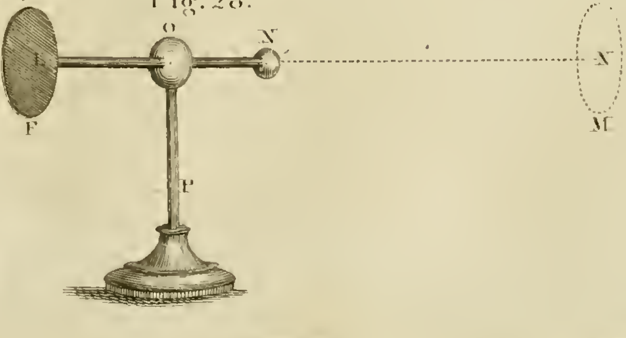


Fig. 28.



D Lizars sculp

ELECTRICITY. PLATE XXVI.

Fig. 29.

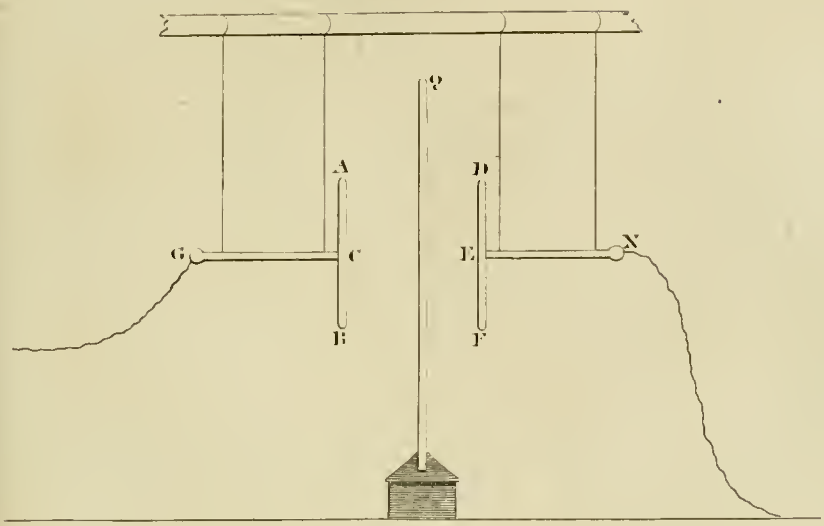


Fig. 30.

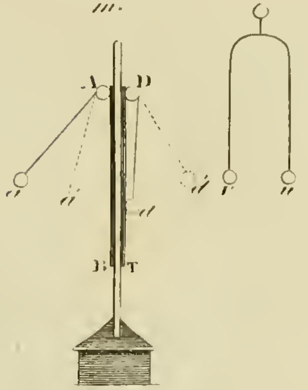


Fig. 31.

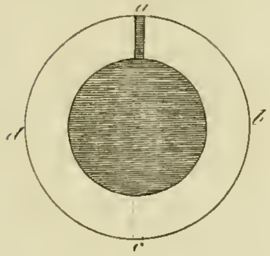


Fig. 32.

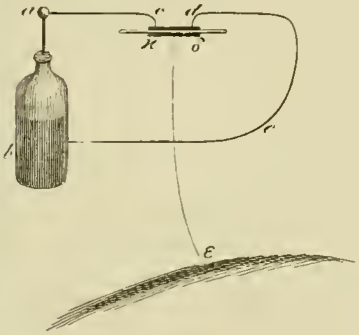


Fig. 34.

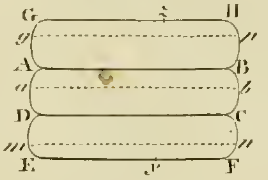


Fig. 33.

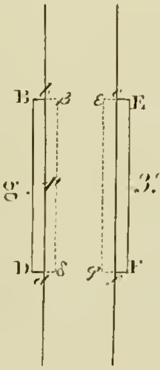


Fig. 35.

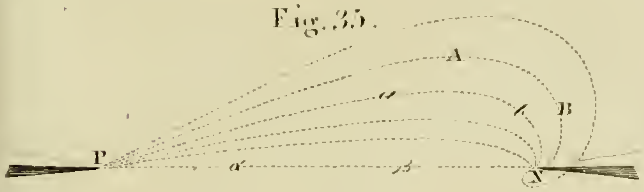


Fig. 36.

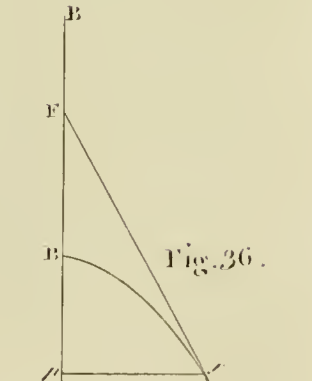


Fig. 38.

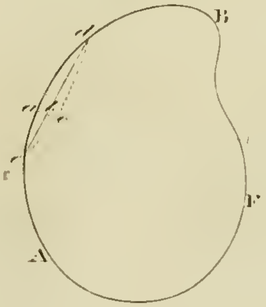
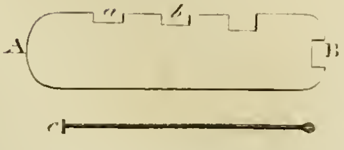


Fig. 37.



[illegible]

great one was not more than five times that of the middle one, but ſhewed no electricity when the diſproportion was greater.

When three equal globes were in contact, the denſity of fluid in the middle globe was $\frac{\cdot 1}{1,34}$ of that of the other two. A ſmall globe being removed to a very ſmall diſtance from an overcharged great one, *after having been in contact*, ſhewed oppoſite electricity in the fronting point; when a little farther off, it was neutral; and beyond this, it was overcharged.

The diameters being 11 and 8, the fronting point of the ſmall one was negative till the diſtance was 1; here it was neutral, and when it was removed farther, it was poſitive. When the diameters were 11 and 4, the ſmall globe was negative till their diſtance was 2, where it was neutral. When the diameters were 11 and 2, the diſtance which rendered the ſmall globe neutral in the fronting point was $2\frac{1}{2}$.

All theſe facts are perfectly conformable to a mathematical deduction, from the ſuppoſition that the redundant fluid is ſpread over the ſurface, and that the interior points are neutral. If any ſort of doubt ſhould remain in the minds of thoſe who are not converſant in ſuch diſcuſſions, it muſt be greatly removed by the fact, that it is quite indifferent whether one or both globes be ſolid, or be an extremely thin ſhell.

When an electrified body is touched with a long wire, and by another of equal diameter and length, coated to any thickneſs with lac or ſealing wax, the two wires take off preciſely the ſame quantity of electricity. This was demonſtrated by touching a globe repeatedly till the electricity was reduced to $\frac{1}{2}$

Hence we muſt conclude, that the electric fluid does not form active atmoſpheres around bodies, by the action of whoſe particles in contact (mathematical or phyſical) the phenomena of attraction and repulſion are produced, but by the action of the fluid in the body, agreeable to the theory of Æpinus.

Such are the obſervations of Mr Coulomb They are extremely valuable, becauſe they confirm in the completeſt manner the legitimate conſequences of the theory.

We think that the materiality of that which is transferred from place to place in the exhibition of electric phenomena, is greatly confirmed by ſome obſervations of Mr Wilſon's in the Pantheon. When a ſpark was taken from the whole of the long wire extended in that vaſt theatre, the ſenſation was ſo different from a ſpark which conveyed even a much greater quantity of fluid from a pretty large, but compact, ſurface, that they could hardly be compared. The laſt was like the abrupt twitch with the point of a hooked pin, as if pulling off a point of the ſkin; the ſpark from the long wire was more like the forcible piercing with a needle, not very ſharp, breaking the ſkin, and puſhing it inward. We had this account from the Doctor in converſation. He aſcribed it, with ſeeming juſtice, to the momentum acquired by the fluid accelerated along that great extent of wire.

lectricity, *Animal Electricity*. See Galvanism, in this Supplement.

lectrometer. ELECTROMETER, is an inſtrument which meaſures the quantity of electricity in any electrified body. The moſt common electrometers are deſcribed in the article Electricity *(Encycl.)*, n° 27, and 182—233. A very valuable one is likewiſe deſcribed in n° 85. of the article Electricity in this volume; but there are ſtill two electrometers, of which we have hitherto given no account, though they are of ſuch value, that to paſs them unnoticed would be unpardonable. The firſt, which is incomparably the moſt accurate and delicate inſtrument of the kind that we have ſeen, was invented by Mr Coulomb, and is adapted to aſcertain the ſmalleſt quantity of redundant electricity. The ſecond is a late invention of Mr Cuthbertſon, the ingenious improver of the air-pump, and is employed only to meaſure the charge of large jars and batteries.

Electrometer, by *Mr Coulomb* of the Royal Academy of Sciences at Paris, deſcribed in the Memoirs for 1785.

Mr Coulomb had made ſome experiments in examination of Dr Hook's theory of ſprings "*ut tenſio ſic vis*;" and found, that it was ſurpriſingly exact, in regard to the force neceſſary for twiſting elaſtic wires. Having ſuſpended a nicely turned metal cylinder by a fine wire in the direction of its axis, and having given it ſeveral turns, and left it to regain its natural poſition, he obſerved, that it performed all its revolutions of untwiſting and twiſting in times preciſely equal, whether theſe oſcillations were of a few degrees, or conſiſted of ſeveral revolutions. He thence concluded, that the force with which the wire endeavoured to regain its natural poſition was exactly proportional to its diſtance from it. Electrometer. Engaged, ſoon after, by order from the Miniſter of Marine, in an examination of the phenomena of the mariner's compaſs, he took this method of ſuſpending his needles, in order to obtain exact meaſures of the forces which cauſed them to deviate from the magnetic meridian. He made ſome obſervations with needles ſo ſuſpended; which are highly valuable to the philoſopher engaged in that ſtudy. When his ſucceſs in this reſearch had fully gratified his wiſhes, he turned his thoughts to the examination of the law of electric action by the help of an electrometer ſuſpended in the ſame manner. It is conſtructed as follows:

ABDC (fig. 1.) repreſents a glaſs cylinder, 12 Plate XXVII. inches in diameter and in height. This is covered by a glaſs plate fitted to it by a projecting fillet on the under ſurface. This cover is pierced with two round holes of $1\frac{3}{4}$th inches in diameter. One of them *f* is in the centre, and it receives the lower end of the glaſs tube *f h*, of 24 inches height, which is fixed in the hole with a cement made of ſealing wax, or other electric ſubſtance. The top of this tube receives the braſs collar H (fig. 2. n° 3.), bored truly cylindrical, and having a ſmall ſhoulder, which reſts on the top of the tube. This collar is faſtened with cement, and receives the hollow cylinder Φ (fig. 2. n° 2.), to which is joined the circular plate *a b*, divided on the edge into 360 degrees. It is alſo pierced with a round hole G in the centre, which receives the cylindrical pin *i* (fig. 2. n° 1.), having a milled head *b*, and an index *i o*, whoſe point is bent down, ſo as to mark the diviſions on the circle *a b*. This pin turns ſtiffly in the hole G, and the cylinder Φ turns ſteadily in the collar H. To the lower end of the centre pin is faſtened a little pincer *q*, formed like the end of a port-crayon, and tightened by the ring *q*, ſo as to hold faſt the ſuſpenſion wire, the lower end of which is graſped by a ſimilar pincer P *o* (fig. 3.), tightened by the ring *φ*. The lower end *φ o* is cylindrical, and it is of ſuch weight as to ſtrain the wire perfectly ſtraight, but without any riſk of breaking it. It may be made half of the weight that will juſt break it.

This pincer is enlarged at C, and pierced with a hole, which receives tightly the arm *g* C *q* of the electrometer. This is eight inches long, and conſiſts of a dry ſilk thread, or ſlender ſtraw of ſome graſs completely dried, and dipped in melted gum lac or fine ſealing wax, and held upright before a clear fire, till it form a ſlender cylinder of about $\frac{1}{10}$th of an inch in diameter. This occupies ſix of the eight inches, from *g* to *q*: the remaining two inches is a fine thread of the lac or ſealing wax, as it drains off in forming the arm. At *a* is a ball of pith of elder or fine cork, one-fourth or one-half of an inch in diameter, made very ſmooth, and gilded. It is balanced by a vertical circle *g* of paper, of large dimenſions, ſtiffened with varniſh. The reſiſtance of the air to this plane ſoon checks the oſcillations of the arm.

The whole is ſeen in its place in fig. 1. where the arm hangs horizontally about the middle of the height of the great cylinder. In its oſcillations the ball *a* moves round in a circle, whoſe centre is in the axis of the whole inſtrument. Its ſituation is indicated by a graduated circle Z O Q, drawn on a ſlip of paper, and adhering to the glaſs with varniſh. The electrified body, whoſe action is to be obſerved, is another ſmall ball of cork *t*, alſo gilt, or a braſs ball well poliſhed. This is carried by a ſtalk of gum lac *m φ*, incloſing a dry ſilk thread. This ſtalk is graſped by a clamp of cleft deal, or any ſimilar contrivance which lies firm on the glaſs cover. When this ball is let down through the hole *m*, it ſtands ſo as to touch the ball *a* on the arm when that ball is oppoſite *o* on the graduated circle.

To electrify the ball *t*, we employ the inſulating handle, fig. 4. which is a ſlender ſtick of ſealing wax or lac, holding a metal wire that carries a ſmall poliſhed metal ball. We touch with it ſome electrified body, ſuch as the prime conductor of a machine, the knob of a jar, &c. Introduce this electrified ball cautiouſly into the hole *m*, and touch the ball *t* with it. The ball *a* is immediately repelled, and goes to a diſtance, twiſting the ſuſpenſion-wire, till the force of twiſt exerted by the wire balances the mutual repulſion of the balls *t* and *a*.

Such is the proceſs for examining the law of electric action. But when we would examine the action of different bodies in different ſtates, another apparatus is wanted. This is repreſented by the piece *c* A *d* (fig. 5.), conſiſting of a plug of ſealing wax A, which fits tight into the hole *m*, and is pierced by the wire *c d*, hooked at *c*, to receive a wire connecting it occaſionally with an electrified body, and having below a poliſhed metal ball *d*.

The inſtrument is fitted for obſervation in the following manner: Turn the milled button *b* at top, till the twiſt-index *i o* is on the mark *o* of the twiſt circle. Then turn the whole in the collar H, till the ball *a* ſtands oppoſite to the mark *o* of the paper circle *z* OQ, and at the ſame time touches the ball *t* or *d*.

The obſervation is made thus: The ball *t* is electrified as already ſaid, and *a* is repelled, and retires from *t*, twiſting the wire, and, after a few oſcillations, ſettles at a diſtance correſponding to the repulſion. Now turn the twiſt-index, ſo as to force the ball *a* nearer to *t*. We eſtimate the force of this new repulſion by adding the motion of the twiſt-index to the angle at which the ball firſt reſted. By turning the twiſt-index ſtill more, we bring the balls ſtill nearer, and have a meaſure of another repulſion.—And thus may we obtain as many meaſures as we pleaſe.

In this way Coulomb aſcertained the relation between the repulſion and the diſtance to be the inverſe duplicate ratio of the diſtances. He diſcovered the law of diſſipation by air in contact, and the relation which this bears to the primitive repulſion, by obſerving the gradual approach of *a* to *t* as the electricity diſſipates from both, and by ſlackening the twiſt-index till the ball *a* retires to its primitive diſtance. He aſcertained the diſſipation along imperfect conductors and the length neceſſary for inſulation, by completely inſulating the ball *t*, and obſerving the loſs by air in contact with it, and then ſliding a metal rod down the inſulating ſtalk, till the diſſipation began to exceed what took place by the air alone. He examined the proportion of redundant fluid in communicating bodies, by connecting them alternately with the piece, fig. 5.; as alſo by electrifying one ball, and obſerving its repulſive force, and then ſharing its electricity with another, and obſerving the diminution. He examined the graduation of his electrometer, by ſharing the electricity of one ball with an equal ball, which gave him the poſition that indicated one-half; and, by repeating this, for one-fourth, &c. in the ſame manner as we practiſed and related in ELECTRICITY (*Suppl.*), n° 141, &c.

An example of one or two of thoſe trials will give a clear conception of the concluſions deduced from theſe obſervations.

The ball *t* was introduced and electrified; *a* was repelled, and ſettled at 40°; the index was twiſted 140°, which brought *a* to 20; and the time was noted. The electricity gradually diſſipated, and *a* came nearer to *t*. The index was untwiſted 30°, and *a* retired a little beyond 20°; but on waiting a few ſeconds, it ſtood exactly at 20°. The time was again noted. The interval was exactly three minutes. The concluſion from the experiment was as follows:

When the ball was brought to 20°, the repulſion was evidently 140 + 20, or 160. Three minutes afterwards it was 210 + 20, or 130; and 30° were loſt in three minutes, or 10° per minute. The mean force was 145. Therefore the mean loſs per minute was $\frac{10}{145}$. Obſerve alſo, that the primitive force correſponding to the diſtance was 40; and the force correſponding to 20 was 160, or inverſely as 20^2 to 40^2.

But obſerve, that the diſtances were not meaſured by the angles, but by the chord of the angles. The obliquity of action muſt alſo be accounted for; and the real lever is leſs than the arm, in the proportion of radius to the coſine of $\frac{1}{2}$ the angle.

The wire uſed by Coulomb in his firſt experiments on the law of action was of ſuch ſtrength, that $\frac{1}{340}$th of a French grain, applied at the point *a*, held it faſt till

till the twiſt-index was turned 360°; ſo that one degree correſponded to $\frac{1}{111400}$ of a grain. A foot of this wire weighed $\frac{1}{15}$th of a grain. Experience having ſhewn that this was a ſenſibility far exceeding what was neceſſary for the meaſures that he had in view, and made the inſtrument too delicate for common uſes, he ſubſtituted much ſtronger and ſhorter wires, and recommends much ſmaller dimenſions for the whole inſtrument. We have made two of only five inches in diameter and 14 inches high; the arm *a g* being $2\frac{1}{2}$ inches, and the ſuſpenſion a ſingle fibre of ſilk, carrying 30 grains. It is far more ſenſible than Bennet's gold leaf electrometer. The ſame inſtrument, with a ſilver wire ſuſpenſion, and a thread of lac projecting from the end *g*, as an index to coincide more cloſely with the ſcale, is ſufficiently nice for all experiments of meaſurement. It is always proper to have the diameter of the cylinder double the length of the arm, that the action of the glaſs may not diſturb the poſition of the arm. It is greatly improved by having a round hole in the bottom of the inſtrument, in which the cylinder C *o* of the lower pincer may hang freely: this prevents much tedious oſcillation. For ordinary experiments, for meaſuring charges of batteries, and the like, a much leſs delicate inſtrument, with a ſuſpenſion-wire ſtrained at both ends, is abundantly delicate, and vaſtly more manageable. The wire ſhould extend as far below the arm as above it, and ſhould be graſped below, by a pincer turning by a milled head in a hole at the end of a ſlender ſpring. This enables us to adjuſt the inſtrument ſpeedily. Having placed the twiſt-index at o, turn this lower button gently till the ball *a* points exactly to o on the paper circle. Even in this coarſeſt ſtate we have found it more delicate, and much more exact, than the electrometer deſcribed in Electricity (*Suppl.*), n° 85. which was much more coſtly, and liable to accidents. Coulomb's electrometer has the great advantage of waſting very little electricity; whereas Henly's, or Brookes's, or de Luc's, waſte it very faſt when it is intenſe.

We improved it greatly by taking away the apparatus with the ball *t*, and ſubſtituting the piece, fig. 5. for it, after changing its conſtruction a little. Inſtead of the wire *c d*, we uſed the ſmalleſt glaſs tube that we could varniſh on the inſide, by drawing through it a ſilk thread dipped in varniſh. Having varniſhed it with lac both within and without, a braſs ball *d* was fixed on its lower end, and a fine wire, with a ball at top, was put down into the tube, ſo as to touch the ball below. When the plug was fitted into the hole *m* once for all, the ſituation of the ball *d* ſuffered no alteration. When delicate experiments are to be made, the upper ball *c* is touched by the charger, fig. 4. which electrifies *d*. C is immediately drawn out with a glaſs forceps; and thus *d* is left completely inſulated. When external electricity, ſuch as the faint electricity of the atmoſphere is to be examined, the wire is allowed to remain in the tube.—*N. B.* A ſcrupulous experimenter, who may object to the ſtraining ſpring recommended above, may ſubſtitute a ſmall weight, which will be conſtant in its action.

The reader will obſerve, that this electrometer, as hitherto managed, meaſures only repulſions. It is not ſo eaſy to meaſure attractions with it; and Mr Coulomb was obliged to take a very circuitous method, during which a great deal of electricity was diſſipated. In this reſpect, the electrometer deſcribed in the article Electricity (*Suppl.*) has the advantage; but in every other reſpect, Mr Coulomb's is the fineſt electrometer that has yet been publiſhed, giving *abſolute* meaſures, and this with great accuracy. The Hon. Mr Cavendiſh has employed the conſtruction in his moſt valuable experiments on the force of gravity (*Phil. Tranſ.* 1798, Part II.); an experiment which Newton would have been delighted with obſerving.

Cuthbertſon's Electrometer is thus deſcribed by himſelf in the laſt number of the ſecond volume of *Nicholſon's Philoſophical Journal.* GH (fig. 6.) is an oblong piece of wood, about 18 inches in length and ſix in breadth, in which are fixed three glaſs ſupporters, D, E, F, mounted with braſs balls, *a*, *c*, *b*. Of theſe ſupporters E and F are exactly of the ſame length; but D is four inches ſhorter. Under the braſs ball *a* is a long braſs hook; the ball *c* is made of two hemiſpheres, the under one being fixed to the braſs mounting, and the upper turned with a groove to ſhut upon it, ſo that it can be taken off at pleaſure. The ball *b* has a braſs tube fixed to it, about three inches long, cemented on the top of F, and the ſame ball has a hole at the top, of about one-half inch diamater, correſponding with the inſide of the tube. AB is a ſtraight braſs wire, with a knife-edged centre in the middle, placed a little below the centre of gravity, and equally balanced with a hollow braſs ball at each end, the centre, or axis, reſting upon a proper ſhaped piece of braſs fixed in the inſide of the ball *c*; that ſide of the hemiſphere towards *c* is cut open, to permit the end *c* A of the balance to deſcend till it touches the ball *a*, and the upper hemiſphere C is alſo cut open to permit the end *c* B to aſcend; *i* is a weight, weighing a certain number of grains, and made in the form of a pin with a broad head; the ball B has two holes, one at the top, and the other at the bottom; the upper hole is ſo wide, as to let the head of the pin paſs through it, but to ſtop at the under one, with its ſhank hanging freely in *b*; *k* is a common Henley's quadrant electrometer; and when in uſe it is ſcrewed upon the top of *c*.

It is evident, from the conſtruction, that if the foot ſtand horizontal, and the ball B be made to touch *b*, it will remain in that poſition without the help of the weight *i*; and if it ſhould by any means receive a very low charge of electric fluid, the two balls *b*, B, will repel each other; B will begin to aſcend, and, on account of the centre of gravity being above the centre of motion, the aſcenſion will continue till A reſt upon *a*. If the balance be ſet again horizontal, and the pin *i* be put into its place in B, it will cauſe B to reſt upon *b*, with a preſſure equal to that weight, ſo that more electric fluid muſt be communicated than formerly before the balls will ſeparate; and as the weight in B is increaſed or diminiſhed, a greater or leſs quantity of electric fluid will be required to effect a ſeparation.

When this inſtrument is to be applied to a jar, or battery, one end of a wire L muſt be inſerted into a hole in *b*, and the other end into a hole of any ball proceeding from the inſide of a battery, as M. A chain, or wire, or any body through which the charge is to paſs, muſt be hung to the hook at *m*, and carried from thence to the outſide of the battery, as is repreſented by the line N. *k* muſt be ſcrewed upon *c*, with its index towards A. The reaſon of this inſtrument being added, is to ſhew, by the index continuing to riſe, that the charge of the battery is increaſing, becauſe the other

other part of the inſtrument does not act till the battery has received its required charge.

It is almoſt needleſs to obſerve that this inſtrument conſiſts of three electrometers, viz. Henley's electrometer, Lane's diſcharging electrometer conſiderably improved, and Brookes's ſteelyard electrometer improved likewiſe. By this combination and theſe improvements, we poſſeſs all that can be required in an electrometer for batteries and large jars; for, by *k*, we ſee the progreſs of the charge; by the ſeparation of B *b*, we have the repulſive power in weight; and by the ball A, the diſcharge is cauſed when the charge has acquired the ſtrength propoſed.

In the journal from which this abſtract is taken, the reader will find ſome curious experiments made with batteries by means of this electrometer; but one will be ſufficient to explain its uſe. Prepare the electrometer in the manner ſhewn in the figure, with the jar M annexed, which contains about 168 ſquare inches of coating. Take out the pin in B, and obſerve whether the ball B will remain at reſt upon *b*; if not, turn the adjuſting ſcrew at C till it juſt remains upon A. Put into B the pin, marked *i*, weighing 15 grains; take two inches of watch-pendulum wire, fix to each end a pair of ſpring tongs, as is repreſented at G *m*, hook one end to *m*, and the other to the wire N, communicating with the outſide of the jar; let the uncoated part of the jar be made very clean and dry; and let the prime conductor of an electrical machine, or a wire proceeding from it, touch the wire L; then, if the machine be put in motion, the jar and electrometer will charge, as will be ſeen by the riſing of the index of *k*; and when charged high enough, B will be repelled by *b*, and A will deſcend and diſcharge the jar through the wire which was confined in the tongs, and the wire will be fuſed and run into balls. The ingenious author, by breathing through a glaſs pipe into the jar, damped it a little in the inſide. Then loading B with a pin of 30 grains, he obtained ſuch a charge as fuſed eight inches of watch pendulum wire, diſpoſed exactly as the two inches were diſpoſed in the former experiment. By repeating and varying his experiments, he found that double quantities of electrical fluid, in the form of a diſcharge, will melt four times the length of wire of a certain diameter.

ELECTROPHORUS. See ELECTRICITY in this *Supplement*.

ELEPHAS, the ELEPHANT. See *Encyclopædia*; where the natural hiſtory of this huge and ſagacious animal is detailed at conſiderable length. Since that article was publiſhed, we have ſeen the third volume of the Aſiatic Reſearches, in which ſome important queſtions, which we were then obliged to leave in uncertainty, ſeem to be decided by John Corſe, Eſq. They relate, 1*ſt*, To the mode in which elephants copulate; which Buffon aſſerts (and in proof of his aſſertion adduces the ſtructure and poſition of the generative organ in the female) to be performed while that female remains recumbent on the back; but which Mr Corſe inſiſts from ocular evidence, takes place after the manner in which the horſe copulates with the mare. 2*d*, To the method of receiving nouriſhment from the mother; which is not, as Buffon avers, by the trunk, but by the mouth, which ſucks the dug, while the trunk of the young animal graſps it round to preſs out the milk. 3*d*, To the period of their going with young; which Mr Corſe conceives cannot be leſs than two years; whereas Buffon and Pennant aſſign only nine months for the geſtation of their young. His reaſons for this ſuppoſition are unanſwerable, and ſhall be given in his own words.

"As far as I know, the exact time an elephant goes with young has not yet been aſcertained; but it cannot be leſs than two years, as one of the elephants brought forth a young one, twenty one months and three days after ſhe was taken. She was obſerved to be with young in April or May 1788, and ſhe was only taken in January preceding; ſo that it is very likely ſhe muſt have had connection with the male ſome months before ſhe was ſecured, otherwiſe they could not have diſcovered that ſhe was with young, as a fœtus of leſs than ſix months cannot well be ſuppoſed to make any alteration in the ſize or ſhape of ſo large an animal The young one, a male, was produced October 16, 1789, and appeared in every reſpect to have arrived at its full time. The gentleman to whom it belongs examined its mouth a few days after it was brought forth, and found that one of its grinders on each ſide had partly cut the gum."

When Mr Corſe wrote his memoir, the young elephant was active and well, and beginning to eat a little graſs. In Africa the Hottentots feed on the elephant; and M. Vailant declares, that an elephant's foot, when baked in their manner, is a moſt delicious morſel.

ELEPHANTIASIS (ſee MEDICINE, n° 352. *Encycl.*) is one of the moſt dreadful maladies with which the human race is anywhere afflicted. It is not indeed common, if it be found at all, in the temperate climates of Europe; but it is frequent in the Eaſt and Weſt Indies, where it too often baffles the ſkill of the ableſt phyſicians. In the ſecond volume of the Aſiatic Reſearches we have the following preſcription for its cure:

"Take of fine freſh white arſenic one tólá, or 105 grains; of picked black pepper ſix times as much: let both be well beaten at intervals for four days ſucceſſively in an iron mortar, and then reduced to an impalpable powder in one of ſtone with a ſtone peſtle, and thus completely levigated, a little water being mixed with them. Make pills of them as large as tares or ſmall pulſe, and keep them dry in a ſhady place. One of thoſe pills muſt be ſwallowed morning and evening with ſome betel leaf, or in countries where betel is not at hand, with cold water: if the body be cleanſed from foulneſs and obſtructions by gentle cathartics and bleeding before the medicine is adminiſtered, the remedy will be ſpeedier."

This preſcription, we are told, is an old ſecret of the Hindoo phyſicians, which they conſider as a powerful remedy againſt all corruptions of the blood, whether occaſioned by the elephantiaſis or the venereal diſeaſe, which they call the *Perſian* fire, and which they apply likewiſe to the cure of cold and moiſt diſtempers, or palſy, diſtortions of the face, relaxation of the nerves, and ſimilar diſeaſes. As the Hindoos are an ingenious and ſcientific people, it might be worth ſome European phyſician's while to make trial of this ancient medicine in the Weſt Indies, where the elephantiaſis or kindred diſeaſes prove ſo frequently fatal.

ELEVATION, in architecture, denotes a draught or deſcription of the principal face or ſide of a building; called alſo its *upright* or *orthography*.

ELLIPSE, or ELLIPSIS, is one of the conic ſections,

ELECTROMETER. PLATE XXVII.

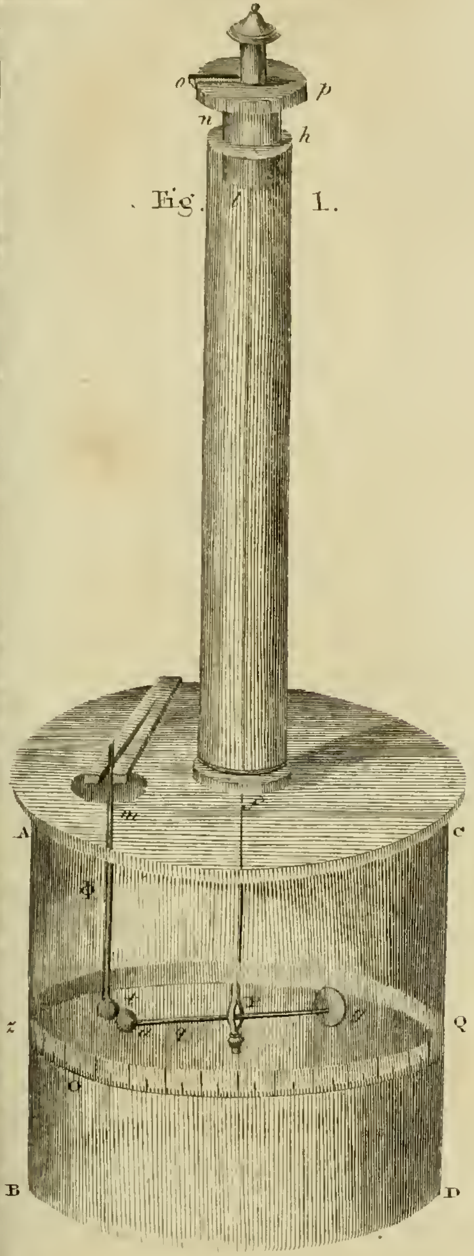


Fig. 1.


Fig. 5.

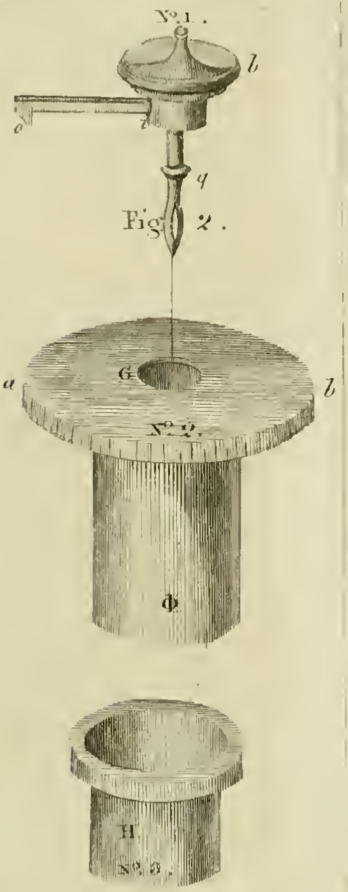
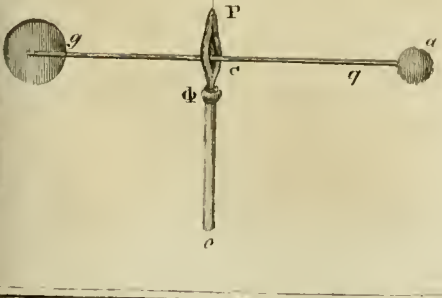


Fig. 2.


Fig. 4.

Fig. 3.



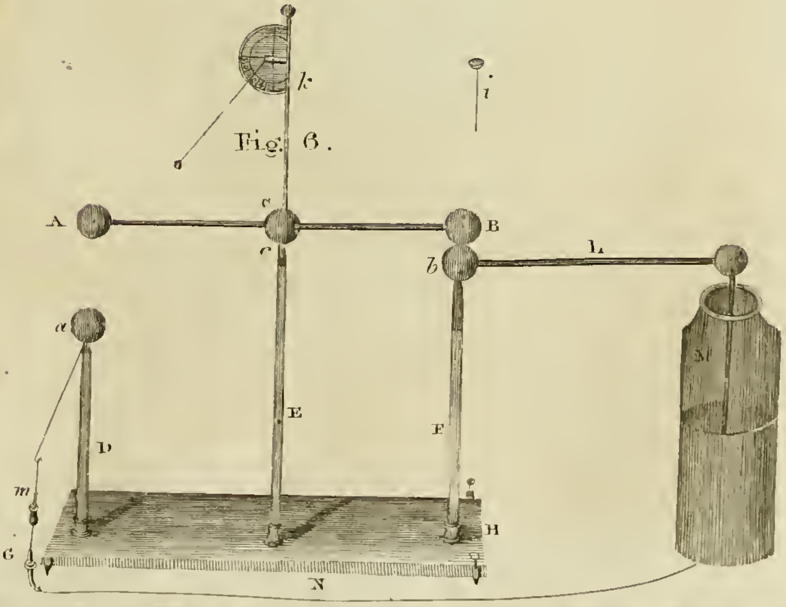


Fig. 6.

D. Lizars Sculpt.

tions, popularly called an *oval;* being called an *ellipſe* or *ellipſis* by Apollonius, the firſt and principal author on the conic ſections, becauſe in this figure the ſquares of the ordinates are *leſs* than, or *defective* of, the rectangles under the parameters and abſciſſes. See *Conic Sections*, Encycl.

ELLIPSOID, is an elliptical ſpheroid, being the ſolid generated by the revolution of an ellipſe about either axis.

ELLIPTOIDE, an infinite or indefinite ellipſis, defined by the indefinite equation $ay^{m+n} = bx^{m} . \overline{a - x}^{n}$ when *m* or *n* are greater than 1: for when they are each = 1, it denotes the common ellipſe.

There are ſeveral kinds or degrees of elliptoides, denominated from the exponent $m + n$ of the ordinate *y*. As the cubical elliptoide, expreſſed by $ay^{3} = bx^{2} . \overline{a - x}$; the biquadratic, or furſolid $ay^{4} = bx^{2} . \overline{a - x}^{2}$; &c.

EMINENTIAL equation, a term uſed by ſome algebraiſts, in the inveſtigation of the areas of curvilineal figures, for a kind of aſſumed equation that contains another equation eminently, the latter being a particular caſe of the former.

ENAMELLING of Vessels for the Kitchen. In the year 1779 the Society of Emulation in Paris propoſed as a prize queſtion, " To diſcover a compoſition fit for making kitchen utenſils which ſhould be free from the diſadvantages attending copper, lead, tinned veſſels, glazed earthen-ware, &c. which ſhould be as ſtrong as poſſible, leſs coſtly than the veſſels uſed at preſent, and which ſhould be able to bear the higheſt degree of kitchen fire, and the moſt ſudden changes from heat to cold."

In conſequence of this propoſal, Mr Sven Rinman of the Royal Academy of Stockholm, without any intention of being a candidate for the premium offered by the Society of Emulation, inſtituted a ſet of experiments on ſmall veſſels of copper and hammered iron, with the view of giving to them a coating of what may properly be called *enamel*, which ſhould not have the defects of tinning, and which, when applied to iron, ſhould take from it the inconveniency of ruſting, and of blackening many ſorts of victuals when they are dreſſed in it. Theſe experiments he ſubmitted to the academy, of which he was a member; and as we think them important, we ſhall lay the ſubſtance of them before our readers.

The moſt common, and the cheapeſt, kind of white enamel that is to be met with in the ſhops (which is an opaque white glaſs, compoſed of powdered quartz, of glaſs of lead, and of calx of tin), was tried for coating kitchen-utenſils; and he found that it was excellent for the purpoſe, as it produced a coating, which was not only clean and agreeable in its appearence, but poſſeſſed likewiſe all the power of reſiſting the action of fire and of acids that could be deſired. But, as it is very difficult to apply, is very dear for common uſe, and is beſides conſidered as not being capable of reſiſting violent blows or falls, he made various experiments with ſubſtances of leſs price; of which the following are certainly worthy of being related.

1. The white ſemi-tranſparent fluor ſpar was reduced into a fine powder, with an equal quantity of unburnt gypſum, and afterwards calcined in a ſtrong fire with a white heat; the whole being, from time to time, carefully ſtirred. The veſſel which he intended to coat, having firſt been wetted by dipping it in water, had as much of the aforeſaid powder applied to its inſide, by means of a very fine ſilk ſieve, as would adhere to it of itſelf, or could be made to do ſo by preſſing it with the finger. After this veſſel had been dried and gradually heated, it was expoſed to a ſudden and violent heat, partly in a coal-fire, kept up by a pair of bellows (the veſſel being at the ſame time covered, ſo that no coals or aſhes could fall into it), and partly in an aſſaying furnace.

In the coal-fire, and with a heat as violent as is commonly uſed to make copper-ſolder run, the mixture was melted, in about the ſpace of a minute, into an opaque white enamel, which evenly covered the ſurface of the copper, and fixed itſelf pretty firmly to the metal; it alſo bore hard blows without breaking, and reſiſted the trials made by boiling things in it, and by applying acids to it. The forementioned mixture was alſo reduced into a fine powder in a glaſs mortar, and made into a ſort of thin paſte with water; it was then applied to the veſſel with a ſmall bruſh, an operation as eaſy as that of applying any other wet colouring matter. He likewiſe tried this paſte, by covering veſſels with it in the ſame way the potters apply their common glazing for ſtone-ware. By both the above-mentioned proceſſes he obtained a very ſmooth coating, particularly by the latter, which is more quickly performed. When the paſte is applied, the veſſel ſhould be made a little warm, ſo alſo ſhould the paſte itſelf.

If the conſtituent parts of theſe two ſubſtances be conſidered (that is to ſay, that gypſum is compoſed of calcareous earth ſaturated with vitriolic (ſulphuric) acid, and fluor ſpar of a particular acid united to ſiliceous earth; alſo, that the whole, when put into the fire without the addition of any other ſubſtance, is, of all earthy or ſtony mixtures, that which the moſt eaſily melts into an opaque white glaſs, not very brittle), and if, on the other hand, the action of acids be attended to—we ſhall eaſily conceive theſe ſubſtances muſt attach themſelves ſtrongly to copper, and that the varniſh formed by them cannot afterwards be diſſolved or acted upon by acids.

The greateſt difficulty attending on this ſimple mixture is, the ſtrong and ſudden heat neceſſary to apply it with effect, that heat being greater than is commonly to be obtained in an aſſaying furnace. On that account, M. Rinman endeavoured to render it more fuſible by the addition of ſome other ſubſtance.

Of his experiments made with this view, ſome failed, and others ſucceeded. We ſhall record only ſuch as were ſucceſsful, and at ſame time attended with ſuch moderate expence as not to preclude them from common uſe.

2. With the ſubſtances employed in his firſt experiment, which, with the author, we ſhall henceforth call n° 1. he mixed an equal quantity of what is called *fuſible glaſs (vitrum fuſibile)*, compoſed of ſix parts of lime, four of fluor ſpar, two of quartz reduced into a fine powder, and one tenth of a part of manganeſe; the whole having been calcined, and ground with water in the manner colours are ground, he ſpread it on the veſſel with a bruſh. This mixture ran pretty well upon the copper in the coal fire; it alſo attached itſelf very ſtrongly to it, and produced an enamel which was firm and hard, and ſeemed likely to bear wear; but it was of a dark grey colour, and without any brillian-

cy. The mixture did not melt more readily in the aſſaying furnace.

Two parts of n° 1. with one part of the fuſible glaſs, and a quarter of a part of mangaueſe, had nearly the ſame effect. This laſt mixture, indeed, was rather more eaſily melted, but it had a darker colour.

3. Eight parts of n° 1. with one half of a part of borax, one quarter of a part of nitre, and half a part of manganeſe, were melted, in the ſpace of ten minutes, into a brown liver-coloured glaſs; which, in the aſſaying furnace, produced upon the copper veſſel a black enamel, which had a dull ſurface. In other reſpects it was firm, even, and hard; but it did not ſufficiently cover the veſſel by a ſingle application, nor was it capable of reſiſting the action of acids.

4. One part of the brown glaſs mentioned in the laſt experiment, with three parts of n° 1. became in the aſſaying furnace with a red heat, almoſt as fluid as the laſt, and held an even and ſmooth ſurface; but it was of a dark colour, and had not any brilliancy. It was not ſenſibly acted upon by vitriolic (ſulphuric) acid.

5. Four parts of n° 1. mixed with one half of a part of litharge, were melted in a crucible, with the help of the bellows, in five minutes, ſo as to become as fluid as water. This mixture, during the fuſion, emitted a ſmell of ſulphureous acid, and formed an opaque glaſs of a ſtraw colour; which, after being ground, as uſual, and ſpread upon a copper veſſel, produced an enamel which covered the veſſel very evenly, and was without bubbles. It was likewiſe, perhaps, the hardeſt of all, but could not be melted in the aſſaying furnace, requiring a ſtronger fire kept up by the bellows. It preſerved its ſtraw colour, but without any luſtre, and reſiſted the action of acids better than the common glazing of the potters.

6. Mr Rinman mixed together equal quantities of gypſum, fluor ſpar, and what the potters call *white lead* (A), and which ſerves for the baſis of their glazing. This mixture, after being calcined, melted in five minutes, with the aſſiſtance of a pair of bellows, into a very white, hard, and opaque enamel, which was very eaſily poured out of the crucible. This enamel, treated like the others, ran very freely, equally, and without bubbles, by the heat of the aſſaying furnace. It was alſo pretty hard and ſtrong, but without any luſtre, and had green and yellow ſpots, occaſioned by the acids of the gypſum and flour ſpar, which had acted upon the copper during the fuſion of the enamel. It, however, bore melting two or three times, and then appeared of a white colour; it was but very little affected by other acids.

7. Equal parts of fluor ſpar, of gypſum, of litharge, and of pure flint glaſs, powdered and mixed together, melted in five minutes, by the help of a pair of bellows, and produced a white and hard glaſs, very like that of the laſt experiment, but rather harder. After being applied on the veſſel in the uſual manner, it formed, with the greateſt heat of an aſſaying furnace, an enamel of a yellowiſh white colour, firm and hard, but without luſtre. In order to avoid the formation of bubbles, care was taken (as ought always to be done in enamelling) to remove the veſſel from the fire as ſoon as it had acquired a brilliant appearance therein, or as ſoon as the enamel was completely melted.

8. Twelve parts of glaſs of lead, or of litharge, with eight parts of flint glaſs, and two of flowers of zinc, were melted, in the ſpace of ſeven minutes, into a clear yellow glaſs, which, when uſed for enamelling, was diſpoſed to form bubbles; but, by continuing the heat for a longer time, the bubbles were diſperſed, and he obtained a pretty good enamel, of a yellow brown colour with a greeniſh caſt, very hard and firm. It reſiſted the action of the vegetable acids, like the enamels already ſpoken of, but it was a little attacked by the mineral acids.

9. He powdered and mixed together five parts of flour ſpar, five parts of gypſum, two parts of minium, one half of a part of borax, two parts of flint glaſs, one half of a part of calx of tin, and only one twenty-fifth of a part of calx of cobalt. This mixture was melted in a crucible in ſix minutes, by help of the bellows, and produced an opaque glaſs of a pearl colour, a little inclining to blue, on account of the calx of cobalt. It was pretty hard, and, after being ground with water in the uſual way, it became of a very good conſiſtence, ſo as to be very fit for ſpreading over veſſels, to which it adhered very ſtrongly. If any bubbles formed on the veſſel during its drying, they might be rubbed down with the finger, and the whole ſurface rendered ſmooth and even. After being warmed, and gradually heated, it was put into an aſſaying furnace made very hot with birch charcoal, which had been juſt kindled under the muffle. After a minute it melted, and began to appear brilliant; ſo that he found it neceſſary to take out the veſſel very quickly, which was already very evenly coated with a thick, and ſufficiently hard, enamel, the ſurface of which, however, had no brilliancy.

The colour remained always inclining to green, becauſe the copper had been a little attacked by the acids of the gypſum and flour ſpar during the fuſion; but in other reſpects this enamel was very firm, was very little hurt by ſlight blows, and bore very well ſudden changes of heat and cold. Weak acids had no action upon it; but he had ſome reaſon to think that it would, in length of time, have been acted upon, to a certain degree, by vitriolic (ſulphuric) acid. Its colour, except the forementioned ſhade of green, was white, with a dull, and rather changeable ſurface.

The calx of cobalt which has been juſt mentioned, and which Mr Rinman made uſe of merely with the intention of obtaining a fine colour, was prepared by ſaturating a ſolution of cobalt in aquafortis (nitric acid) with common ſalt, and evaporating to dryneſs; by which means he obtained a fine roſe-coloured calx. A very ſmall quantity of this calx, when mixed with any fuſible glaſs, gives it a beautiful blue colour.

Of the various ſpecies of enamel, which had been deſcribed in the courſe of theſe experiments, and which may be all applied, with more or leſs advantage, to kitchen utenſils, the leaſt expenſive are n^{os} 1, 2, and 5; but they are alſo thoſe which require the greateſt heat. On the other hand, n° 9. may be recommended as

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(A) This ſubſtance is itſelf a mixture, being compoſed of four parts of lead and one of tin.

as the moſt eaſy of fuſion, and, at the ſame time, very durable when uſed for coating veſſels in which victuals are to be dreſſed, which is here the principal object, and is of far greater importance than the brilliant appearance reſulting from the enamel generally uſed by artiſts, which however may be employed when the ſaving of expence is not regarded.

The enamels hitherto deſcribed are not applicable to veſſels made of iron, though they may be employed to cover copper with great advantage. Iron will not indeed bear the common practice of enamellers, namely, to be put into the fire and taken out again ſeveral times; for the ſparks which fly from iron, when in a hot fire, detach and carry off the enamel from the parts contiguous to thoſe where the ſparks are formed. The acids, too, of the gypſum and fluor ſpar, made uſe of in the enamels already mentioned, acted upon the iron during the fuſion of the enamel, from which reſulted bubbles and bare ſpots, which entirely ſpoiled the appearance of the work. Our author therefore continued his experiments with a view to diſcover a proper enamel for veſſels made of this metal.

10. He reduced into a very fine powder, and ground together, nine parts of minium (red oxide of lead), ſix parts of flint glaſs, two parts of pure potaſh, two parts of purified nitre, and one part of borax. This mixture was put into a large crucible, which it only half filled; he covered the crucible ſo that no coals could fall into it, and gradually increaſed the fire under it. When the effervеſcence had entirely ceaſed, he cauſed the mixture to melt, by uſing the bellows for four or five minutes; by theſe means he obtained a clear and compact glaſs, which he poured out of the crucible upon a piece of marble. Having quenched it in water, and reduced it to a very fine powder in a glaſs mortar, he ground it with water to the conſiſtence of a very thin paſte. He then covered an iron veſſel with it on both ſides, which, after having dried and heated it by degrees, he put under a muffle well heated in an aſſaying furnace. The enamel melted very readily in the ſpace of half a minute, and with a very brilliant appearance. He immediately withdrew the veſſel, and let it cool: it was found to be entirely coated with a beautiful enamel of a black colour; which colour appeared to be cauſed by a thin layer of calcined iron, which might be ſeen through the tranſparency of the enamel.

A copper veſſel having been covered with the ſame enamel, the fine colour of the copper was viſible through the thin coat of glaſs; and it was as well defended from ruſt by this coating as it would have been by an enamel of a ſtronger kind.

11. To hinder the colour of the metal from being ſeen through the coating, he added to the mixture, uſed in the preceding experiment, only one hundredth part of the calx of cobalt deſcribed in n° 9. The whole was melted into a beautiful blue glaſs; it was prepared for enamelling, and applied in the manner before deſcribed, upon another iron veſſel. The enamel proved to be ſmooth, thick, and brilliant, like the preceding, but it covered the veſſel more perfectly; it was of a fine blue colour, with ſome black ſpots in thoſe parts where it had been moſt thinly applied.

12. The glaſs of n° 10. reduced into powder, and ground with potters white lead, of which mention has already been made, melted with the ſame facility; it produced a very ſmooth enamel, of a grey colour, but more firm and hard than the former, and, on account of the addition made to it, of a ſtill leſs price. By mixing with the ſame glaſs a ſmall quantity of crocus martis, he obtained a very fine enamel, of a dark red colour, not to mention other colours in it ſtill more beautiful. The crocus martis he uſed in this experiment was prepared from a ſolution of iron in aqua regia (nitro-muriatic acid), which was evaporated to dryneſs, and the matter thus edulcorated and calcined.

13. In order to render the forementioned enamel more ſolid, and to give it what is called *body*, he melted together a mixture of twelve parts of flint glaſs, eighteen parts of minium, four parts of potaſh, four parts of nitre, two parts of borax, three parts of calx of tin, and one eighth part of calx of cobalt, obſerving always the uſual precautions. He obtained a glaſs of a light blue colour, which, after having been ground with water, and ſpread upon ſmall iron baſins, or tea cups, produced, by means of a briſk fire in an aſſaying furnace, an enamel which was ſmooth and even, and of a pearl colour. The coating was of a proper thickneſs, to obtain which requires a certain degree of dexterity and practice. He alſo tried to paint upon this enamel with what is called *mineral purple (purpura mineralis)*, which he uſed with a little powdered quartz, nitre, and borax; it produced a very beautiful red colour.

Though this laſt mentioned compoſition is more beautiful when applied upon iron, and more even than the preceding, it has the diſadvantage, on account of the ſalts which it contains, of not reſiſting the action of the ſtronger vegetable acids, and ſtill leſs that of the mineral ones. But as a veſſel when coated with this enamel bears, without any injury, ſudden changes of heat and cold, and alſo to have any greaſy mixtures baked or boiled in it (even thoſe which are of a cauſtic alkaline nature, or thoſe which contain the uſual weak acids which are uſed in the preparation of our food), it may be applied to veſſels of various kinds, among others, to tea cups; particularly as it is neither brittle nor ſubject to crack, provided it is not expoſed to violent blows. It is hardly neceſſary to ſay, that this enamel can only be applied upon veſſels made of hammered iron, and not upon thoſe of caſt iron, theſe laſt being always too thick to be heated with ſufficient quickneſs; for the greater is the ſpace of time neceſſary to make the veſſels red hot, the greater is the quantity of ſcales formed upon them, and, of courſe, the enamel becomes more injured.

Our author makes ſome other judicious obſervations on the enamel for iron, of which he has deſcribed the compoſition, and ſays, that, independent of its uſe for coating kitchen utenſils, it might be made to ſerve many other purpoſes, ſuch as preſerving things made of that metal, not only from ruſt, but alſo, as he proved by experiment, to a certain degree, from calcination.

ENCAUSTIC PAINTING. See PAINTING in this *Supplement*.

ENFIELD (William, L. L. D.), well known in the learned world by ſeveral uſeful and elegant publications, was born at Sudbury, on March 29. O. S. 1741, of parents in a humble walk of life, but of very reſpectable characters. His amiable diſpoſition and promiſing talents early recommended him to the Rev.

Mr Hextall, the diſſenting miniſter of that place, who took great care of his education, and infuſed into his young mind that taſte for elegance in compoſition which ever afterwards diſtinguiſhed him.

In his 17th year he was ſent to the academy at Daventry, then under the direction of the Rev. Dr Aſhworth, where he paſſed through the uſual courſe of inſtruction preparatory to the office of the miniſtry; and with ſuch ſucceſs did he cultivate the talents of a preacher, and of an amiable man in ſociety, that, on leaving the academy, he was at once choſen, in 1763, miniſter of the very reſpectable congregation of Benn's Garden in Liverpool.

In that agreeable town he paſſed ſeven of the happieſt years of his life, very generally beloved and eſteemed. He married, in 1767, the daughter of Mr Holland draper in Liverpool, with whom he paſſed all the reſt of his days in moſt cordial union. His literary reputation was extended, during his reſidence in this place, by the publication of two volumes of ſermons, which were very well received, and have ſerved to grace many pulpits beſides that in which they were originally preached. A collection of hymns and of family prayers, which he alſo publiſhed at Liverpool, did credit to his taſte and judgment.

About 1770, he was invited to take a ſhare in the conduct of the academy at Warrington, and alſo to occupy the place of miniſter to the diſſenting congregation there, both vacant by the death of the Rev. Mr Seddon. His acceptance of this honourable invitation was a ſource of variety of mixed ſenſations and events to him, of which anxiety and vexation compoſed too large a ſhare for his happineſs. No aſſiduity on his part was wanting in the performance of his various duties; but the diſeaſes of the inſtitution were radical and incurable; and perhaps his gentleneſs of temper was ill adapted to contend with the difficulties, in matter of diſcipline, which ſeem entailed on all diſſenting academies, and which, in that ſituation, fell upon him, as the domeſtic reſident, with peculiar weight. He always, however, poſſeſſed the reſpect and affection of the beſt diſpoſed of the ſtudents; and there was no reaſon to ſuppoſe that any other perſon, in his place, could have prevented that diſſolution which the academy underwent in 1783.

During the period of his engagement there, his indefatigable induſtry was exerted in the compoſition of a number of works, moſtly, indeed, of the claſs of uſeful compilations, but containing valuable diſplays of his powers of thinking and writing. The moſt conſiderable was his "Inſtitutes of Natural Philoſophy" (quarto, Johnſon, 1783); a clear and well-arranged compendium of the leading principles, theoretical and experimental, of the ſciences compriſed under that head. And it may be mentioned, as an extraordinary proof of his diligence and power of comprehenſion, that, on a vacancy in the mathematical department of the academy, which the ſtate of the inſtitution rendered it impoſſible to ſupply by a new tutor, he prepared himſelf, at a ſhort warning, to fill it up; and did fill it with credit and utility, though this abſtruſe branch of ſcience had never before been a particular object of his ſtudy. He continued at Warrington two years after the academy had broken up, taking a few private pupils.

In 1785, receiving an invitation from the principal diſſenting congregation at Norwich, he accepted it, and firſt fixed his reſidence at Thorpe, a pleaſant village near the city, where he purſued his plan of taking a limited number of pupils to board in his houſe. He afterwards removed to Norwich itſelf; and, at length, fatigued with the long cares of education, entirely ceaſed to receive boarders, and only gave private inſtructions to two or three ſelect pupils a few hours in the morning. This too he at laſt diſcontinued, and devoted himſelf ſolely to the duties of his congregation, and the retired and independent occupations of literature. Yet, in a private way and ſmall circle, few men had been more ſucceſsful in education, of which many ſtriking examples might be mentioned, and none more ſo than the members of his own family. Never, indeed, was a father more deſervedly happy in his children; but the eldeſt, whom he had trained with uncommon care, and who had already, when juſt of age, advanced in his profeſſional career ſo far as to be choſen town-clerk of Nottingham, was moſt unfortunately ſnatched away by a fever a few years ſince.

This fatal event produced effects on the doctor's health which alarmed his friends. The ſymptoms were thoſe of *angina pectoris*, and they continued till the uſual ſerenity of his mind was reſtored by time and employment. Some of the laſt years of his life were the moſt comfortable: employed only in occupations which were agreeable to him, and which left him maſter of his own time; witneſſing the happy ſettlement of two of his daughters; contracted in his living within the domeſtic privacy which he loved; and connected with ſome of the moſt agreeable literary companions, and with a ſet of the moſt cordial and kind-hearted friends that perhaps this iſland affords, he ſeemed fully to enjoy life as it flowed, and indulged himſelf in pleaſing proſpects for futurity. Alas! an unſuſpected and incurable diſeaſe was preparing a ſad and ſudden change: a ſchirrous contraction of the rectum, the ſymptoms of which were miſtaken by himſelf for a common laxity of the bowels, brought on a total ſtoppage, which, after a week's ſtruggle, ended in death. Its gradual approach gave him an opportunity to diſplay all the tenderneſs, and more than the uſual firmneſs of his nature. He died November 3. 1797, amidſt the kind offices of mourning friends, and his laſt hours were peace!

Beſides the literary performances already mentioned, Dr Enfield completed, in 1791, the laborious taſk of an abridgment of "Brucker's Hiſtory of Philoſophy," which he compriſed in two volumes quarto. It may be truly ſaid, that the tenets of philoſophy and the lives of its profeſſors were never before diſplayed in ſo pleaſing a form, and with ſuch clearneſs and elegance of language. Indeed it was his peculiar excellence to arrange and expreſs other mens ideas to the utmoſt advantage. Perhaps, at the time of his deceaſe, there was not in England a more perfect maſter of what is called the middle ſtyle in writing, combining the qualities of eaſe, elegance, perſpicuity, and correctneſs, entirely free from affectation and ſingularity, and fitted for any ſubject. If his caſt of thought was not original, yet it was free, enlarged, and manly. What he was in the capacity of a teacher of religion, his ſeveral congregations will teſtify with grateful and affectionate remembrance. Few miniſters have paid ſuch unremitting attention to the perfection of their pulpit compo-

Enfield || Engrafting.

ſitions; nor was it only by detached diſcourſes that he inculcated the truths of morality and religion, but by methodical plans of inſtruction, drawn up with great care and comprehenſion. The valuable ſtores of this kind which he left behind him will not be conſigned to oblivion; but, it is hoped, will inform and improve numbers to whom the voice of the preacher could never have extended. In delivery, his manner was grave and impreſſive, depending rather on the weight of juſt enunciation than on the arts of oratory. Little need be added to this ſketch of the moral qualities of the excellent man above commemorated. If moderation, compliancy, and gentleneſs were ever prevalent in him to a degree of exceſs, who that knew him will blame an exceſs which opened his ſoul to every emotion and office of affection and friendſhip?

This account of Dr Enfield, which is taken from the *Monthly Magazine*, is acknowledged by its author to be the effuſion of friendſhip; but we believe that the panegyric, though high, is in general juſt. It is our duty, however, to warn our readers againſt placing implicit confidence in the Doctor's repreſentation of ancient philoſophy; for though we have frequently found him correct, and have therefore quoted him with approbation ourſelves, we have likewiſe found him ſometimes miſtaking the ſenſe of his authors. In a work like his, miſtakes were indeed unavoidable; for when he reſolved to compreſs the ſubſtance of Brucker's five volumes within the compaſs of two, he could not avoid ſometimes giving what he thought the *ſenſe* of the ancients, when accuracy required their very *words* to be given. This we believe to be the ſource of thoſe errors in his elegant hiſtory, which we have heard others unjuſtly attribute to deſign; for had it been his *deſign* to deceive, he would not ſurely have ſtored his margin with references to enable every reader to detect the deceit.

ENGINEER, is the appellation of him whoſe profeſſion it is to contrive or make any kind of uſeful engine or machine. He is denominated either a civil or military engineer, according as the objects of his profeſſion reſpect civil or military purpoſes. See FORTIFICATION, *Encycl.* and MACHINE in this *Supplement*.

ENGONASIS, in aſtronomy, the ſame as Hercules, one of the northern conſtellations.

ENGRAFTING. See GRAFTING, *Encycl.* where it is ſaid that there is little hope of producing mixed fruits by engrafting one tree upon another of the ſame claſs. We confeſs ourſelves to be unwilling to relinquiſh this opinion; but it would be very unfair to withhold from the public any fact which ſeems to militate againſt it, and has come to our knowledge. We ſhall therefore tranſcribe from the *Philoſophical Magazine* the following communication from Dr Thornton, lecturer on medical botany at Guy's Hoſpital, reſpecting a ſuppoſed *luſus naturæ*, which he conſiders as the conſequence of engrafting.

In the firſt volume of the *Philoſophical Tranſactions*, N° 29. publiſhed November 1667, you have the following communication, intitled,

Enneadecateris || Scotch Epiſcopalians.

“Some Hortulan Experiments about the engrafting of Oranges and Lemons or Citrons, whereby is produced an individual Fruit, half Orange and half Lemon, growing together as one Body upon the ſame Tree.”

We have here orange trees (ſaith the intelligence from Florence) that bear a fruit which is citron on one ſide and orange on the other. They have been brought hither out of other countries, and they are now much propagated by engrafting. This was confirmed to us (ſays the editor of the Tranſactions of the Royal Society) by a very ingenious Engliſh gentleman, who aſſerted, that himſelf not only had ſeen, but bought of them, anno 1660, in Paris, whither they had been ſent by Genoa merchants; and that on ſome trees he had found an orange on one branch and a lemon on another branch (which is not ſo remarkable as what follows); as alſo, one of the ſame fruit, half orange and half lemon; and ſometimes three quarters of one and a quarter of the other.

In the third part of the Reports of the Board of Agriculture, among the foreign communications, we ſee, with equal pleaſure and aſtoniſhment, an account of the American apple, which, by a peculiar mode of budding (A), is half ſweet and half ſour, half white and half red, without the leaſt confuſion of the reſpective halves.

At Mr Maſon's, floriſt, Fleet-ſtreet, oppoſite the Bolt and Tun, there is a production now, September 1798, to be ſeen half peach and half nectarine. It has all the ſoftneſs and yellow down of the peach, and the ſleek red ſmoothneſs of the nectarine; ſuppoſed to be a *luſus naturæ*, but probably is rather the ſportings of art than of nature, and which perhaps will be the cauſe why we ſhall in future ſee many other ſuch vegetable wonders, which, as we ſee, were known to our anceſtors.

ENNEADECATERIS, in chronology, a cycle or period of 19 ſolar years, being the ſame as the golden number and lunar cycle, or cycle of the moon.

ENSETE. See MUSA, *Encycl.*

EOLIPILE. See ÆOLIPILE, *Encycl.*

EPAULE, or ESPAULE, in fortification, the ſhoulder of the baſtion, or the angle made by the face and flank, otherwiſe called the angle of the epaule.

EPISCOPACY, the government of the church by dioceſen biſhops. See *Encycl.*

SCOTCH EPISCOPALIANS, are a ſociety of Chriſtians, certainly as reſpectable, if not ſo numerous, as any other in the kingdom which diſſents from the worſhip and diſcipline of the eſtabliſhed church. For many years, however, the public worſhip of that ſociety was proſcribed by the legiſlature; and there is reaſon to ſuſpect that its real principles are not yet univerſally underſtood. If this be ſo, it ſurely becomes the editors of a work in which ſome account is given of almoſt every denomination of Chriſtians down to the novel ſect which ſtyles its members BEREANS, to do juſtice to the venerable remains of what was once the eſtabliſhed church of their native country.

1 Eſtabliſhment of Epiſcopacy in Scotland.

That the reformation from popery was, in Scotland, tumultuous and irregular, is known to all Europe; and very few of our readers can be ignorant that there was

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(A) the manner in which the extraordinary nectarine-peach firſt produced in this country was effected, was by inſerting the bud of one fruit upon the ſtock bearing a different ſort.

neither order in the reformed church, nor decency in her worſhip, till James VI. with much addreſs, accompliſhed the eſtabliſhment of a very moderate epiſcopacy. To this form of church-government the better part of the nation was ſufficiently attached; and it continued to be the eccleſiaſtical polity, ſupported by the ſtate, till the grand rebellion, when it was overthrown by the partizans of the *national covenant*. It was reſtored, however, in 1662; and again aboliſhed in 1689 by that convention which placed the Prince and Princeſs of Orange on the ancient throne of the Scottiſh monarchs.

2
No liturgy uſed in the Scotch church,

Theſe events are ſo univerſally known, that it is ſufficient in this place barely to mention them; but there are probably many of our readers who do not know that, during the whole period of her legal eſtabliſhment, the Scotch epiſcopal church had no public liturgy. It appears indeed, that the firſt reformers made uſe of the Engliſh book of common prayer; and there is on record ſufficient evidence that John Knox himſelf, though he diſapproved of ſome things in that book, had no objection either to ſtated forms of prayer in general, or to a ſubordination among the miniſters of the goſpel; but his ſucceſſor Andrew Melvil, who poſſeſſed neither his learning nor his worth, had influence enough to introduce into the church a perfect parity of miniſters, and to excite among the people a very general abhorrence of liturgical worſhip. So rooted indeed was that abhorrence, that, as every one knows, an attempt to introduce into the church of Scotland a book of common prayer, copied with ſome alterations from that of England, produced the *ſolemn league and covenant*, which involved in one common ruin the unfortunate Charles and his darling Epiſcopacy. At the reſtoration of the monarchy, the Epiſcopal conſtitution of the church was reſtored, but no new attempt was made to eſtabliſh the uſe of a public liturgy; and except at the ordinations of the clergy, when the Engliſh forms were uſed, no ſervice book was ſeen in a Scottiſh church.

3
Except at ordinations.

For ſome years after Epiſcopacy had ceaſed to be the religion of the ſtate, the deprived clergy made no alteration in their modes of ſocial worſhip. Having refuſed to transfer to King William that allegiance which they had ſworn to King James, they were treated, during his reign, with ſuch ſeverity, that on the Lord's day they durſt not venture further than to officiate "in their own hired houſes, where they received ſuch friends as choſe to come in unto them;" and in thoſe ſmall congregations, if congregations they may be called, they continued to pray, if not extempore, at leaſt without book, till the acceſſion of Anne to the throne of her anceſtors. The attachment of that Princeſs, not only to the conſtitution, but alſo to the worſhip of the church of England, was well known to them; and they very reaſonably thought, that they could not more effectually recommend themſelves to her protection than by adopting the uſe of the Engliſh liturgy, which the moſt enlightened among them had long profeſſed to admire. It was accordingly introduced by degrees into Scotland; and an act of parliament being paſſed on the 3d of March 1712, "to prevent the diſturbing of thoſe of the Epiſcopal communion in that part of Great Britain called Scotland, in the exerciſe of their religious worſhip, and in the uſe of the liturgy of the church of England," that liturgy was univerſally adopted by the Scotch Epiſcopalians; and public chapels, which had hitherto been prohibited, were everywhere built, and well frequented.

4
Introduction of the Engliſh liturgy.

That thoſe who had refuſed allegiance to King William and Queen Anne ſhould ſcruple to pay it to a new family, clogged as it was by ſo many oaths, can excite no wonder; nor is it at all wonderful that, for their attachment to the abdicated family, the public worſhip of the Scotch Epiſcopalians was, after the inſurrection of 1715 and 1716, laid under ſome reſtraints. Theſe, however, were neither rigorouſly ſevere, nor of long duration; and by the year 1720, their congregations were as numerous as formerly, conſiſting, eſpecially in the northern counties, of men of all ranks, even ſuch as held offices of truſt under the eſtabliſhed government, who frequented the Epiſcopal chapels in preference to the pariſh churches.

Hitherto the Epiſcopalians had been ſafely conducted through all dangers and difficulties by the prudence of Dr Roſe, the deprived biſhop of Edinburgh; but ſoon after his death, which happened on the 20th of March 1720, diviſions broke out among them, which threatened to prove more fatal to their church than any perſecution to which they had yet been ſubjected. For reaſons which will be ſeen afterwards, it is proper to trace thoſe diviſions from their ſource.

5
Sources of diviſion among the Scotch Epiſcopalians.

No native of Britain, who knows any thing of the hiſtory of his country, can be ignorant that Dr Sancroft, the archbiſhop of Canterbury, and five other biſhops, were at the Revolution deprived of their ſees by an act of parliament; becauſe, like the Scotch biſhops, they could not bring themſelves to transfer to King William and Queen Mary that allegiance which they had ſo lately ſworn to King James. As thoſe prelates were extremely popular for the vigorous oppoſition which they had given to ſome of the Popiſh projects of the late king, and as a number of inferior clergymen, of great eminence for piety and learning, were involved in the ſame fate with them—it need not excite great ſurpriſe, that a ſweeping deprivation, which, in all its circumſtances, was perhaps without a precedent in eccleſiaſtical hiſtory, produced a ſchiſm in the church of England. The deprived clergy, conſidering the biſhops who were placed in the ſees thus vacated as intruders, and all who adhered to them as ſchiſmatics, opened ſeparate chapels under the authority of the primate and his nonjuring ſuffragans; and contended, that they and their adherents conſtituted the only orthodox and catholic branch of the church in England.

Both churches, however, made uſe of the ſame liturgy; and during the lives of the deprived prelates, there was no other apparent difference in their worſhip than what neceſſarily reſulted from their paying allegiance to different ſovereigns. But this uniformity was not of long duration. The biſhops, who had been poſſeſſed of ſees before the Revolution, were ſcarcely dead, when their ſucceſſors, being under no civil reſtraint, found, in the principles which they had brought with them from the eſtabliſhment, the means, not only of dividing their own little church, but likewiſe of ſowing the ſeeds of diſſenſion among their brethren in Scotland.

It has been obſerved elſewhere *, that in the church of England there are three opinions reſpecting the nature and end of the Lord's Supper, which, in oppoſition to each other, have been all patroniſed by men of great eminence for theological learning. It appears, indeed,

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* Supper of the Lord, *Encycl.*

Scotch Epiſcopalians.

indeed, from the firſt liturgy ſet forth by authority in the reign of King Edward VI. that the reformers of that church from the errors of popery unanimouſly held the Lord's Supper to be a euchariſtical ſacrifice; and this opinion, which has been adopted by great numbers in every age ſince, ſeems to have been the moſt prevalent of the three among thoſe clergy who were deprived of their livings at the Revolution. It is indeed countenanced by ſeveral paſſages in the preſent order for the adminiſtration of the Lord's Supper; and therefore, though there are other things in that order which cannot be eaſily reconciled to it, archbiſhop Sancroft and his ſuffragans, whatever their own opinions might be, choſe not to widen the breach between themſelves and the eſtabliſhment, by deviating in the ſmalleſt degree from the form in which they had been accuſtomed to celebrate that ſacrament. Their ſucceſſors, however, in office, were men of different diſpoſitions. Conſidering themſelves as totally unconnected with the ſtate, and no longer bound by the act of uniformity, one party, at the head of which was biſhop Collier, the celebrated eccleſiaſtical hiſtorian (A), judged it proper to make ſuch alterations in the communion office as might render it more ſuitable to their own notions of the Lord's Supper, and bring it nearer, both in matter and form, to the moſt ancient liturgies of the Chriſtian church.

Of the propoſed alterations, ſome were perhaps proper in their circumſtances; whilſt others, to ſay the beſt of them, were certainly needleſs, if not inexpedient. They were accordingly *all* oppoſed by another powerful party of nonjurors; and the queſtions in diſpute were referred, firſt to Dr Roſe, the deprived biſhop of Edinburgh, and afterwards to Dr Atterbury and Dr Potter, the biſhops of Rocheſter and Oxford. What judgment the two Engliſh prelates gave in this controverſy we know not; but that of biſhop Roſe did him much honour. Declining the office of umpire between the parties, he recommended mutual forbearance and occaſional communion with each other, according to either form; and employed a gentleman, well verſed in eccleſiaſtical literature, to prove that ſuch a compliance of biſhop's with each others innocent prejudices was not uncommon in the pureſt times.

Theſe diſputes among the Engliſh nonjurors, and the appeal which was made to Dr Roſe, drew, more cloſely than hitherto it had been drawn, the attention of the Scotch Epiſcopal clergy, not only to their own liturgy, which had been authoriſed by King Charles I. but likewiſe to the moſt ancient liturgies extant, as well as to what the fathers of the firſt three centuries have taught concerning the nature of the Lord's Supper. The conſequence was, that ſuch of them as were ſcholars ſoon diſcovered, that the Scotch communion office approached much nearer to the moſt ancient offices than the Engliſh; and a powerful party was formed for reviving the uſe of it in Scotland.

Had thoſe men aimed at nothing farther, it is probable they would have met with very little oppoſition. Their opponents, who, in general, were leſs learned than they, were ſo ſtrongly attached to the houſe of Stuart, that they would have adopted almoſt any thing ſanctioned by the royal martyr's authority; but the advocates for the Scotch office knew not where to ſtop. They wiſhed to introduce ſome other uſages of the primitive church; ſuch as the commemoration of the faithful departed, and the mixture of the euchariſtic cup (See *Supper of the Lord*, n° 2. and 3. *Encycl.*); and their brethern, perceiving no authority from Charles I. for theſe things, and being accuſtomed to conſider them as Popiſh practices, a violent controverſy was ready to burſt forth about what every enlightened mind muſt conſider as matters of very little importance.

6 Revival of ancient uſages.

That the euchariſtic cup was in the primitive church mixed with a little water, is a fact incontrovertible; that the practice was harmleſs and decent, it is wonderful that any man ſhould deny: but that ſuch a mixture is *eſſential* to the ſacrament, we cannot believe, for the reaſons aſſigned in the article referred to; and therefore it ought ſurely to have been no object of contention.

That the faithful departed were commemorated in the primitive church long before the invention of purgatory, is known to every ſcholar; that in thoſe days ſuch a commemoration tended to invigorate the faith and the charity of Chriſtians, it would, in our opinion, be very eaſy to preve; and that at preſent every Chriſtian prays in private for his deceaſed friends, we have proved elſewhere by arguments, of the confutation of which we are under no apprehenſion (See *Greek-church* in this *Supplement*): but we ſee not the *neceſſity* of introducing ſuch prayers into public worſhip at any period; and we perceive impropriety in doing it at a period when, from various circumſtances, they may cauſe weak brethren to err. But thoſe who pleaded for the revival of this practice in the beginning of the current century, were blinded by their very erudition (B); and thoſe who oppoſed it ſeem not to have been acquainted with

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(A) This very learned, though violent man, of whom the reader will find ſome account in the *Encyclopædia*, was, with Dr Hickes and others, conſecrated by the deprived prelates, for the purpoſe of preſerving the Epiſcopal ſucceſſion in what they conſidered as the true church of England.

(B) Paradoxical as this aſſertion may at firſt ſight appear, nothing is more certain than that erudition, and even ſcience, if *partially* cultivated, is as likely to blind as to enlighten the underſtanding. When a man devotes all his time, and all his attention, to *one* purſuit, he contracts ſuch a fondneſs for it, as gradually to conſider it as the *only* valuable purſuit, which will infallibly lead to truth, and to nothing but truth; and in this diſpoſition of mind, he is ready to embrace the moſt extravagant abſurdity to which it may conduct him. Of this the reader will find one very ſtriking inſtance in page 547 of this volume, where the celebrated Euler appears ſo devoted to his darling analyſis, as to place implicit confidence in it, even when he himſelf ſeems ſenſible that it had led him to a concluſion contrary to common ſenſe, and the nature of things. That Dr Bentley was a very eminent philologiſt, is univerſally known; that his emendatory criticiſms on the Claſſics are often happy, no man will deny; and yet, miſled by his favourite purſuits, he never pronounces more dogmatically than when the dogma which he utters is untenable. We appeal to his criticiſms on Milton. Perhaps there is not a man alive with the workings of a benevolent and devout mind, or indeed to have known in what the eſſence of a prayer conſiſts.

The ancient uſages, however, were not the only ſubjects which, on the death of biſhop Roſe, furniſhed matter for controverſy among the Scotch Epiſcopalians. That excellent prelate, together with the deprived archbiſhop of Glaſgow, and the deprived biſhop of Dunblain, had, from time to time, as they ſaw occaſion, raiſed to the Epiſcopal dignity ſome of the moſt deſerving Preſbyters of the church; but it was reſolved, for what reaſon we do not very well know, that none of the new biſhops ſhould be appointed to vacant dioceſes during the life of any one prelate who had poſſeſſed a legal eſtabliſhment; ſo that biſhop Roſe, who ſurvived all his brethren, was for ſeveral years the eccleſiaſtical governor of the whole Epiſcopal church in Scotland. On his death, therefore, though there were four biſhops in Scotland, and two Scotch biſhops reſiding in London, there was not one of thoſe prelates who could claim to himſelf the authority of a dioceſan over any portion of the Catholic church. This they at firſt unanimouſly acknowledged; and one of them, in the name of himſelf and his brethren, recommended to the clergy of the dioceſe of Edinburgh to elect, after the primitive plan, a ſucceſſor to their late venerable dioceſan. The advice was followed; the election was made, and approved by the biſhops: and Dr Fullarton, the biſhop choſen, became biſhop of Edinburgh, by the ſame means and the ſame authority as, in the primitive church, St Cyprian became biſhop of Carthage, or Cornelius biſhop of Rome.

The clergy in other diſtricts, following the example of thoſe in Edinburgh, dioceſan Epiſcopacy was about to be revived throughout all Scotland upon principles purely eccleſiaſtical, when ſome of the biſhops, whom Dr Roſe had left behind him merely for preſerving the Epiſcopal ſucceſſion, conceived a new and very extraordinary conſtitution for the Scotch Epiſcopal church. Whether they were envious of their colleagues, and offended that none of the elections had fallen upon them; whether they were ſo ignorant as not to know that dioceſan Epiſcopacy had ſubſiſted long before the converſion of the Roman empire, in abſolute independence on the ſtate; or that they were actuated, as there is reaſon to ſuſpect, by ſome political principle which they could not with ſafety avow;—ſo it was, that they oppoſed dioceſan Epiſcopacy of every kind, and propoſed to govern the whole Scotch church by a college of biſhops. Againſt this unprecedented ſcheme the more learned biſhops oppoſed all their influence; and, being exceedingly diſagreeable to the inferior clergy, it was very ſoon abandoned by its authors themſelves, who, after ſome acrimonious controverſy, were glad to come to an agreement with their dioceſan brethren.

7
College of biſhops.

8
Thoſe diviſions healed.

Of this agreement, or *concordate* as it was called, the following were the principal articles: 1. "That the Scotch or Engliſh liturgy, and no other, might be indifferently uſed in the public ſervice; and that the peace of the church ſhould not be diſturbed by the introduction of any of the ancient uſages which had lately excited ſuch diſſenſions. 2. That no man ſhould thenceforward be conſecrated a biſhop of the Scotch church without the conſent and approbation of the majority of the biſhops. 3. That the biſhops, by a majority of voices, ſhould chooſe one of their number to preſide in the meetings of his brethren, and to convocate ſuch meetings when he judged them neceſſary: that this preſident ſhould be ſtyled *Primus Epiſcopus*, or more ſhortly *Primus*; but that he ſhould not poſſeſs metropolitical power, or claim any kind of juriſdiction without the bounds of his own dioceſe or diſtrict. 4. That upon the vacancy of any dioceſe or diſtrict, the preſbyters ſhould neither elect, nor ſubmit to, another biſhop, without receiving a mandate by the Primus, iſſued with the conſent of the majority of his colleagues."

This concordate was in 1731-2 ſubſcribed by all the biſhops then in Scotland, who immediately became dioceſans, and thought no more of the college ſyſtem. It was afterwards, with a few additions, for aſcertaining more preciſely the prerogatives of the Primus; for regulating the conduct of ſynods; for exempting biſhops from the juriſdiction of other biſhops, in whoſe diſtricts they might chance to reſide; and for preventing inferior clergymen from deſerting their congregations, or removing from one diſtrict to another, without the conſent of the biſhops of both—thrown into the form of canons; and theſe canons have continued to be the code of the Scotch Epiſcopal church down to the preſent day.

9
Political opinions.

The members, and more eſpecially the clergymen of this church, had always been conſidered as unduly attached to the family of Stuart; and though there was undoubtedly at firſt ſome ground for that ſuſpicion, the writer of this article knows, from the moſt incontrovertible evidence, that it was continued too long, and carried by much too far. Jacobitiſm was imputed

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alive who will refuſe to Dr Warburton the praiſe of learning and ingenuity. The addreſs with which he detects the double doctrines of the ancient philoſophers, is ſometimes almoſt aſtoniſhing; yet, miſled by his own ardour in this purſuit, he diſcovers hidden meanings everywhere, and has found a rational ſyſtem of religion in ſome of the ancient myſteries, where there is every reaſon to believe that nothing in reality was to be found but atheiſm and vice. Juſt ſo it is with the ardent reader of the Chriſtian fathers. If he devote all his time to the ſtudy of their writings, he not only becomes enamoured of his employment, but acquires gradually ſuch a veneration for the character of his maſters (and venerable they undoubtedly are) as renders him afraid to queſtion any thing which they advance, and unable to diſtinguiſh between their teſtimony, which is deſerving of all credit, and their reaſonings, which are often inconcluſive. We truſt it is needleſs to diſclaim any wiſh to diſcourage, by this note, the ſtudy either of the Chriſtian fathers, the Greek philoſophers, philological criticiſm, or the modern analyſis; we only wiſh to diſſuade men of letters from devoting their whole time to any *one* purſuit whatever; for they may depend upon it, that ſuch *partial* ſtudies contract the mind. One of the moſt eminent mathematicians at preſent in England is reported to have declared his contempt of the *Paradiſe Loſt*, becauſe he found in it nothing *demonſtrated!*

ted to the ſociety as its diſtinguiſhing tenet ; but the members of that ſociety have at all times contended, that their diſtinguiſhing tenets were the apoſtolical inſtitution of Epiſcopacy, and in the exerciſe of thoſe powers which are purely ſpiritual, the independency of the church upon the ſtate. In politics, indeed, they have unanimouſly maintained, that the only ruler of princes or *legiſlatures* is God, and not the people. They are, of courſe, no friends to the faſhionable doctrine of reſiſtance, which they believe to be not only condemned in expreſs terms by Chriſt and two of his apoſtles, but to be alſo the ſource of that anarchical tyranny which lately deluged Europe with blood. They conſider a limited monarchy, like that of Britain, as the moſt perfect form of civil government which the world has ever ſeen; and hereditary monarchy is infinitely preferable to one that is elective: and with reſpect to the title of the monarch, when they take a retroſpective view of the origin of all civil governments, they cannot but look upon a permanent and unqueſtioned eſtabliſhment as an indication of the plan and determination of Providence furniſhing the beſt right to a crown which any modern ſovereign can claim.

10
Perſecution

Surely theſe are harmleſs opinions; and yet the worſhip of thoſe who held them was, in 1746 and 1748, laid under ſuch reſtraints as were calculated to produce diſaffection where it did not previouſly exiſt. Two laws were then enacted againſt the Scotch Epiſcopalians ; which, under the pretence of eradicating their attachment to the houſe of Stuart, were ſo contrived as to preclude ſuch of their clergy as were willing to pay allegiance to the reigning ſovereign, and to pray for the royal family by name, from reaping the ſmalleſt benefit from their loyalty. The experiment was tried by ſome of them ; of whom one venerable perſon, who was never ſuſpected of undue attachment to the houſe of Stuart, is ſtill alive; but he, and his complying brethren, had their chapels burnt, and were themſelves impriſoned, as if they had been the moſt incorrigible Jacobites. This was a kind of perſecution which, ſince the Reformation, has had no precedent in the annals of Britain. A prieſt of the church of Rome, by renouncing the errors of Popery, has at all times been qualified to hold a living in England ; a diſſenting miniſter, of whatever denomination, might at any time be admitted into orders, and riſe to the higheſt dignities of the Engliſh church;—but while the laws of 1746 and 1748 remained in force, there was nothing in the power of a Scotch Epiſcopal clergyman to do from which he could reap the ſmalleſt benefit. By taking the oaths to government, he was not qualified to hold a living in England, or even to enjoy a toleration in Scotland ; and his clerical character being acknowledged by the Engliſh Biſhops, he could not by thoſe prelates be canonically reordained.

11
Toleration.

Upon the clergy, however, thoſe laws of uncommon rigour were not long rigorouſly executed. After a few years, the burning of chapels, and the impriſoning of miniſters, were occurrences far from frequent ; but the laws to which we allude affected likewiſe the political privileges of ſuch laymen as frequented the Epiſcopal chapels : and in that part of their operation, thoſe laws were never relaxed till 1792, when they were wholly repealed, and the Epiſcopalians in Scotland tolerated like other well affected diſſenters from the national eſtabliſhment.

12
Faith of the Scotch Epiſcopal church.

While Epiſcopacy was the eſtabliſhed form of church government in Scotland, the clergy of that church ſubſcribed a confeſſion of faith ſummed up in twenty-five articles, which the reader will find in the hiſtory attributed to John Knox. It is ſufficient to obſerve in this place, that in eſſentials it differs little from the articles of moſt other reformed churches ; and in every thing which does not immediately relate to *papiſtry*, it is moderate and unexceptionable ; perhaps more ſo than the preſent confeſſion of either of the Britiſh churches. During the period which intervened between the Revolution and the year 1792, no ſubſcription was indeed required from Scotch Epiſcopalian clergymen to any ſummary of Chriſtian doctrine ; but at their ordinations, thoſe clergy ſolemnly profeſſed their belief of all the canonical books of the Old and New Teſtaments ; declared their perſuaſion that thoſe books contain ſufficiently all doctrines neceſſary to ſalvation, through faith in Jeſus Chriſt ; and were obliged to read daily in their chapels the Engliſh book of Common Prayer, which contains the Apoſtles, Nicane, and Athanaſian creeds. But now thoſe clergymen are enjoined by act of parliament to ſubſcribe the 39 articles of the church of England ; ſo that the principles of their faith are well known. No doubt there are differences of opinion among them about the ſenſe of ſome of thoſe articles ; and it is well known that there are ſimilar differences among the Engliſh clergy themſelves: but there is every reaſon to believe, that the faith of the Scotch Epiſcopalians has, in every important point, been at all times orthodox.

13
Their worſhip.

We are aware, that they have been repreſented as unfriendly to the Engliſh ſervice ; but ſuch a repreſentation appears to be either a wilful falſehood, or the offspring of ignorance. The only reformed liturgy that ever had the ſanction of a civil eſtabliſhment in Scotland, is *the Book of Common Prayer, and Adminiſtration of the Sacraments, and other parts of Divine Service* authoriſed by King Charles I. In that book, the order of adminiſtration of the Lord's Supper differs in ſome particulars from the Engliſh order, and is unqueſtionably better adapted to the opinions of thoſe who conſider that holy ordinance either as an euchariſtical ſacrifice, or as a feaſt upon a ſacrifice. In the one or other of theſe lights, the Lord's Supper is viewed by a great majority of the Scotch Epiſcopalians ; and of courſe the Scotch communion office is uſed in a great majority of their chapels : but it is not uſed in them all. Their biſhops, who, when in England, communicate with the eſtabliſhed church, leave the inferior clergy at liberty to uſe either the Engliſh or the Scotch form, as is moſt agreeable to themſelves and to the people among whom they miniſter ; and to ſilence the clamour of ſymbolizing with the church of Rome, which was ſome years ago either ignorantly or maliciouſly raiſed againſt them, they altered the *arrangement* of the Scotch prayer of conſecration, ſo as not only to bring it nearer to the moſt primitive forms, but alſo to make it abſolutely inconſiſtent with the real preſence, as taught either by the church of Rome or by the Lutheran churches. On this ſubject, ſee *Greek-Church*, n° 17. in this *Supplement*.

14
Engliſh clergymen in Scotland.

Thus have we given a ſhort view of the diſtinguiſhing principles of what muſt ſurely be conſidered as a very reſpectable ſociety of Chriſtians, and the only reformed *Epiſcopal* ſociety in that part of Great Britain called Scotland. There are, indeed, chapels in Scotland diſtinct from the church of which we have been treating, where the Engliſh liturgy is read by clergymen who have received Epiſcopal ordination either in England or in Ireland; but thoſe chapels being all independent of each other, and under the inſpection of no biſhop, the perſons who frequent them ſeem to be rather Congregationaliſts than Epiſcopalians, and certainly do not conſtitute what can, with any propriety, be called an *Epiſcopal church*.

EQUANT, in aſtronomy, a fanciful circle, introduced into ſcience to remove ſome of the defects of the Ptolemaic ſyſtem of the univerſe. In this artificial ſyſtem of epicycles and eccentric circles, the idea of circular and equable motion was by no means abandoned; but while each of the heavenly bodies revolved in its own orb, the centre of that orb was ſuppoſed to be carried at the ſame time round the circumference of another circle. The more obvious inequalities were thus explained with a geometrical preciſion. With all its nice combination, however, of circles, the ſyſtem was ſoon found to have defects; to remove which, the fine contrivance of the equant was introduced. Though the angular motion of a planet viewed from the earth was confeſſed to be unequal, a point could be conceived from which it would be ſeen to move with perfect uniformity. That point was made the centre of the equant, and lay at the ſame diſtance from the centre of the eccentricity on the one ſide, as the earth was removed on the other. "Nothing (ſays Dr Smith, from whom this account of the equant is taken) can more evidently ſhew how much the repoſe and tranquillity of the imagination is the ultimate end of philoſophy, than the invention of this equalizing circle."

EQUATION OF A CURVE. See ALGEBRA (*Encycl.*) Part III. chap. ii.

Secular EQUATION, in aſtronomy. See ASTRONOMY in this *Supplement*, nº 25—38.

EQUICURVE CIRCLE, the ſame with CIRCLE *of Curvature*, which ſee in this Supplement.

ERGETT EL KRANE } Two Abyſſinian ſhrubs of
ERGETT Y'DIMMO } the genus MIMOSA, which ſee *Encycl.*

ERKOOM, an Abyſſinian bird, part of a large tribe, "in which (ſays Mr Bruce) the greateſt variety lies in his beak and horn. The horn he wears ſometimes upon the beak and ſometimes upon the forehead above the root of the beak." This bird is by naturaliſts called the *Indian crow* or *raven;* and our author, though he ſeems to think this claſſification improper, admits that he has one charecteriſtic of the raven; he walks, and does not hop or jump in the manner that many others of that kind do; but then he at times runs with very great velocity, and, in running, very much reſembles the turkey or buſtard when his head is turned from you.

The colour of the eye of this bird is of a dark brown, or rather reddiſh, caſt, but darker ſtill as it approaches the pupil; he has very large eyelaſhes, both upper and lower, but eſpecially his upper. From the point of the beak to the extremity of the tail is three feet ten inches; the breadth, from one point of the wing to the other extended, is ſix feet, and the length twenty-two inches; the length of the neck ten inches, and its thickneſs three inches and a half; the length of the beak, meaſuring the opening near the head ſtraight to the point, ten inches; and from the point of the beak to the root of the horn, ſeven inches and three eighths. The whole length of the horn is three inches and a half. The length of the horn, from the foot to the extremity where it joins the beak, is four inches. The thickneſs of the beak in front of the opening is one inch and ſeven eighths. The thickneſs of the horn in front is one inch and five eighths. The horn in height, taken from the upper part of the point to the beak, two inches. The length of the thighs ſeven inches, and that of the legs ſix inches and five eighths. The thickneſs in profile ſeven lines, and in front four lines and a half. It has three toes before and one behind, but they are not very ſtrong, nor ſeemingly made to tear up carcaſes. The length of the foot to the hinder toe is one inch ſix lines, the innermoſt is one inch ſeven lines, the middle two inches two lines, and the laſt outer one two inches one line. This bird is all of a black, or rather black mixed with ſoot-colour; the large feathers of the wing are ten in number, milk-white both without and within. The tip of his wings reaches very nearly to his tail; his beak and head meaſured together are eleven inches and a half, and his head three inches and a quarter. At his neck he has thoſe protuberances like the Turkey-cock, which are light blue, but turn red upon his being chafed, or in the time the hen is laying.

The erkoom, though not eaſily raiſed, flies (ſays our author) both ſtrong and far. It has a rank ſmell, and is ſaid in Abyſſinia to feed upon dead carcaſes. This, however, he thinks a miſtake, as he never ſaw it following the army, nor approaching a dead carcaſe; and as often as he had occaſion to open this bird, he found in its ſtomach nothing but the green ſcarabeus or beetle. It builds in large thick trees, always, if it can, near churches; has a covered neſt like that of a magpie, but four times as large as the eagle's. It places its neſt firm upon the trunk, without endeavouring to make it high from the ground: the entry is always on the eaſt ſide.

ETON is a place which, on account of its college, ſhould not be omitted in a repoſitory of arts, ſciences, and literature; and as no notice is taken of it in the *Encyclopædia*, we ſhall deviate for once from the plan which we had laid down for this Supplement, and which is, not to admit into it deſcriptions of places in our own iſland that may be viſited by the greater part of our readers with little trouble.

Though in a different county, namely, Buckinghamſhire, Eton may be ſaid to be one and the ſame town with Windſor, for which ſee *Encycl.* It is pleaſantly ſituated on the banks of the Thames, in a delightful valley, which is of a remarkably healthy ſoil. Its college was founded by Henry VI. for the ſupport of a provoſt and ſeven fellows, one of whom is vice-provoſt, and for the education of ſeventy King's ſcholars, as thoſe are called who are on the foundation. Theſe, when properly qualified, are elected, on the firſt Tueſday in Auguſt, to king's college Cambridge, but they are not removed till there are vacancies in the college, and then they are called according to ſeniority; and after they have been three years at Cambridge, they claim a fellowſhip. Beſides thoſe on the foundation there

there are ſeldom leſs than three hundred ſcholars, and often many more, who board at the maſters houſes, or within the bounds of the college. The ſchool is divided into upper and lower, and each of theſe into three claſſes. To each ſchool there is a maſter and four aſſiſtants or uſhers. The revenue of the college is about L. 5000 a-year. Here is a noble library, and in the great court is a fine ſtatue of the founder, erected at the expence of a late provoſt Dr Godolphin dean of St Paul's. The chapel is in a good ſtyle of Gothic architecture. The ſchools and other parts, which are in the other ſtyle of building, are equally well, and ſeem like the deſign of Inigo Jones.

At Eton there is a ſingular, and we think a laudable, feſtival called the *Montem*, celebrated triennially (formerly duennially) by the ſcholars of the ſchool upon Whit-Tueſday. The following account of this feſtival, taken from the Monthly Magazine, will probably be acceptable to many of our readers.

It commences by a number of the ſenior boys taking poſt upon the bridges or other leading places of all the avenues around Windſor and Eton ſoon after the dawn of day. Theſe youths ſo poſted are chiefly the beſt figures, and the moſt active of the ſtudents; they are all attired in fancy dreſſes of ſilks, ſatins, &c. and ſome richly embroidered, principally in the habits or faſhion of running footmen, with poles in their hands; they are called *ſalt-bearers*, and demand ſalt, i. e. a contribution from every paſſenger, and will take no denial.

When the contribution is given, which is *ad libitum*, a printed paper is delivered with their motto and the date of the year, which paſſes the bearer free through all other ſalt-bearers for that day, and is as follows, viz.

"Pro more et monte,
1799, (A)
Vivant Rex et Regina."

Theſe youths continue thus collecting their ſalt at all the entrances for near ſeven miles round Windſor and Eton, from the dawn of day until about the cloſe of the proceſſion, which is generally three o'clock in the afternoon.

The proceſſion commences about twelve o'clock at noon, and conſiſts of the Queen's and other bands of muſic; ſeveral ſtandards borne by different ſtudents; all the Etonian boys, two and two, dreſſed in officers uniforms; thoſe of the king's foundation wearing blue, the others ſcarlet uniforms, ſwords, &c.

The Grand Standard-bearer.

The Captain, or Head Boy of Eton School.

The Lieutenant, or Second Boy.

His Majeſty, attended by the Prince of Wales, and other male branches of the royal family on horſeback, with their ſuite.

The Queen and Princeſſes in coaches, attended by their ſuite.

Band of muſic, followed by a great concourſe of the Nobility and Gentry in their carriages and on horſeback.

The proceſſion commences in the great ſquare at Eton, and proceeds through Eton to Slough, and round to Salt Hill, where the boys all paſs the king and queen in review, and aſcend the Montem: here an oration is delivered, and the grand ſtandard is diſplayed with much grace and activity by the ſtandard bearer, who is generally ſelected from among the ſenior boys.

There are two extraordinary ſalt-bearers appointed to attend the king and queen, who are always attired in fanciful habits, in manner of the other ſalt-bearers already deſcribed, but ſuperbly embroidered. Theſe ſalt-bearers carry each an embroidered bag, which not only receives the royal ſalt, but alſo whatever is collected by the out-ſtationed ſalt-bearers. The donation of the king and queen, or, as it is called upon this occaſion, the *royal ſalt*, is always fifty guineas each; the Prince of Wales thirty guineas; all the other princes and princeſſes twenty guineas each. As ſoon as this ceremony is performed, the royal family return to Windſor. The boys are all ſumptuouſly entertained at the tavern at Salt Hill; and the beautiful gardens at that place are laid out for ſuch ladies and gentlemen as chooſe to take any refreſhments, the different bands of muſic performing all the time in the gardens.

About ſix o'clock in the evening all the boys return in the ſame order of proceſſion as in the morning (with the exception only of the royal family), and, marching round the great ſquare in Eton ſchool, are diſmiſſed. The captain then pays his reſpects to the royal family at the queen's lodge, Windſor, previous to his departure for King's College, Cambridge; to defray which expence, the produce of the montem is preſented to him; and upon Whit-Tueſday, in the year 1796, it amounted to more than 1000 guineas. The day concludes by a brilliant diſplay of beauty, rank, and faſhion, a promenade on Windſor Terras, bands of muſic performing, &c. and the ſcene highly enlivened and enriched by the affable condeſcenſion of the royal family, who indiſcriminately mix with the company, and parade the Terrace till nearly dark.

SPONTANEOUS EVAPORATION. See WEATHER, n° 17, &c. *Encycl.*

EUDIOMETER, an inſtrument for aſcertaining the purity of the atmoſpherical air. Many have been the contrivances of chemiſts for this purpoſe (ſee EUDIOMETER, *Encycl.*); but perhaps the beſt eudiometer is that of *Morveau* (or *Guyton*, as he now chooſes to call himſelf), of which mention has been made in CHEMISTRY, n° 420. in this Supplement. The following ſhort deſcription will make the nature and uſe of this inſtrument plain to every reader.

AB, (Plate XXVIII.) repreſents a ſmall glaſs retort with a long neck; its whole capacity being from ſeven to nine ſolid inches. It muſt be choſen of ſuch a curvature that, when the neck is ſet upright, the bulb may form at its lower part a cavity to retain the matters introduced. The extremity of the neck of this retort is ground with emery to enter the glaſs tube CD, which is open at both ends, and about 12 or 15 inches in length. The retort then cloſes the tube in the manner of a ground ſtopper, and intercepts all external communication. A cylindrical glaſs veſſel F is provided, of the form of a common jar, in which the glaſs tube CD may be entirely plunged beneath the level of the water. Laſtly, the ſulphuret of potaſh is prepared and broken into pieces ſufficiently ſmall to be introduced

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(A) Or whatever the year may be.

into the retort. Theſe are to be incloſed, dry and even hot, in a bottle for uſe. Theſe conſtitute the whole apparatus and preparation of materials.

When it is required to examine an aeriform fluid, by ſeparating its oxygen, two or three pieces of the ſulphuret, of the ſize of a pea, are put into the retort. It is then filled with water, taking care to incline it ſo that all the air may paſs out from the bulb. The orifice of the retort is then to be cloſed, and inverted into the pneumatic tube, in order that the gas propoſed for examination may be tranſferred into it in the uſual manner. By an eaſy manœuvre of alternately inclining the retort in different directions, all the water is made to flow out of the bulb in which the ſulphuret remains. When this is done, the retort is placed in the vertical ſituation, and its extremity introduced into the tube of glaſs CD, which muſt always be under water. A ſmall lighted taper is then to be placed under the bulb. To ſupport the retort in its poſition, the jar is provided with a wooden cover, in which there is a notch to receive it.

The firſt impreſſion of the heat dilates the gaſeous fluid ſo much that it deſcends almoſt to the bottom of the tube, which is diſpoſed expreſsly for its reception; otherwiſe the partial eſcape would prevent an accurate determination of its change of bulk. But as ſoon as the ſulphuret begins to boil, the water quickly riſes, not only in the inferior tube, but likewiſe in the neck of the retort, notwithſtanding the application, and even the increaſe of the heat.

If the fluid be abſolutely pure vital air, the abſorption is total. In this caſe, to prevent the rupture of the veſſel by too ſudden refrigeration, the aſcent of the water muſt be rendered ſlower, either by removing the taper, or by increaſing the perpendicular height; which will not prevent the abſorption from continuing while any gas remains which is proper to ſupport combuſtion.

If the fluid be common air, or oxygen mixed with any other gas, the quantity of water which has entered the retort muſt be accurately meaſured after the cooling. It repreſents the volume of air abſorbed. Care muſt be taken to incloſe the remaining gas under the ſame preſſure, by plunging the retort to the level of the line at which the incloſed water reſts, before the orifice is ſtopped.

This operation of meaſuring, which is very eaſy when meaſuring veſſels are at hand, may be habitually performed by a ſlip of paper paſted on the neck of the retort, upon which diviſions are drawn from obſervation, and which muſt be covered with varniſh to defend it from the action of the water.

EUDOXUS of Gnidus was a celebrated philoſopher of the ſchool of Pythagoras. His firſt preceptor was Archytas, by whom he was inſtructed in the principles of geometry and philoſophy. About the age of twenty-three he came to Athens; and though his patrimony was ſmall, by the generous aſſiſtance of Theomedon a phyſician, he was enabled to attend the ſchools of the philoſophers, particularly that of Plato. The liberality of his friends afterwards ſupported him during a viſit to Egypt, where he was introduced by Ageſilaus to king Nectanebis II. and by him to the Egyptian prieſts. It has been ſaid that he accompanied Plato into Egypt; but this is inconſiſtent with chronology; for Nectanebis II. reigned in Egypt from the ſecond year of the hundred and fourth Olympiad, to the ſecond year of the hundred and ſeventh; and it was before Plato opened his ſchool, that is, before the ninety-eighth Olympiad, about the fortieth year of his age, that he viſited Egypt. Eudoxus is highly celebrated by the ancients for his ſkill in aſtronomy; but none of his writings on this or any other ſubject are extant. Aratus, who has deſcribed the celeſtial phenomena in verſe, is ſaid to have followed Eudoxus. He flouriſhed about the ninety-ſeventh Olympiad, and died in the fifty-third year of his age. *Enfield's Hiſt. of Philoſophy.*

EVECTION is uſed by ſome aſtronomers for the libration of the moon, being an inequality in her motion, by which, at or near the quadratures, ſhe is not in a line drawn through the centre of the earth to the ſun, as ſhe is at the ſyzygies, or conjunction and oppoſition, but makes an angle with that line of about 2° 51′. The motion of the moon about her axis only is equable; which rotation is performed exactly in the ſame time as ſhe revolves about the earth; for which reaſon it is that ſhe turns always the ſame face towards the earth nearly, and would do ſo exactly, were it not that her monthly motion about the earth, in an eliptic orbit, is not equable; on which account the moon, ſeen from the earth, appears to librate a little upon her axis, ſometimes from eaſt to weſt, and ſometimes from weſt to eaſt; or ſome parts in the eaſtern limb of the moon go backwards and forwards a ſmall ſpace, and ſome that were conſpicuous are hid, and then appear again.

The term *evection* is uſed by ſome aſtronomers to denote that equation of the moon's motion which is proportional to the ſine of double the diſtance of the moon from the ſun, diminiſhed by the moon's anomaly. This equation is not yet accurately determined; ſome ſtate it at 1° 30′, others at 1° 16′, &c. It is the greateſt of all the moon's equations, except the equation of the centre. *Hutton's Dictionary.*

EVENLY EVEN NUMBER. See NUMBER, *Encycl.*

EVENLY Odd Number. See NUMBER, *Encycl.*

EVOLVENT, in the higher geometry, a term uſed by ſome writers for the involute or curve reſulting from the evolution of a curve, in contradiſtinction to that evolute or curve ſuppoſed to be opened or evolved. See EVOLUTE and INVOLUTE, *Suppl.*

EVOLUTE, in the higher geometry, a curve firſt propoſed by Huyghens, and ſince much ſtudied by mathematicians. It is any curve ſuppoſed to be evolved or opened, by having a thread wrapped cloſe upon it, faſtened at one end, and beginning to evolve or unwind the thread from the other end, keeping the part evolved or wound off tight ſtretched; then this end of the thread will deſcribe another curve, called the *involute*. Or the ſame involute is deſcribed the contrary way, by wrapping the thread upon the evolute, keeping it always ſtretched. For the INVOLUTION and EVOLUTION *of Curves*, ſee INVOLUTION in this Supplement.

Imperfect EVOLUTE, a name given by M. Reaumur to a new kind of evolute. The mathematicians had hitherto only conſidered the perpendiculars let fall from the involute on the convex ſide of the evolute: but if other lines not perpendicular be drawn upon the ſame points, provided they be all drawn under the ſame angle, the effect will ſtill be the ſame; that is, the oblique lines will all interſect in the curve, and by their interſections form the infinitely ſmall ſides of a new curve, to which they would be ſo many tangents. Such a curve is a kind of evolute, and has its radii; but it is an imperfect one, ſince the radii are not perpendicular to the firſt curve or involute.

EUPHON, a muſical inſtrument invented lately by Dr Chladni of Wittenberg, well known by his various publications on philoſophical ſubjects, eſpecially the theory of muſical ſounds. The euphon conſiſts of forty-two immoveable parallel cylinders of glaſs of equal length and thickneſs; but its conſtruction, tone, and the method of playing it, are totally different from thoſe of the harmonica, with which indeed it has nothing in common but the glaſs. See Harmonica, *Encycl.*

Dr Chladni gives the following account of his invention. In his 19th year he began to learn to play the harpſichord; and he afterwards read a great many of the principal works on the theory of muſic, by which he found that the phyſico-mathematical part of that ſcience was far more defective than other branches of natural philoſophy. Being therefore poſſeſſed with an idea that his time could not be better employed than in endeavouring to make diſcoveries in this department, he accordingly tried various experiments on the vibrations of ſtrings and the different kinds of vibration in cylindric pieces of wood, firſt diſcovered, through calculation, by the elder Euler; and found, that though a great deal had been ſaid on the nature of theſe elaſtic bodies, yet the manner of vibration and the proportion of tones in other elaſtic bodies, which do not proceed, as in the former, in ſtraight lines, but depend on the vibration of whole ſurfaces, were totally unknown, and that the little which had been written on that ſubject, by ſome authors, did not correſpond with nature. He had already long remarked, that every plate of glaſs or metal emitted various tones according as it was held and ſtruck in different places; and he was deſirous to diſcover the cauſe of this difference, which no one had ever examined. He fixed in a vice the axle of a braſs plate which belonged to a poliſhing machine, and found, that by drawing the bow of a violin over it, he produced very different tones, which were ſtronger and of longer duration than thoſe obtained merely by ſtriking it.

The obſervation, that not only ſtrings but alſo other elaſtic bodies may be made to produce ſounds by drawing a violin bow over them, Dr Chladni does not give as a diſcovery of his own; as the ſo called iron violin has been long known, and as he had read of an inſtrument conſtructed in Italy*, where glaſs or metal bells were made to ſound by means of two or more violin bows drawn over them. But the idea of employing this inſtrument to examine vibrating tones was firſt entertained by himſelf. Having accurately remarked the tones produced by the abovementioned metal plate, he found that they gave a progreſſion which correſponded with the ſquares of 2, 3, 4, &c.

In all pro- ability the *armonica* f the Abbé Mazzuchi.

Not long before he had read, in the Tranſactions of the Royal Society of Gottengen, the obſervations of Mr Lichtenberg on the phenomena produced by ſtrewing pounded reſin over a glaſs plate or cake of reſin, and he repeated many of his experiments. This led him to the idea that, perhaps, the various vibratory movements of ſuch a plate would be diſcovered by a diverſity of phenomena, if he ſtrewed over it ſand or any thing of the like kind. By this experiment there was produced a ſtar-formed figure; and the author, having continued his reſearches, publiſhed the reſult of them in a work entitled, Diſcoveries reſpecting the Theory of Sound, printed at Leipſic in 1787.

Whilſt he was employed in theſe inveſtigations, he reſolved to invent a new muſical inſtrument; and he began to conſider whether it might not be poſſible by rubbing glaſs tubes in a ſtraight line, with the wet fingers, to produce ſounds in the ſame manner as is done in the harmonica by rubbing them circularly. That glaſs tubes, like thoſe in his euphon, would not merely by ſuch rubbing emit any tones, he had long known by theory and experience; and he therefore applied himſelf to the ſolution of the difficult queſtion, in what manner the inſtrument ought to be conſtructed to anſwer the intended purpoſe? After various fruitleſs attempts for a year and a half, during which his imagination was ſo full of the idea, that ſometimes in his dreams he thought he ſaw the inſtrument and heard its tones, that is, like thoſe of the harmonica, but with more diſtinctneſs and leſs confuſion, he at length, in a ſtate between ſleeping and waking, obtained a ſolution of the problem which had given ſo much employment to his thoughts. On the ſecond of June 1789, being tired with walking, he ſat down on a chair, about nine in the evening, to enjoy a ſhort ſlumber; but ſcarcely had he cloſed his eyes when the image of an inſtrument, ſuch as he wiſhed for, ſeemed to preſent itſelf before him, and terrified him ſo much that he awoke as if he had been ſtruck by an electric ſhock. He immediately ſtarted up in a kind of enthuſiaſm; and made a ſeries of experiments, which convinced him that what he had ſeen was perfectly right, and that he had it now in his power to carry his deſign into execution. He made his experiments and conſtructed his firſt inſtrument in ſo private a manner, that no perſon knew any thing of them. On the 8th of March 1790 his firſt inſtrument of this kind was completed; and in a few days he was able to play on it ſome eaſy pieces of muſic. It was now neceſſary to give to this inſtrument, as it was entirely new, a new name; and that of *euphon*, which ſignifies an inſtrument that has a pleaſant ſound, appeared to him the moſt proper.

It was not, however, brought to perfection at once, for he made a ſecond inſtrument which was an improvement of the firſt, and a third which was an improvement of the ſecond. In ſound, indeed, and particularly in the higher tones, the firſt was equal to either of the other two; but the conſtruction was deficient in ſtrength, ſo that every week ſome hours were neceſſary to keep it in proper repair; and it was impoſſible to convey it the diſtance of a mile without almoſt totally deſtroying it. Dr Chladni alſo, for want of better tubes, employed thoſe uſed for thermometers, and marked the whole and half tones by a coating of ſealing-wax on the under ſide; but as the wax, owing to the moiſture and vibration, often cracked and flew off, it was attended with danger to the eyes. It was therefore extremely difficult to give to the conſtruction of the inſtrument ſufficient ſtrength; but this the inventor at length accompliſhed, ſo that his new euphon cannot be injured or put out of tune either by playing or by carriage. The third inſtrument was ſomewhat different from the firſt and ſecond; as the fore part, which in the two former roſe upwards with an oblique angle, ſtood at right angles, ſo that it could be tranſported with eaſe in a particular carriage made for that purpoſe. Inſtead of the thermometer tubes uſed in the firſt, the Doctor now employs tubes of different colours. In the ſecond inſtrument thoſe for the whole tones were of dark green glaſs; but he uſed for the half tones, in both, a milk white kind of glaſs. In a word, the euphon has ſome reſemblance to a ſmall writing-deſk. When opened, the abovementioned glaſs tubes, of the thickneſs of the barrel of a quill and about 16 inches long, are ſeen in a horizontal poſition. They are wetted with water, by means of a ſponge, and ſtroked with the wet fingers in the direction of their length, ſo that the increaſe of the tone depends merely on the ſtronger or weaker preſſure, and the ſlower or quicker movement of the fingers. The number of tubes at preſent is forty-two. In the back part there is a perpendicular ſounding-board divided in the middle, through which the tubes paſs. It appears therefore that the euphon ought not to be conſidered as an altered or improved harmonica, but as a totally new and different inſtrument. In regard to ſweetneſs of ſound, it approaches very near to the harmonica; but it has ſeveral advantages which no unprejudiced perſon, who examines both inſtruments, will deny.

1. It is ſimpler, both in regard to its conſtruction and the movement neceſſary to produce the ſound, as neither turning nor ſtamping is required, but merely the movement of the finger. 2. It produces its ſound ſpeedier; ſo that as ſoon as it is touched you may have the tone as full as the inſtrument is capable of giving it; whereas, in the harmonica, the tones, particularly the lower ones, muſt be made to increaſe gradually. 3. It has more diſtinctneſs in quick paſſages; becauſe the tones do not reſound ſo long as in the harmonica, where the ſound of one low tone is often heard when you wiſh only to hear the following tone. 4. The uniſon is purer than is generally the caſe in the harmonica, where it is difficult to have perfect glaſſes, which in every part give like tones with mathematical exactneſs. It is however as difficult to be tuned as the harmonica. 5. It does not affect the nerves of the performer; for a perſon ſcarcely feels a weak agitation in the fingers; whereas in the harmonica, particularly in concords of the lower notes, the agitation extends to the arms, and even through the whole body of the performer. 6. The expence of this inſtrument will be much leſs in future than that of the harmonica. 7. When one of the tubes breaks, or any other part is deranged, it can be ſoon repaired, and at very little expence; whereas, when one of the glaſſes of the harmonica breaks, it requires much time, and is very difficult to procure another capable of giving the ſame tone as the former, and which will correſpond ſufficiently with the ſeries of the reſt.

EUPHORBIA (See *Encycl.*). Of this plant three new ſpecies were diſcovered by Le Vaillant during his Plate XXVIII. fig. 1. laſt travels into the interior parts of Africa. The firſt, which he calls the Cucumber-Euphorbia, adheres to the earth no otherwiſe than by a few ſlender roots. It riſes to the height of nine or ten inches only; and exactly reſembles a cucumber, of which it has the bent ſhape. It contains abundance of milky juice, which appeared to him as cauſtic as that of the great euphorbia. Its colour, which is a yellowiſh-green, tinted with a beautiful ſhade of violet towards the root, gives it a very attractive appearance: but woe betide the man who ſhould be tempted to eat of it! as it is a virulent poiſon. The ſecond, to which he gave the name of the Melon-ribbed Euphorbia, does not riſe more than three or Fig 2. four inches from the ground, to which it adheres by a collection of fibrous roots, iſſuing from ſeveral tubercles diſpoſed in the manner of a crown. The ſtem forms a flatted globe excavated at the ſummit, and has ribs like the apple which in France is called *calville blanche*. Theſe ribs are elevated, thick, and convex, have a greeniſh colour, and are marked with brown tranſverſal bands. From the ſummit of the ribs iſſue ſeveral little tufts of pedunculate flowers. The third he called the Caterpillar-Euphorbia, becauſe when he firſt found Fig. 3. it, he thought he perceived on it ſeveral beautiful caterpillars. The deſcription of it in a few words is as follows: From a very large tuberous root, which here and there throws out a few thready fibres, iſſue ſeveral ſtalks almoſt of the length of the finger: they creep along the ground, are twiſted, woody, deſtitute of leaves, and furniſhed with ſeveral rows of round tubercles, each guarded by two prickles.

All theſe kinds of euphorbia are to be dreaded, the laſt two in particular; becauſe being low and mixed with the herbage like muſhrooms, animals, as they feed, run the riſk of eating them with their paſture. Our author confirms the account which has been given in the *Encyclopædia* of the ſavages poiſoning the reſervoirs of water with this plant, in order to procure the game which ſhall drink of it. To effect the death of the animal, it is neceſſary that the poiſon reach the blood and mingle with it. Yet, unconceivable as it may be, the animal, though poiſoned, is not the leſs wholeſome food, as our author ſays he has experienced. However great may be the proportion of euphorbia thrown into a pond of water, he is perſuaded that it never diffuſes itſelf through the whole maſs. It is his opinion, that the poiſon is a reſinous juice, which, being from its nature incapable of combining with water, ſwims on the ſurface, and there forms a ſhining greeniſh oil, which with a little attention may be diſcerned by the naked eye when the ſurface is ſmooth. I tried (ſays he) the qualities of this oil on myſelf, taking with a ſtraw, from the ſurface of the baſin, a ſingle drop, which I put upon my tongue; and it gave me that kind of burning pain which a cauſtic occaſions. I then took up ſome water from the reſervoir in the hollow of my hand, and blowing off the oily fluid which ſwam on the ſurface, I dipped the end of my tongue into the remainder, but could not perceive in it the ſlighteſt taſte different from that of water itſelf. He ſeems to think that milk is an antidote to the poiſon of euphorbia; becauſe he ſqueezed ſome of the juice into a baſon of milk and gave it to an ape, which ſwallowed part of it without the leaſt injury. He confeſſes, however, that the doſe was trifling.

EUSTYLE, is the beſt manner of placing columns, with regard to their diſtance; which, according to Vitruvius, ſhould be four modules, or two diameters and a quarter.

EXCENTRIC, or Excentric Circle, in the ancient Ptolomaic aſtronomy, was the very orbit of the planet itſelf, which it was ſuppoſed to deſcribe about the earth, and which was conceived excentric with it; called alſo the deferent.

Inſtead of theſe excentric circles round the earth, the moderns make the planets deſcribe elliptic orbits about the ſun; which accounts for all the irregularities of their motions, and their various diſtances from the earth, &c. more juſtly and naturally.

EXCENTRIC, or *Excentric Circle*, in the new aſtronomy, is the circle deſcribed from the centre of the orbit of a planet, with half the greateſt axis as a radius; or it is the circle that circumſcribes the elliptic orbit of the planet.

EXCHANGE. See *Encycl.* under that word, and likewiſe under *Bills of Exchange*, where the antiquity of ſuch bills, eſpecially among the Chineſe, is mentioned. In Profeſſor Beckmann's Hiſtory of Inventions the reader will find an ordinance of the year 1394 concerning the acceptance of bills of exchange, and alſo copies of two bills of the year 1404, which ſufficiently prove that the method of tranſacting buſineſs by bills of exchange was fully eſtabliſhed in Europe ſo early as the fourteenth century; and that the preſent form and terms were even then uſed. The ordinance, which was iſſued by the city of Barcelona, decreed that bills of exchange ſhould be accepted within twenty-four hours after they were preſented, and that the acceptance ſhould be written on the back of the bill.

But there are queſtions relating to bills of exchange of much greater importance than their antiquity; and theſe queſtions are not yet decided. For inſtance, Ought a bill of exchange to be conſidered by the law merely as a *depoſit* belonging to the drawer, and ſucceſſively confided to the remittees? or ſhould it be conſidered as transferable *property*, at all times abſolutely veſted in the holder, whoſe neglect therefore, when it vitiates the value, falls wholly on himſelf?

In a work publiſhed 1798 by Profeſſor Buſch of Hamburgh, entitled, *Additions to the Theoretical and Practical Delineation of Commerce* (A), the reader will find ſome arguments, which, to ſay the leaſt of them, are certainly plauſible, to prove that bills of exchange ought to be at all times conſidered as the abſolute property of the holder. This theory is then applied to the difficult and ſtill unſettled caſe of the holder of a bill having many indorſements, where the drawer, drawee, and early indorſers, have all failed. It is evident that, if the holder proves under each bankruptcy the whole amount of the bill, he will receive much more than his due. May he make his election where to prove the whole demand, and where to prove the reſidue? or ought he not (which ſeems moſt equitable) to be compelled to prove his debt againſt his immediate predeceſſor only?—the aſſignees of that predeceſſor proving in their turn, in like manner (each party once only), back to the drawer. This is a caſe of great importance to diſcounters, and the reader will find ſome judicious obſervations on it in the Profeſſor's work.

EXEGESIS, or EXEGETICA, in algebra, is the finding, either in numbers or lines, the roots of the equation of a problem, according as the problem is either numeral or geometrical.

EXPECTATION OF LIFE, in the doctrine of life annuities, is the ſhare, or number of years of life, which a perſon of a given age may, upon an equality of chance, expect to enjoy.

By the expectation or ſhare of life, ſays Mr Simpſon (*Select Exerciſes*, p. 273), is not here to be underſtood that particular period which a perſon hath an equal chance of ſurviving; this laſt being a different and more ſimple conſideration. The expectation of a life, to put it in the moſt familiar light, may be taken as the number of years at which the purchaſe of an annuity, granted upon it, without diſcount of money, ought to be valued. Which number of years will differ more or leſs from the period abovementioned, according to the different degrees of mortality to which the ſeveral ſtages of life are incident. Thus it is much more than an equal chance, according to the table of the probability of the duration of life which the ſame author has given us, that an infant, juſt come into the world, arrives not to the age of ten years; yet the expectation or ſhare of life due to it, upon an average, is near twenty years. The reaſon of which wide difference is the great exceſs of the probability of mortality in the firſt tender years of life, above that reſpecting the more mature and ſtronger ages. Indeed if the numbers that die at every age were to be the ſame, the two quantities above ſpecified would alſo be equal; but when the ſaid numbers become continually leſs and leſs, the expectation muſt of conſequence be the greater of the two.

EXPONENTIAL CALCULUS, the method of differencing, or finding the fluxions of exponential quantities, and of ſumming up thoſe differences, or finding their fluents.

EXPONENTIAL *Curve*, is that whoſe nature is defined or expreſſed by an exponential equation; as the curve denoted by $a^x = y$, or by $x^x = y$.

EXPONENTIAL *Equation*, is one in which is contained an exponential quantity: as the equation $a^x = b$, or $x^x = a b$, &c.

EXPONENTIAL *Quantity*, is that whoſe power is a variable quantity; as the expreſſion a^x, or x^x. Exponential quantities are of ſeveral degrees and orders according to the number of exponents or powers, one over another.

EXTRA-CONSTELLARY STARS, ſuch as are not properly included in any conſtellation.

Extra-Mundane Space, is the infinite, empty, void ſpace, which is by ſome ſuppoſed to be extended beyond the bounds of the univerſe, and conſequently in which there is really nothing at all. The phraſe *extramundane ſpace* has been ſo long in uſe among our beſt writers, that it is now impoſſible to baniſh it from the language; and yet it has been the ſource of ſome extravagant miſtakes. Many philoſophers conſider ſpace as ſomething *real*, diſtinct both from body and mind; and no leſs a man than Dr Clarke conſidered it as an attribute of the Deity. Yet we think nothing more evident, than that if body had never exiſted, ſpace would never have been thought of; and if this be ſo, extramundane ſpace, inſtead of denoting any *real* thing, or attribute infinitely extended, can mean nothing more than the *poſſibility* of enlarging the corporeal univerſe, however widely extended it may be. See METAPHYSICS, *Encycl.* Part II. ch. iv.

(A) Profeſſor Buſch publiſhed in 1792 a work entitled *A Theoretical and Practical Delineation of Commerce.*

EXTRADOS, the outſide of an arch of a bridge, vault, &c. See Arch in this *Supplement*.

EXTREMES Conjunct, and *Extremes Disjunct*, in ſpherical trigonometry, are, the former the two circular parts that lie next the aſſumed middle part; and the latter are the two that lie remote from the middle part. Theſe were terms applied by Lord Napier in his univerſal theorem for reſolving all right-angled and quadrantal ſpherical triangles, and publiſhed in his *Logarithmorum Canonis Deſcriptio*, ann. 1614. In this theorem, Napier condenſes into one rule, in two parts, the rules for all the caſes of right angled ſpherical triangles, which had been ſeparately demonſtrated by Pitiſcus, Lanſbergius, Copernicus, Regiomontanus, and others. In this theorem, neglecting the right angle, Napier calls the other five parts circular parts, which are, the two legs about the right angle, and the complements of the other three, viz. of the hypothenuſe, and the two oblique angles. Then taking any three of theſe five parts, one of them will be in the middle between the other two, and theſe two are the extremes conjunct when they are immediately adjacent to that middle part, or they are the extremes disjunct when they are each ſeparated from the middle one by another part.

F.

FACE or Façade, in architecture, is ſometimes uſed for the front or outward part of a building, which immediately preſents itſelf to the eye; or the ſide where the chief entrance is, or next the ſtreet, &c.

FALCONRY, is a ſpecies of ſport, about the antiquity of which there has been ſome diſpute. Under the word Hawking, *Encycl.* we have deduced what we thought ſufficient evidence of its being practiſed among the Thracians, and likewiſe among the Britons before the invaſion of this iſland by the Romans. Flavius Blondus, however, and Laurentius Valla, both writers of the 15th century, and the latter, one of the moſt learned men of his time, affirm that no nation or people were accuſtomed to catch either land or water fowls with any rapacious bird trained for the purpoſe.

We were pleaſed to ſee our own opinion, ſo different from this, completely eſtabliſhed by the learned labours of Profeſſor Beckmann. So early (ſays he) as the time of Cteſias (and he refers to the page and edition of his author) hares and foxes were hunted in India by means of rapacious birds. The account of Ariſtotle *, however, is ſtill more to the purpoſe, and more worthy of notice. "In Thrace (ſays he) the men go out to catch birds with hawks. The men beat the reeds and buſhes which grow in marſhy places, in order to raiſe the ſmall birds, which the hawks purſue and drive to the ground, where the fowlers kill them with poles." The ſame account is to be found in another book aſcribed alſo to Ariſtotle; and which appears, at any rate, to be the work of an author not much younger. Reſpecting Thrace, which is ſituated above Amphipolis, a wonderful thing is told, which might appear incredible to thoſe who had never heard it before. It is ſaid that boys go out into the fields, and purſue birds by the aſſiſtance of hawks. When they have found a place convenient for their purpoſe, they call the hawks by their names, which immediately appear as ſoon as they hear their voices, and chaſe the birds into the buſhes, where the boys knock them down with ſticks and ſeize them. What is ſtill more wonderful, when theſe hawks lay hold of any birds themſelves, they throw them to the fowlers; but the boys, in return, give them ſome ſhare of the prey. *De mirabilibus auſcultat.* cap. 128.

In this paſſage, there are two additions which render the circumſtance ſtill more remarkable. The firſt is, that the falcons appeared when called by their names; and the ſecond, that of their own accord they brought to the fowlers whatever they caught themſelves. Nothing is here wanting but the ſpaniel employed to find out game, the hood which is put upon the head of the hawk while it ſtands on the hand, and the thong uſed for holding it, to form a ſhort deſcription of falconry as ſtill practiſed. Our falconers, when they have taken the bird from the hawk, give him, in return, a ſmall ſhare of it; and in the like manner the Thracian hawks receive ſome part of their booty.

Other writers after Ariſtotle, ſuch as Antigonus, Ælian, Pliny, and Phile, have alſo given an account of this method of fowling. Ælian, who ſeldom relates any thing without ſome alteration or addition, ſays, that in Thrace nets were uſed, into which the birds were driven by the hawks; and in this he is followed by the poet Phile. Ælian, alſo, in another place deſcribes a manner of hunting with hawks in India, which, as we are told by ſeveral travellers, is ſtill practiſed in Perſia, where it is well underſtood, and by other eaſtern nations.

The Indians (ſays he) hunt hares and foxes in the following manner: They do not employ dogs, but eagles, crows, and, above all, kites, which they catch when young, and train for that purpoſe. They let looſe a tame hare or fox, with a piece of fleſh faſtened to it, and ſuffer theſe birds to fly after it, in order to ſeize the fleſh, which they are fond of, and which, on their return, they receive as the reward of their labour. When thus inſtructed to purſue their prey, they are ſent after wild foxes and hares in the mountains; theſe they follow in hopes of obtaining their uſual food, and ſoon catch them and bring them back to their maſters, as we are informed by Cteſias. Inſtead of the fleſh, however, which was faſtened to the tame animals, they receive as food the entrails of the wild ones which they have caught.

It ſeems, therefore, that the Greeks received from India

* *Hiſt Animat*, lib. ix. cap. 6.

dia and Thrace the firſt information reſpecting the method of fowling with birds of prey; but it does not appear that this practice was introduced among them at a very early period. In Italy, however, it muſt have been very common, for Martial and Apuleius ſpeak of it as a thing every where known: the former calls a hawk the fowler's ſervant.

The Profeſſor traces the hiſtory of this art with great learning down to the preſent time. It was carried to the higheſt perfection at the principal courts of Europe (he ſays) in the 12th century, when the ladies kept hawks, which were as much fondled by thoſe who wiſhed to gain their favour as lap dogs are at preſent. Among the oldeſt writers on falconry, as an art, he reckons Demetrius, who about the year 1270 was phyſician to the Emperor Michael Paleologus. His book, written in Greek, was firſt printed at Paris in 1612 with a Latin tranſlation; but its precepts (ſays our author) would be thought of very little value at preſent. For an account of the modern art of FALCONRY, ſee *Encyclopædia*.

FALK (John Peter), known to the world as one of the ſcientific travellers employed by the late Empreſs of Ruſſia to explore her vaſt dominions, was born in Weſtrogothia, a province in Sweden, about the year 1727. He ſtudied medicine in the univerſity of Upſal, and went through a courſe of botany under the celebrated Linnæus, to whoſe ſon he was tutor. He publicly defended the diſſertation (A) which that famous botaniſt had compoſed on a new ſpecies of plants, which he called *aſtromeria*.

In the year 1760, he was ſo deeply affected with depreſſion of ſpirits, that M. de Linné, in the view of obliging him to take exerciſe and diſſipation, ſent him to travel over the iſland of Gothland, to make a collection of the plants it produces, and the various kinds of corals and corallines which the ſea leaves on its ſhores. This voyage was attended with no diminution of his diſtemper, which found a continual ſupply of aliment in a ſanguine melancholy temperament, in a too ſedentary way of life, and in the bad ſtate of his finances.

Profeſſor Forſkael having left Upſal for Copenhagen in 1760, Falk followed him thither, in the deſign of applying, by the advice of M. de Linné, to be appointed aſſiſtant to M. Forſkael in his famous journey thro' Arabia; but notwithſtanding all the pains that M. Œder, and ſeveral other men of literary reputation at Copenhagen, took in his behalf, his application failed, as the ſociety that were to go on that important expedition was already formed. Obliged, with much diſcontent, to return, he herboriſed as he travelled, and enriched the Flora Suecica with ſeveral new diſcoveries.

A man in office at St Peterſburgh having written to M. Linné to ſend him a director for his cabinet of natural hiſtory, M. Falk accepted the poſt, which led him to the chair of profeſſor of botany at the apothecaries garden at St Peterſburgh, a place that had been long vacant. His hypochondriac complaint ſtill continued to torment him. When the Imperial Academy of Sciences was preparing in 1768 the plan of its learned expeditions, it took M. Falk into its ſervice, though his health was uncertain. He was recalled in 1771; but having got only to Kaſan in 1773, he there obtained permiſſion to go and uſe the baths of Kiſliar, from which he returned again to Kaſan at the end of the year, with his health apparently better.

But his diſeaſe ſoon returned with redoubled violence. From the month of December 1773 he had never quitted his bed, nor taken any other nouriſhment than bread dried in the Swediſh manner (knækebrœd), of which he ſcarcely took once a day ſome mouthfuls dipped in tea. At firſt he received the viſits of a few friends; but afterwards denied himſelf to them, and was reduced to the ſtricteſt ſolitude. When M. Georgi, member of the ſociety of natural hiſtory at Berlin, who had been deſtined to aſſiſt and relieve the profeſſor in the duties of his expedition, went to ſee him on this occaſion, nothing ſeemed left of him but a ſkeleton of a wild and terrifying aſpect. The few words he drew from him conſiſted in complaints, occaſioned by a hoſt of diſeaſes which kept his body in torture, and threw him into the moſt cruel ſleepleſſneſs. The laſt evening M. Georgi kept him company till midnight. He ſpoke little, and ſaid nothing that could give reaſon to ſuſpect the deſign he was meditating. His hunter, and at the ſame time his truſty ſervant, offered to ſit up with him the night; but he could not be perſuaded to conſent.

M. Georgi being requeſted the next day, March 31, to come to the lodging of the unfortunate gentleman, he found him lying before his bed, covered with blood; beſide him lay a razor, with which he had given himſelf a ſlight wound in the throat, the fatal piſtol, and a powder-horn; all together preſenting a tremendous ſpectacle. He had put the muzzle of the piſtol againſt his throat, and, reſting the pommel upon his bed, he diſcharged the contents in ſuch a manner, that the ball, having gone through his head, had ſtuck in the cieling. His ſoldier had ſeen him ſtill ſittting up in his bed at four o'clock, at which time he uſually fell into a ſhort ſlumber. In his chamber was found a note written the evening before, betraying throughout the diſtracted ſtate of his mind, but nothing declaratory of his deſign, or that was of any importance.

M. Falk, like all hypochondriac perſons, was not very communicative, and on certain occaſions was diſtruſtful. But, at the ſame time, he was of a ſedate temper, complaiſant, and upright, which made it a very eaſy matter to bear with him, and ſecure to him the indulgence of all his acquaintance. His extreme ſobriety had enabled him to make ſome ſavings from his pay, though he was very beneficent; it was not, therefore, indigence that drove him to this act of violence. He was of a cold conſtitution, preferring ſolitude and quiet to ſociety, to the company of his friends, and to ordinary amuſements, which yet he did not ſhun, except in the latter period of his life. As to religion, he ſhewed on all occaſions more reſpect for it than any ſtrong effuſions of zeal. It was ſolely to be aſcribed to the violence of his diſtemper, and the weakneſs of mind which it brought on, that led him to put a period to his days. The fate of this unfortunate ſcholar was generally and juſtly lamented.

His papers were found in the greateſt diſorder. They contain,

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(A) In the collection known under the title of *Linnæi Amænitates Academicæ*.

contain, however, very uſeful and important relations. He particularly made it his buſineſs to inquire about the Kirguiſes, and other Tartarian nations; and as he frequently remained for the ſpace of nine months together in the ſame place, he was enabled to procure ſatisfactory notions concerning the objects of his inveſtigations. The Imperial Academy, in 1774, appointed Profeſſor Laxmann to arrange his manuſcripts in order for publication; which was done accordingly.

FARMER (Richard, D. D.), ſo well known as one of the commentators on Shakeſpeare, was a man of ſuch pleaſing, though ſingular manners, that we regret the very imperfect account which we muſt give of his life. One of us, who had the pleaſure of being a little known to him, has been ſo much delighted with the natural eaſe and pleaſantry of his converſation, that we made all the inquiries which we judged requiſite to enable us to draw up ſuch a biographical ſketch of this agreeable man as might be acceptable to our readers, and not unworthy of his character; but theſe inquiries were made in vain. Thoſe to whom we applied knew little more of the incidents of his life than what we had previouſly found in a miſcellany, of which the writers ſeem to conſider it as a principle of duty to vilify the character of every perſon who, like Dr Farmer, is the friend of order, and the enemy of ſudden or rapid innovations. To that miſcellany, therefore, we muſt be beholden for many facts; but we ſhall certainly copy none of its malevolence.

Dr Farmer was born at Leiceſter 1735; but what was the ſtation of his father we have not learned. Of his ſchool education he received part, perhaps the whole, in his native town; and from ſchool he was removed to the univerſity of Cambridge, where he devoted himſelf chiefly to claſſical learning and the belles lettres. In 1757 he was admitted to the degree of bachelor of arts; in 1760 to that of maſter of arts; a bachelor of divinity in 1767, and a doctor of divinity in 1775; in which year he was alſo elected maſter of Emanuel on the deceaſe of Dr Richardſon, and principal librarian on the deceaſe of Dr Barnardiſton.

The diſturbances in America having by this time become ſerious, the univerſity of Cambridge, with numberleſs other loyal bodies, voted an addreſs to the king, approving of the meaſures adopted by government to reduce the factious coloniſts to their duty. The addreſs, however, was not carried unanimouſly. It was, of courſe, oppoſed by JEBB, ſo well known for his free opinions in politics and religion, and by ſome others, of whom one man, a member of the CAPUT, carried his oppoſition ſo far, as actually to refuſe the key of the place which contained the ſeal neceſſary on ſuch occaſions. In this emergency, Dr Farmer, who was then vice-chancellor, is ſaid to have forced open the door with a ſledge-hammer; an exploit which his democratical biographers affect to ridicule, by calling it *his courtly zeal*, and the occaſion of all his ſubſequent preferments.

If it be indeed true that he broke the door in pieces with his own hands, his conduct muſt be acknowledged to have been not very decorous; but if the office which he filled be taken into conſideration, we apprehend it would be as difficult to prove that conduct eſſentially wrong, as to vindicate the obſtinate arrogance of him who occaſioned it. The ſeal was the property of the univerſity, of which this outrageous ſupporter of the bill of rights was but an individual member. The univerſity had reſolved that it ſhould be employed for a certain purpoſe, which it was the duty of the vice chancellor to carry into effect; and ſince the ſeal was refuſed to him, he had no alternative but to get poſſeſſion of it by force. We hope, however, that he employed a ſervant to break the door; and, indeed, as vice-chancellor, he muſt have had ſo many ſervants at his command, that it is not conceivable he would wield the ſledge hammer himſelf.

Some time after this he was made a prebendary of Canterbury, we believe through the recommendation of Lord North, then premier; and it was at Canterbury that the writer of this ſketch had the happineſs of being introduced to him, and witneſſing his hoſpitality. After enjoying his prebend for ſeveral years, he reſigned it on being preferred, by the preſent premier, to a reſidentiaryſhip of St Paul's; and we have reaſon to believe that he declined a biſhopric, which was offered to him as a reward for the conſtitutional principles which he was at pains to propagate, not only in his college, but, as far as his influence went, through the whole univerſity.

It has been ſaid that the delights of the pipe and the bottle in Emanuel parlour outweighed, in his eſtimation, the dazzling ſplendor of the mitre; but he had other and better reaſons for preferring a private to a public ſtation. In early life, at leaſt before he was advanced in years, he had felt the power of love, and had ſuffered ſuch a diſappointment as ſunk deep in his mind, and for a time threatened his underſtanding. From that period, though he retained his faculties entire, he acquired ſome peculiarities of manner, of which he was ſo far conſcious as to be ſenſible that they would hardly become the character of a biſhop: being likewiſe ſtrongly attached to dramatic entertainments, which, if we miſtake not, the Engliſh biſhops never witneſs, and delighting in clubs, where he could have rational converſation without ſtate or ceremony of any kind—he very wiſely preferred his reſidentiaryſhip to the higheſt dignity in the church. At the time of his death, which happened in the autum of 1797, he was a fellow of the Royal and Antiquarian Societies, maſter of Emanuel college, principal librarian of the public library in the univerſity, one of the canons reſidentiary of St Paul's, chancellor of the dioceſe of Lichfield and Coventry, and prebendary of Worceſter.

Though a good claſſical ſcholar, Dr Farmer has been celebrated only for that kind of literature which is connected with the Engliſh drama; and having a ſtrong predilection for old Engliſh writers, he ranked high among the commentators upon Shakeſpeare. His 'Eſſay upon the Learning of Shakeſpeare,' dedicated to Mr Cradock, the intelligent reſident of Gumley-Hall in Leiceſterſhire, has paſſed through ſeveral editions. This eſſay was, in fact, the firſt foundation of his fame, which an unconquerable indolence prevented him from carrying to that height to which the exerciſe of his literary talents could not have failed to raiſe it. So great indeed was his love of eaſe, that after having announced for ſubſcriptions a hiſtory of Leiceſterſhire, and actually begun to print it, rather than ſubmit to the fatigue of carrying it through the preſs, he returned the ſubſcriptions, and preſented the MSS. and plates to Mr Nichols,

Nichols, the reſpectable printer of the Gentleman's Magazine, who has ſince carried on the hiſtory with a degree of ſpirit, ability, and induſtry, perhaps unprecedented in this department of literature.

Indolence and the love of eaſe were indeed the Doctor's chief characteriſtics; and to them, with the diſappointment already mentioned, may be attributed a want of propriety in his external appearance, and in the uſual forms of behaviour belonging to his ſtation. The prevailing features of his character diſtinguiſhed themſelves by ſeveral oddities: There were three things, it was ſaid, which the maſter of Emanuel loved, *viz.* old port, old clothes, and old books; and three things which no one could perſuade him to perform, *viz.* to riſe in the morning, to go to bed at night, and to ſettle an account. When in Cambridge, if an old houſe were pulled down, the maſter of Emanuel was always there in an old blue great coat, and a ruſty hat. When in London, he was ſure to be found in the ſame garb at an old book-ſtall, or ſtanding at the corner of a dirty lane, poring through his glaſs at an old play-bill.

This character is not drawn by a friendly pencil; but it is nevertheleſs not unjuſt. His inattention to the common decencies of dreſs and behaviour was notorious, inſomuch that, in the company of ſtrangers, the eccentricity of his appearance and of his manners made him ſometimes be taken for a perſon half crazed. The writer of this ſketch ſaw him one morning at Canterbury dreſſed in ſtockings of unbleached thread, brown breeches, and a wig not worth a ſhilling; and when a brother prebendary of his, remarkable for elegance of manners, and propriety of dreſs, put him in mind that they were to attend on the archbiſhop, Dr Farmer replied, that it had totally eſcaped him; but he went home, and dreſſed himſelf like a clergyman. That he ſat late reading, and occaſionally drinking brandy and water, cannot be denied; and it is literally true, that he could not eaſily be prevailed upon to ſettle his accounts. His accounts with ſome of his pupils, when tutor of his college, were never ſettled to the day of his death; and the young gentlemen not unfrequently took advantage of this unconquerable indolence to borrow of him conſiderable ſums, well knowing that there was little chance of a demand being ever made upon their parents. One gentleman, in particular, told a friend of ours, who was himſelf a penſioner of Emanuel, that when he left that college, he was near fifty pounds in debt to Dr Farmer; "a debt (ſaid he) which I would have ſcrupulouſly paid, but, after repeated ſolicitations, I could get no bill from him."

Having been a warm partizan of government during the American war, it will readily be believed that Dr Farmer was the determined enemy of levellers and anarchiſts. He was ſuch a whig as thoſe who placed King William on the throne; and of courſe deemed a violent tory by our preſent republicans, of whom, to ſay the truth, he could hardly ſpeak with temper. By his enemies he is admitted to have been a man of generoſity. As he obtained money eaſily, ſo he parted with it eaſily. Whilſt he was always ready to relieve diſtreſs, his bounty was frequently beſtowed on the patronage of learned men and learned publications. He was, accordingly, a favourite with all good men who knew him. In his own college he was adored; in the univerſity he had, for many years, more influence than any other individual; and, with all his eccentricities, his death was a loſs to that learned body, which, in the opinion of ſome of its members, will not ſoon be made up.

A ſhort time before his death, his character was thus juſtly and ably drawn by the celebrated Dr Parr:

"Of any undue partiality towards the maſter of Emanuel College, I ſhall not be ſuſpected by thoſe perſons who know how little his ſentiments accord with mine, upon ſome eccleſiaſtical, and many political matters. From rooted principle and ancient habit he is a tory; I am a whig; and we have both of us too much confidence in each other, and too much reſpect for ourſelves, to diſſemble what we think, upon any grounds, or to any extent. Let me then do him the juſtice which, I am ſure, that he will ever be ready to do to me. His knowledge is various, extenſive, and recondite. With much ſeeming negligence, and perhaps, in later years, ſome real relaxation, he underſtands more, and remembers more, about common and uncommon ſubjects of literature, than many of thoſe who would be thought to read all the day and meditate half the night. In quickneſs of apprehenſion, and acuteneſs of diſcrimination, I have not often ſeen his equal. Through many a convivial hour have I been charmed by his vivacity: and upon his genius I have reflected, in many a ſerious moment, with pleaſure, with admiration, but not without regret that he has never concentrated and exerted all the great powers of his mind in ſome great work, upon ſome great ſubject. Of his liberality in patroniſing learned men I could point out numerous inſtances. Without the ſmalleſt propenſities to avarice, he poſſeſſes a large income; and, without the mean ſubmiſſion of dependence, he is riſen to a high ſtation. His ambition, if he has any, is without inſolence; his munificence is without oſtentation; his wit is without acrimony; and his learning without pedantry."

FASCINATION, the art of bewitching, enchantment, an unſeen inexplicable influence. Under the title SERPENS (*Encycl.* n° 22.) we have mentioned ſeveral inſtances of the faſcinating power of the rattleſnake, which were related by men of character, and certainly gained ſome degree of credit among men of ſcience. In Vaillant's New Travels into the Interior Parts of Africa, an account is given of ſimilar inſtances of faſcination by African ſervants, ſome of them witneſſed by himſelf, and others reported to him by men of veracity.

On the confines of the European colony, at a place called *Swart-land*, our traveller ſaw a ſhrike on the branch of a tree, tremble as if in convulſions, whilſt it uttered the moſt piercing cries of diſtreſs. Cloſer attention led him to diſcover upon the next branch of the ſame tree a large ſerpent, that, with ſtretched-out neck, and fiery eyes, though perfectly ſtill, was gazing on the poor animal. He ſhot the ſerpent; but, in the mean time, the bird had died. Having meaſured the diſtance between the place where the ſhrike was ſeen in convulſions and that occupied by the ſerpent when it was ſhot, he found it to be three feet and a half; which convinced him and his attendants that the bird had not died either from the bite or the poiſon of its enemy. Indeed he ſtripped it before the whole company, and made them obſerve that it was untouched, and had not received the ſlighteſt wound.—In another diſtrict of Africa, during the courſe of the ſame travels, he ſaw a ſmall mouſe die in convulſions, occaſioned by the faſcinating power of a ſerpent, at the diſtance of two yards from it; and when he conſulted his Hottentots upon this incident, they expreſſed, he ſays, no ſort of aſtoniſhment, but aſſured him that the ſerpent had the faculty of attracting and faſcinating ſuch animals as it wiſhed to devour.

We have already had occaſion to remark how regardleſs this author is of inconſiſtencies in his narrative; and we perceive ſomething like an inconſiſtency in the narratives before us. Though his Hottentots expreſſed no ſurpriſe at the faſcination of the mouſe, and declared that nothing was more common, he ſays expreſsly, that to thoſe who witneſſed the faſcination of the ſhrike, the fact appeared ſo extraordinary, that they could hardly believe it, even after they had ſeen it.

The moſt wonderful inſtance of faſcination which we have anywhere met with, was that of a Captain in the Dutch ſervice at the Cape, who, after aſſuring our traveller that it is an event which happens very frequently, proceeded thus: "My teſtimony ought to have the more weight, as I had once nearly become myſelf a victim to this faſcination. While in garriſon at Ceylon, and amuſing myſelf, like you, in hunting in a marſh, I was, in the courſe of my ſport, ſuddenly ſeized with a convulſive and involuntary trembling, different from any thing I had ever experienced, and at the ſame time was ſtrongly attracted, and in ſpite of myſelf, to a particular ſpot of the marſh. Directing my eyes to this ſpot, I beheld, with feelings of horror, a ſerpent of an enormous ſize, whoſe look inſtantly pierced me. Having, however, not yet loſt all power of motion, I embraced the opportunity before it was too late, and ſaluted the reptile with the contents of my fuſee. The report was a taliſman that broke the charm. All at once, as if by a miracle, my convulſion ceaſed; I felt myſelf able to fly; and the only inconvenience of this extraordinary adventure was a cold ſweat, which was doubtleſs the effect of my fear, and of the violent agitation my ſenſes had undergone."

This inſtance of faſcination differs in one very material circumſtance from the two ſomewhat ſimilar inſtances mentioned in the *Encyclopædia*. In both theſe, the eyes of the perſons faſcinated were fixed on the eyes of the ſnake; but here the Dutch Captain was ſtrongly attracted towards the ſerpent before he ſaw, or even ſuſpected, that ſo formidable an enemy was in his neighbourhood. If the ſtory therefore be true, the effect which he deſcribes could not poſſibly have been the effect of fear, but of ſome unſeen influence on his whole nervous ſyſtem.

The ſubject has of late attracted the attention of men of ſcience, whoſe local ſituation gives them an opportunity of making experiments upon different ſerpents, with a view to aſcertain whether they really poſſeſs or not this moſt unaccountable of all powers. In the year 1796 was printed at Philadelphia, *a Memoir concerning the Faſcinating Faculty which has been aſcribed to the Rattle-ſnake, and other American Serpents*, by Benjamin Smith Barton, M. D. Profeſſor of natural hiſtory and botany in the univerſity of Pennſylvania. In this memoir, the manner in which the faſcinating power is ſuppoſed to be exerted is thus ſtated by the ingenious profeſſor:

"The ſnake, whatever its ſpecies may be, lying at the bottom of the tree or buſh upon which the bird or ſquirrel ſits, fixes its eyes upon the animal it deſigns to faſcinate or enchant. No ſooner is this done, than the unhappy animal is unable to make its eſcape. It now begins to utter a moſt piteous cry, which is well known by thoſe who hear it, and underſtand the whole machinery of the buſineſs, to be the cry of a creature enchanted. If it is a ſquirrel, it runs up the tree for a ſhort diſtance, comes down again, then runs up, and, laſtly, comes lower down. 'On that occaſion (ſays an honeſt, but rather credulous writer*), it has been obſerved, that the ſquirrel always goes down more than it goes up.' The ſnake ſtill continues at the root of the tree, with its eyes fixed on the ſquirrel, with which its attention is ſo entirely taken up, that a perſon accidentally approaching, may make a conſiderable noiſe without the ſnake's ſo much as turning about. The ſquirrel, as before mentioned, comes always lower, and at laſt leaps down to the ſnake, whoſe mouth is already wide open for its reception. The poor little animal then, with a piteous cry, runs into the ſnake's jaws, and is ſwallowed at once, if it be not too big; but if its ſize will not allow it to be ſwallowed at once, the ſnake licks it ſeveral times with its tongue, and ſmoothens it, and by that means makes it fit for ſwallowing."

From Dr Barton's memoir, it appears that the North American Indians are by no means of one opinion reſpecting the faſcinating power of the rattle-ſnake. Some intelligent friends of his, well acquainted with the manners, religious opinions, and ſuperſtitious prejudices of thoſe people, informed him, that though they had often heard the Indians ſpeak of the ingenuity of theſe reptiles in catching birds, ſquirrels, &c. they did not recollect having ever heard them ſay that ſnakes *charm* birds. On the other hand, however, a Mohegan Indian told the Doctor himſelf, that the Indians are of opinion, that the rattle-ſnake can charm, or betwitch, ſquirrels and birds, and that it does this with its rattle, which it ſhakes, thereby inviting the animals to deſcend from the trees, after which they are eaſily caught. According to this Indian, his countrymen do not think that the ſnake, in any manner, accompliſhes the buſineſs with its eyes. A Choktah Indian aſſured the Doctor, that the rattle ſnake does charm birds, &c.; but he was honeſt enough to confeſs, that he did not know in what manner it does it. The interpreter, through whom the converſation was carried on with this Indian, ſaid that the ſnake charms by means of its rattle.

This opinion of the interpreter was the opinion of Dr Mead. That eminent naturaliſt, controverting, about fifty years ago, the common opinion, that Providence has furniſhed the rattle-ſnake with its rattle to give warning to travellers, was the firſt who aſſerted that this ſingular appendage is given to the animal to terrify ſquirrels and ſmall birds, which are then ſo ſtupified by the ſight of ſo formidable an enemy, that at length they drop down, and become its prey; and that this is what the Indians call *faſcination*. The ſame opinion has been adopted by profeſſor Blumenbach of Gottingen, who, in his Manual of Natural Hiſtory, thus expreſſes himſelf on this curious ſubject:

"That ſquirrels, ſmall birds, &c. fall down ſpontaneouſly from trees into the mouth of the rattle-ſnake, lying

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* *Profeſſor Peter Kalm.*

lying below them, is an undiſputed fact; and is the leſs ſurpriſing, as the like phenomena have been remarked in regard to other ſnakes, and alſo toads, hawks, and cats; all of which, in certain circumſtances, as appears, have the power of drawing towards them ſmall animals, merely by fixing their eyes ſtedfaſtly on them. In regard to the rattle-ſnake, this effect is produced by the rattle in its tail, the hiſſing noiſe of which makes ſquirrels, &c. whether through curioſity, miſtake, or terror, ſeem to approach the animal as it were ſpontaneouſly. At any rate, I know, from the information of intelligent eye-witneſſes, that it is a common ſtratagem of the young ſavages in America to conceal themſelves in the buſhes, where they imitate the hiſſing noiſe of the rattle-ſnake, and by theſe means attract ſquirrels, which they are then enabled to catch."

To this opinion Dr Barton oppoſes an inſuperable objection. It is, that this faſcinating power is by no means peculiar to the rattle-ſnake. With regard to the ſtratagem of the ſavages, he thinks that Dr Blumenbach has been impoſed upon; as neither he, nor any other perſon of whom he made the inquiry, ever heard of ſuch a ſtratagem. The young Indians, he ſays, place a reed croſs-wiſe in their mouth, and by a tremulous motion of the lips, imitate the cry of young birds; by which means they entice the old ones, ſo that they can eaſily ſhoot them: And this practice may have given riſe to the ſtory of their imitating the hiſſing noiſe of the rattle-ſnake.

Some have ſuppoſed that ſerpents, under certain circumſtances, emit from their bodies a ſtupifying vapour; and that it is this vapour which produces the effect called *faſcination*: But againſt this opinion Dr Barton alleges the following arguments: "I know, indeed (ſays he), that in ſome of the larger ſpecies of ſerpents, inhabiting South America and other countries, there is evolved in the ſtomach, during the long and tedious proceſs of digeſtion in theſe animals, a vapour or a gas, whoſe odour is intenſely fetid. I have not, however, found that this is the caſe with the rattle-ſnake, and other North American ſerpents, that I have examined. But my own obſervations on this head have not been very minute. I have made inquiry of ſome perſons (whoſe prejudices againſt the ſerpent tribe are not ſo powerful as my own), who are not afraid to put the heads and necks of the black ſnake, and other ſerpents that are deſtitute of venemous fangs, into their mouths, and have been informed, that they never perceived any diſagreeable ſmell to proceed from the breath of theſe animals. I have been preſent at the opening of a box which contained a number of living ſerpents; and although the box had been ſo cloſe as to admit but a very ſmall quantity of freſh air, although the obſervation was made in a ſmall warm room, I did not perceive any peculiarly diſagreeable effluvium to ariſe from the bodies of theſe animals. I am, moreover, informed by a member of this ſociety *, who has, for a conſiderable time, had a rattle-ſnake under his immediate care, that he has not obſerved that any diſagreeable vapour proceeds from this reptile. On the other hand, however, it is aſſerted by ſome creditable perſons of my acquaintance, that a moſt offenſive odour, ſimilar to that of fleſh in the laſt ſtage of putrefaction, is continually emanating from every part of the rattle-ſnake, and ſome other ſpecies of ſerpents. This odour extends, under certain circumſtances, to a conſiderable diſtance from the body of the animal. Mr William Bartram aſſures me, that he has obſerved 'horſes to be ſenſible of, and greatly agitated by it, at the diſtance of forty or fifty yards from the ſnake. They ſhewed (he ſays) their abhorrence by ſnorting, winnowing, and ſtarting from the road, endeavouring to throw their riders, in order to make their eſcape." This fact, related by a man of rigid veracity, is extremely curious; and, in an eſpecial manner, deſerves the attention of thoſe writers who imagine that this fetid emanation from ſerpents is capable of affecting birds, at ſmall diſtances, with a kind of aſphyxy. It even gives *ſome* colour of probability to the ſtory related by Metrodorus, and preſerved in the Natural Hiſtory of Pliny *."

Some experiments, however, which were made in Philadelphia a little before the Doctor compoſed his memoir, ſeem to have been deciſive not only as to the fetor, but as to every thing which reſembles faſcination in the rattle-ſnake. Birds which were put into a cage which contained a rattle-ſnake, flew or ran *from* the reptile, as though they were ſenſible of the danger to which they were expoſed. The ſnake made many attempts to catch the birds, but could ſeldom ſucceed. When a dead bird was thrown into the cage, the ſnake devoured it immediately. He ſoon caught and devoured a living mole, an animal much more ſluggiſh than the bird. Dr Barton himſelf ſaw a ſnow-bird (ſee EMBERIZE, *Encycl.*) in a cage with a large rattle-ſnake. The little animal had been thus impriſoned for ſeveral hours when he firſt ſaw it, but it exhibited no ſigns of fear. It hopped about from the floor of the cage to its rooſt, and frequently perched on the ſnake's back. Its chirp was nowiſe tremulous, but perfectly natural. It ate the ſeeds which were put into the cage; and by its whole actions moſt evidently demonſtrated that its ſituation was not uneaſy.

Having thus diſpoſed of the doctrines of ſome of his predeceſſors, Dr Barton proceeds to ſay: "The reſult of not a little attention to the ſubject has taught me, that there is but one wonder in the buſineſs;—the wonder that the ſtory ſhould ever have been believed by a man of underſtanding and of obſervation." Faſcination, we are informed, is almoſt entirely limited to birds that build low, and "in almoſt every inſtance, I found that the ſuppoſed faſcinating faculty of the ſerpent was exerted upon the birds at the particular ſeaſon of their laying their eggs, of their hatching, or of their rearing their young, ſtill tender and defenceleſs. I now began to ſuſpect that the cries and fears of birds ſuppoſed to be faſcinated originated in an endeavour to protect their neſt or young. My inquiries have convinced me that this is the caſe."

The rattle-ſnake, which is the lazieſt of all the ſerpent tribe, never moves in a ſpiral manner or climbs up trees; but the black-ſnake, and ſome other ſpecies of the genus coluber, do. When impelled by hunger, and incapable of ſatiſfying it by the capture of animals on the ground, they begin to glide up trees or buſhes upon which a bird has its neſt. The bird is not ignorant of the ſerpent's object. She leaves her neſt, whether it contains eggs or young ones, and endeavours to oppoſe the reptile's progreſs. In doing this, ſhe is actuated by the ſtrength of her inſtinctive attachment to her eggs, or of affection to her young. Her cry is melancholy,

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American iloſophical iety.

* *Lib.* 28. *Cap.* 14.

her motions are tremulous. She expoſes herſelf to the moſt imminent danger. Sometimes ſhe approaches ſo near the reptile that he ſeizes her as his prey. But this is far from being univerſally the caſe. Often ſhe compels the ſerpent to leave the tree, and then returns to her neſt.

It is a well known fact, that among ſome ſpecies of birds, the female, at a certain period, is accuſtomed to compel the young ones to leave the neſt; that is, when the young have acquired ſo much ſtrength that they are no longer entitled to all her care. But they ſtill claim ſome of her care. Their flights are aukward, and ſoon broken by fatigue. They fall to the ground, where they are frequently expoſed to the attacks of the ſerpent, which attempts to devour them. In this ſituation of affairs, the mother will place herſelf upon a branch of a tree or buſh, in the vicinity of the ſerpent. She will dart upon the ſerpent, in order to prevent the deſtruction of her young: but fear, the inſtinct of ſelf-preſervation, will compel her to retire. She leaves the ſerpent, however, but for a ſhort time, and then returns again. Oftentimes ſhe prevents the deſtruction of her young, attacking the ſnake with her wings, her beak, or her claws. Should the reptile ſucceed in capturing the young, the mother is expoſed to leſs danger; for, whilſt engaged in ſwallowing them, he has neither inclination nor power to ſeize upon the old one. But the appetite of the ſerpent tribe is great: the capacity of their ſtomachs is not leſs ſo. The danger of the mother is at hand when the young are devoured. The ſnake ſeizes upon her: and this is the cataſtrophe, which crowns the tale of faſcination!

FAUSSE BRAYE, in fortification, an elevation of earth, about three feet above the level ground, round the foot of the rampart on the outſide, defended by a parapet about four or five fathoms diſtant from the upper parapet, which parts it from the berme and the edge of the ditch. The fauſſe-braye is the ſame with what is otherwiſe called *Chemin des rondes*, and *Baſſe enceinte;* and its uſe is for the defence of the ditch.

FEATHER-EDGED, is a term uſed by workmen for ſuch boards as are thicker on one edge, or ſide, than on the other.

FELTING, the method of working up wool or hair into a kind of cloth or ſtuff, without either ſpinning or weaving it. In this country felting it little practiſed except in hat-making; and as nine-tenths of thoſe who are employed in the manufacturing of hats know nothing of the principles on which they proceed, the following obſervations on the mechaniſm of felting muſt to them be both agreeable and uſeful. They are by M. Monge, and taken from the *Annales de Chemie.*

If we examine, in a microſcope, human hair, wool, the hair of a rabbit, hare, beaver, &c. however great the magnifying power of the inſtrument may be, the ſurface of each hair appears perfectly ſmooth and even; or at leaſt, if any inequalities are to be perceived, they ſeem rather to ariſe from ſome difference in the colour and tranſparency of particular parts of theſe ſubſtances than from the irregularity of their ſurfaces; for their image, when viewed by a ſolar microſcope, is terminated by even lines, without any roughneſs. The ſurface of theſe objects, however, is by no means ſmooth; on the contrary, it appears to be formed either of *lamellæ* which cover each other from the root to the point, pretty much in the ſame manner as the ſcales of a fiſh cover the animal from the head to the tail; or, more probably, of zones placed one over the other, like what is obſerved in the ſtructure of horns: to this conformation it is that the ſubſtances here treated of owe their diſpoſition to what is called felting.

If, with one hand, we take hold of a hair by the root, and draw it between two fingers of the other, from the root towards the point, we are hardly ſenſible of any friction or reſiſtance, nor can we diſtinguiſh any ſound; but if, on the contrary, we hold the hair at the point, and draw it between the fingers, from the point toward the root, we are ſenſible of a reſiſtance which did not exiſt in the former caſe; a ſort of tremulous motion is likewiſe produced, which is not only perceptible to the touch, but may alſo be diſtinguiſhed by the ear.

It is evident, therefore, that the texture of the ſurface of a hair is not the ſame from the root towards the point as from the point towards the root; and that a hair, when graſped, muſt offer more reſiſtance in ſliding or moving progreſſively towards the point than towards the root; *i. e.* in moving with its point foremoſt.

If a hair, after being taken hold of by the fore-finger and thumb, be rubbed by them, in the longitudinal direction of the hair, a progreſſive motion takes place, and this motion is always towards the root. This effect does not at all depend on the nature of the ſkin of the fingers or its texture; for if the hair be turned, ſo that the point is placed where the root was, the movement then becomes contrary to what it was before; that is to ſay, it is always directed towards the root.

What is obſerved, in the above inſtance, is entirely analogous to what happens when country children, by way of ſport, introduce an ear of rye or barley between the wriſt and the ſhirt, the points of the beards of which are directed outwards. By the various motions of the arm, this ear, ſometimes catching againſt the ſhirt, ſometimes againſt the ſkin, takes a progreſſive motion backwards, and ſoon gets up to the arm-pit. It is very clear that this effect is produced by the beards of the ear, and indeed chiefly by the aſperities upon thoſe beards; which, being all directed towards the point, do not permit the ear to move in any other direction than towards that part to which it was united to the ſtalk. There is no doubt that it is the ſame with reſpect to hair; and that its ſurface is beſet with aſperities, which, being laid one upon the other, and turned towards the points, permit no motion but towards the root.

A tight knot, made in the middle of a hair, is very difficult to untie by the uſual means, on account of the extreme thinneſs of the hair; but if we place the hair in the bend of the hand, ſo that the knot is in a line with the little finger, and, after graſping the hair by cloſing the hand, we ſtrike the fiſt ſeveral times againſt the knee, the aſperities of one end of the hair being now in a contrary direction to thoſe of the other, each of the ends recedes a little, one of them one way, the other the contrary way; the knot is thereby opened, and, by introducing a pin into the eye which is formed, it is very eaſy to finiſh untying it.

Theſe obſervations, which it would be uſeleſs to multiply, relate to long hair, that having been taken as an example; but they apply with equal propriety to wool, furs, and in general to every kind of animal hair. The ſurface of all theſe is therefore to be conſidered as compoſed of hard *lamellæ* placed one upon another, like tiles, from the root to the point; which *lamellæ* allow the progreſſive motion of the hair towards the root, but prevent a ſimilar motion towards the point.

From what has been ſaid, it is eaſy to explain why the contact of woollen ſtuffs is rough to the ſkin, while that of linen or cotton cloths is ſmooth; the reaſon is, the aſperities upon the ſurface of the fibres of the wool (notwithſtanding the flexibility of each particular fibre), by fixing themſelves in the ſkin, produce a diſagreeable ſenſation, at leaſt till we are accuſtomed to it; whereas the ſurface of the fibres of hemp or flax, of which linen is made, being perfectly ſmooth, do not cauſe any ſuch ſenſation. It is alſo evident, that the injury ariſing to wounds or ſores, from the application of wool, does not proceed from any chemical property, but is occaſioned ſolely by the conformation of the ſurface of the fibres: the aſperities of which attach themſelves to the raw and expoſed fleſh, which they ſtimulate and irritate to ſuch a degree as to produce inflammation.

This conformation is the principal cauſe of that diſpoſition to what is called felting, which the hair of all animals in general poſſeſſes.

The hatter, by ſtriking the wool with the ſtring of his bow (ſee Hat, *Encycl.*), ſeparates the hairs from each other, and cauſes them to ſpring up in the air; the hairs fall again on the table, in all poſſible directions, ſo as to form a layer of a certain thickneſs, and the workman covers them with a cloth, which he preſſes with his hands, moving them backwards and forwards in various directions. This preſſure brings the hairs againſt each other, and multiplies their points of contact; the agitation of them gives to each hair a progreſſive motion toward the root; by means of this motion the hairs are twiſted together, and the *lamellæ* of each hair, by fixing themſelves to thoſe of other hairs which happen to be directed the contrary way, keep the whole in that compact ſtate which the preſſure makes it acquire. In proportion as the maſs becomes compact, the preſſure of the hands ſhould be increaſed; not only to make it more cloſe, but alſo to keep up the progreſſive motion and twiſting of the hairs, which then takes place with greater difficulty: but throughout the whole of this operation, the hairs fix themſelves only to each other, and not to the cloth with which they are covered, the fibres of which, as we have already ſaid, are ſmooth, and have not that diſpoſition to felting which we have deſcribed above.

It may not be amiſs here to explain why that hair which is intended for making hats is always cut off with a ſharp inſtrument (although that cannot be done without loſing a part of its length), and not plucked out by the roots, as might be done after ſoftening the ſkin: the reaſon is, the bulb of the hair, which in the latter caſe would come out with it, would render that end which was fixed in the ſkin thick and obtuſe; and it would conſequently be leſs diſpoſed to introduce itſelf among the contiguous hairs, and to contribute by its progreſs motion to the contexture of the maſs.

The above deſcribed conformation of the ſurface of hairs and wool is not the only cauſe which produces their diſpoſition to felting. It is not ſufficient that every hair poſſeſſes the forementioned tendency to move progreſſively towards the root, and that the inclined *lamellæ*, by hooking themſelves to each other, preſerve the maſs in that ſtate to which compreſſion has brought it; but it is alſo neceſſary that the hairs ſhould not be ſtraight, like needles; if they were ſo, preſſing and rubbing them together would merely cauſe them to continue their progreſſive motion, without changing their direction; and the effect of thoſe operations would only be to make them move from the centre of the maſs, without producing any compactneſs in it. Every hair muſt therefore be twiſted or curled in ſuch a manner that the extremity which is towards the root may be diſpoſed to change its direction perpetually, to twiſt itſelf about other hairs, and to incline towards itſelf again, in caſe it ſhould be determined thereto by any change in the poſition of the reſt of its length. It is becauſe wool has naturally this crooked form that it is ſo proper for felting, and that it may be made uſe of for that purpoſe without undergoing any previous preparation.

But the hairs of the beaver, the rabbit, the hare, &c. being naturally ſtraight, cannot be employed alone in felting till they have undergone a preliminary operation; which conſiſts in rubbing or combing them, before they are taken off the ſkin, with a bruſh dipped in a ſolution of mercury in aquafortis (nitric acid). This liquor, acting only on one ſide of the ſubſtance of the hairs, changes their direction from a right line, and gives them that diſpoſition to felting which wool naturally poſſeſſes.

When the hairs are not intended to enter into the body of the maſs, but are only to be employed in making a ſort of external coating, ſuch as is ſometimes given to the outer ſurface of hats, the operation juſt mentioned need not be performed; but the felt on which they are to be fixed being finiſhed; the hair is uniformly ſpread upon the ſurface to which the coating is to be applied; and, being covered with a cloth, it is preſſed with the hands, and agitated for a certain time. By theſe means, the hairs introduce themſelves, by the root, a certain depth into the felt, and are there fixed by their *lamellæ* in ſuch a manner as not to be eaſily extracted. A particular direction is afterwards given to them by means of a bruſh, and they are made to keep this direction by having a hot iron paſſed over them. If the agitation were continued for a longer time, theſe hairs, not having their ſtraightneſs deſtroyed by the operation before deſcribed, would paſs entirely through the felt, going out at the oppoſite ſurface, as each hair follows exactly the direction it acquired at the beginning.

It is owing to the very ſame circumſtances which make wool and hair capable of felting, that woollen cloth is thickened by fulling. See Fulling in this Supplement.

FERGUSSON (Robert), who at an early period of life obtained a conſiderable degree of celebrity as a Scottiſh poet, was born at Edinburgh on the 5th of September 1750, according to a manuſcript account of him with which we have been favoured by a relation. In the biographical ſketch prefixed to the Perth edition of his poems he is ſaid to have been born in 1751.

His father William Ferguſſon poſſeſſed, as well as himſelf, ſome talents for poetry; but, marrying early, and being wiſer than his ſon, he abandoned the muſes for trade, and was employed in different mercantile houſes, firſt in Aberdeen and afterwards in Edinburgh. At the time of his death he was an accountant in the Britiſh Linen Hall; but never acquired any thing like opulence.

During the years of infancy and childhood, the conſtitution of our poet was ſo weak, that little hopes were entertained of his arriving at manhood. By the care, however, and attention of his parents, he gradually acquired ſtrength, and at the age of ſix was put to an Engliſh ſchool, where his proficiency in reading and reciting was uncommonly great. At the age of ſeven he was ſent to the high ſchool of Edinburgh, where he continued four years, and with very little labour made a rapid progreſs in the knowledge of the Latin tongue; but for ſome reaſon or other he was removed from the high ſchool to the grammar ſchool of Dundee, whence, after two years, he was ſent to the univerſity of St Andrew's. A gentleman of the name of Ferguſſon had left burſaries in that univerſity for the education of two boys of the ſame name; and Mr William Ferguſſon having with difficulty obtained one of them for his ſon, was induced to educate him at St Andrew's in preference to Edinburgh.

Though at no period of his life a ſevere ſtudent, our poet's attainments in ſcience were ſuch as to keep alive in the univerſity the hopes which had been formed of him at ſchool; and he was confeſſedly the firſt mathematician of his ſtanding. On this account we are told that he became the favourite of Dr Wilkie, who was then profeſſor of natural philoſophy in the univerſity of St Andrew's; but it is not improbable that the Doctor valued him as much for his poetical genius as for his ſkill in geometry; for Wilkie was a poet himſelf, and Mr Ferguſſon had already written ſeveral ſmall poems which attracted conſiderable notice, as well from the profeſſors as from his fellow-ſtudents. But whatever was the bond of union, Dr Wilkie patroniſed the youthful poet; and the poet ſhewed afterwards that he was not ungrateful. Upon the Doctor's death, he publiſhed, in the Scottiſh dialect, a beautiful eclogue to his memory, in which the peculiar merits of that eccentric genius are appreciated with great judgment. See WILKIE, in this Supplement.

During the laſt winter that he reſided in St Andrew's, our poet had collected materials for a tragedy on the death of Sir William Wallace, and had even completed two acts of the play; but having ſeen a ſimilar work on the ſame ſubject, he abandoned his deſign; "becauſe (ſaid he to a friend) whatever I publiſh ſhall be original, and this tragedy might be conſidered as a copy."

Having finiſhed his ſtudies at the univerſity, he returned to Edinburgh without reſolving on any permanent employment. His father had deſigned him for the church; but he was now dead, and our author turned a deaf ear to the intreaties of his mother, and of every other friend who endeavoured to perſuade him to fulfil his father's intention. He was then adviſed to ſtudy phyſic; but he declined it, becauſe, he ſaid, that, when reading the deſcription of diſeaſes, he fancied that he felt the ſymptoms of them all in himſelf. To the law, however, he could not ſtart the ſame objection; and he began to ſtudy it, but made no progreſs. At this his relation and the editor of his poems expreſs no ſurpriſe; for, according to them, it was a ſtudy the moſt improper for him, as it could not be expected that a genius ſo lively would ſubmit to the drudgery of that dry and ſedentary profeſſion.

That the law was a very improper profeſſion for a man of his narrow fortune is indeed true; but we truſt that his two biographers will not conſider us as intending any offence to them, if we embrace the preſent opportunity of expoſing the folly of a very common remark, that a lively genius cannot ſubmit to what is abſurdly called a dry ſtudy. We might inſtance different lawyers at our own bar, who, with great poetical talents in their youth, have riſen to the ſummit of their profeſſion; but to avoid perſonal diſtinctions at home, we ſhall take our examples from England. The genius of the late Earl of Mansfield was at leaſt as lively as that of Mr Ferguſſon, and if he had pleaſed he could have been equally a poet; yet he ſubmitted to the drudgery of ſtudying a law ſtill drier than that of Scotland. To the fine taſte of Atterbury biſhop of Rocheſter, and to his claſſical compoſitions both in proſe and verſe, no man is a ſtranger who is at all converſant in Engliſh literature: yet that elegant ſcholar and poet, after he had riſen to the dignity of Dean of Carliſle, ſubmitted to the drudgery of ſtudying, through the medium of barbarous Latin, the eccleſiaſtical law of England from the earlieſt ages; and declared, that by dint of perſeverance he came in time to reliſh it as much as the ſtudy of Homer and Virgil Whatever be thought of Milton's political principles, no man can read his controverſial writings, and entertain a doubt but that he could have ſubmitted to the drudgery of ſtudying the law.

The truth is, and it is a truth of great importance, that a man of real vigour of mind may bring himſelf to delight in any kind of ſtudy which is uſeful and honourable. Such men were Lord Mansfield, the Biſhop of Rocheſter, and Milton; but, whether through ſome radical defect in his nervous ſyſtem, or in conſequence of early diſſipation, Mr Ferguſſon, with many eſtimable qualities, was ſo utterly deſtitute of this mental vigour, that rather than ſubmit to what his friends call drudgery, he ſeems to have looked with a wiſhful eye to ſome ſinecure place.

With this view he paid a viſit to an uncle who lived near Aberdeen, a man of great learning and in opulent circumſtances, in hopes that, by his intereſt, he might be ſettled in a poſt ſuitable to his merit: But how deluſive were his hopes! His uncle indeed received him with every mark of affection; but his fondneſs gradually cooled, and at the end of ſix months he ordered him abruptly to leave his houſe, without having endeavoured to procure for him any ſettlement.

To a mind like Ferguſſon's, feelingly alive, ſuch treatment from ſo near a relation, to whom he had always behaved with becoming reſpect, muſt have been dreadfully galling. Stung with indignation, he returned to his mother's at Edinburgh; and as ſoon as he recovered from a ſevere illneſs, brought upon him by diſappointment and the fatigue of his journey, he compoſed two elegies; one on "The Decay of Friendſhip," and the other "Againſt Repining at Fortune," both occaſioned by his adventure in the North. How much he felt the daſhing of his hopes, is apparent from the following pathetic lines in the Decay of Friendſhip:

But,

But, ah! theſe youthful ſportive hours are fled,
  Theſe ſcenes of jocund mirth are now no more;
No healing ſlumbers 'tend my humble bed,
  No friends condole the ſorrows of the poor.

And what avail the thoughts of former joy?
  What comfort bring they in the adverſe hour?
Can they the canker-worm of Care deſtroy,
  Or brighten Fortune's diſcontented lour?

So deſtitute was he at this period, that he ſubmitted to copy papers in the commiſſary clerk's office, we believe at ſo much the ſheet; but not liking the employment, and quarrelling with the commiſſary clerk-depute, he ſoon left the office in diſguſt.

Hitherto he had lived rather in obſcurity; and happy had it been for him if in that obſcurity he had been ſuffered to remain; happy had it been for him, had his converſation been leſs faſcinating, and his company leſs courted by the frolic and the gay. Poſſeſſing an inexhauſtible fund of wit, the beſt good nature, much modeſty, and great goodneſs of heart, he was viewed with affection by all to whom he was known; but his powers of ſong, and almoſt unrivalled talents for mimickry, led him oftener into the company of thoſe who wiſhed for him merely to enliven a ſocial hour, than of ſuch as by their virtue were inclined, and by their influence were able, to procure him a competent ſettlement for life. The conſequence of this was great laxity of manners. His moral principles indeed were never corrupted, nor, as we have reaſon to believe, his faith in revelation ſhaken; but there is no doubt but that, courted as he was by the ſyren voice of pleaſure, he yielded to many temptations, and in the hours of ebriety committed actions which, in his cooler moments, he reflected on with abhorrence.

His conſcience was indeed frequently rouſed. Being on a viſit to a friend at Haddington, and ſauntering one day near the churchyard, he was accoſted by a clergyman, who ſeemed to be no ſtranger to the kind of life which he led. This judicious divine contrived to draw his attention to the ſhortneſs of time, the length of eternity, death and judgment, and the awful ſtate that awaits the wicked in an unſeen world; and the converſation made a deep impreſſion on his mind. It ſeemed, however, to be effaced from his memory by the diſſipation of Edinburgh, till it was recalled with double effect by the following accident:

In the room adjoining to that in which he ſlept was a ſtarling, which being ſeized one night by a cat that had found its way down the chimney, awaked Mr Ferguſſon by the moſt alarming ſcreams. Having learned the cauſe of the alarm, he began ſeriouſly to reflect how often he, an immortal and accountable being, had in the hour of intemperance ſet death at defiance, though it was thus terrible in reality even to an unaccountable and ſinleſs creature. This brought to his recollection the converſation of the clergyman, which, aided by the ſolemnity of midnight, wrought his mind up to a pitch of remorſe that almoſt bordered on frantic deſpair. Sleep now forſook his eyelids; and he roſe in the morning, not as he had formerly done, to mix again with the ſocial and the gay, but to be a recluſe from ſociety, and to allow the remembrance of his paſt follies to prey upon his vitals. All his vivacity now forſook him; thoſe lips which were formed to give delight, were cloſed as by the hand of death; and "on his countenance ſat horror plum'd."

From this ſtate of gloomy deſpondency, however, he began gradually to recover; and, except that a ſettled melancholy was viſible in his countenance, his health was completely reſtored, when one evening he fell and cut his head ſo dreadfully, that from the loſs of blood he became delirious. In this deplorable ſtate he continued for ſeveral months, till, being quite exhauſted by want of ſleep and conſtant ſpeaking, he expired on the 16th of October 1774. He was interred in the Canongate churchyard, where his friends erected a monument to his memory, which has been ſince removed to make way for a larger and more elegant monument by his enthuſiaſtic admirer the late poet Burns.

Thus died Robert Ferguſſon, a young man of the brighteſt genius and of the beſt heart, who, had he joined prudence to his uncommon talents, muſt have riſen to great eminence in the republic of letters; but, as a late juvenile poet has obſerved of him——

Complete alike in head and heart,
But wanting in the prudent part,
He prov'd a poet's lot.

Of his poems no general character can be given. The ſubjects of them are ſometimes uncommon and generally local or temporary. They are of courſe very unequal. But ſuch of them as are in the Scottiſh dialect have been univerſally admired by his countrymen; and when it is conſidered that they were compoſed amidſt a round of diſſipation, they will be allowed to furniſh complete evidence of his genius and his taſte.

FERMAT (Peter), who was counſellor of the parliament of Toulouſe in France, flouriſhed in the 17th century, and died in 1663. He was a man of great talents, and a very general ſcholar; but being contemporary and intimately connected with Des Cartes, Merſenne, Torricelli, and Huygens, he was naturally led to devote much of his time to the mathematical ſciences. He was (ſays Dr Hutton) a firſt rate mathematician, and poſſeſſed the fineſt taſte for pure and genuine geometry, which he contributed greatly to improve, as well as algebra.

Fermat was author of, 1. A Method for the Quadrature of all ſorts of Parabolas.—2. Another on Maximums and Minimums: which ſerves not only for the determination of plane and ſolid problems, but alſo for drawing tangents to curve lines, finding the centres of gravity in ſolids, and the reſolution of queſtions concerning numbers: in ſhort, a method very ſimilar to the fluxions of Newton.—3. An Introduction to Geometric Loci, plane and ſolid.—4. A Treatiſe on Spherical Tangencies: where he demonſtrates in the ſolids the ſame things as Vieta demonſtrated in planes.—5. A Reſtoration of Apollonius's two Books on Plane Loci.—6. A General Method for the dimenſion of Curve Lines. Beſides a number of other ſmaller pieces, and many letters to learned men; ſeveral of which are to be found in his *Opera Varia Mathematica*, printed at Toulouſe, in folio, 1679.

FERMENTATION is a chemical proceſs which has been already conſidered in the *Encyclopædia*, and will be again reſumed in this *Supplement* under the title *Animal and Vegetable Substances*. In this place we mean nothing more than to give ſuch directions, principally

cipally from Mr Richardſon of Hull, for the proper fermentation of malt liquors as have not been fully detailed in the article BREWING (*Encycl.*).

This author controverts, we do not think very ſucceſsfully, the concluſions drawn by Mr Henry from the experiments, of which the reader will find an account in the article FERMENTATION (*Encycl*); but it is not his theory with which we are at preſent concerned, but his practice as that of an experienced and enlightened brewer. Having treated of *Worts*, and the proper method of boiling them, for which ſee WORT in this *Supplement*, and having given an hiſtorical view of the proceſs of fermentation, of which a pretty accurate abridgement is inſerted in the articles BREWING and FERMENTATION (*Encycl.*), he proceeds thus:

" The agency of air, in the buſineſs of fermentation, is very powerful; but as all fermentable ſubjects have an abundant ſupply, we are rather to provide for the egreſs of their own, than to ſuffer the admiſſion of the external air, by which a great number of the fine, volatile, oleaginous parts of the ſubject would be carried off, and a proportionate injury in flavour and ſpirituoſity ſuſtained. Hence ſuch a covering ſhould be provided for the gyle-tun as would barely allow the eſcape of the common air produced by the operation; whilſt the *gas*, or fixed air, from its greater denſity, reſting upon the ſurface of the beer the whole depth of the curb, prevents the action of the external air, and conſequently the eſcape of thoſe fine and valuable parts juſt mentioned.

" But towards the conluſion of vinous fermentation, this aerial covering begins to loſe its efficacy; which points out the neceſſity of then getting the beer into caſks as ſoon as poſſible, that the conſequences may be prevented, of expoſing ſo large a ſurface, liable to ſo copious an evaporation. Amongſt theſe, a loſs of ſpirituoſity is not the leaſt; for this evaporation is more and more ſpirituous, as the action approaches the completion of vinous fermentation; and that once obtained, the loſs becomes ſtill more conſiderable, if ſtill expoſed to the air; whence it might be termed the diſtillation of Nature, in which ſhe is ſo much ſuperior to art, that the ethereal ſpirit riſes pure and unmixed, whilſt the higheſt rectification of the ſtill produces at beſt but a compound of aqueous and ſpirituous parts.

" Nor is this entirely conjecture. Experience teaches us, that we cannot produce ſo ſtrong a beer in ſummer, *ceteris paribus*, as in winter; the reaſon is, not becauſe the action of fermentation does not realize ſo much ſpirit in warm weather, but becauſe the fermenting liquor, after the perfection of vinoſity, continues ſo long in a ſtate of rarefaction, that the ſpirituous parts are diſſipated in a much greater degree at that time than at any other, in a ſimilar ſtate of progreſſion. And this doctrine of natural diſtillation ſeems to account for that increaſe of ſtrength obtainable from long preſervation, in well cloſed caſks, and, more particularly ſo, in glaſs bottles; for Nature, in her efforts to bring about her grand purpoſe of reſolving every compound into its firſt principles, keeps up a perpetual internal ſtruggle, as well as an external evaporation; and if the latter be effectually prevented, the former muſt be productive of additional ſpirituoſity, ſo long as the action keeps within the pale of vinous fermentation.

" In order to maintain a due regulation of the fermenting power, and to anſwer the ſeveral purpoſes of the operation, a ſcrupulous attention to the degree of heat at which the action commences, and a particular regard to the quality and quantity of the ferment employed, are indiſpenſably neceſſary." The degree of heat muſt be aſcertained by the thermometer, and regulated by experience: the quantity of yeaſt can be aſcertained only by the intention of the artiſt.

FEZZAN is a kingdom in the anterior of Africa, placed in the vaſt wilderneſs as an iſland in the ocean. The following account of it was given to Mr Lucas the African traveller by an old ſhereef, a native of Fezzan; and that account was confirmed by the governor of Meſurata, who had himſelf viſited Fezzan, and who, having treated the traveller with great kindneſs, ought not to be ſuſpected of having wantonly deceived him.

According to this account, Fezzan is ſituated to the ſouth of Meſurata (ſee MESURATA in this *Suppl.*), and the traveller from the latter place to the former arrives in eight days at Wadan, where refreſhments are procured for the caravan. From thence in five hours they reach the deſart of Soudah, where no vegetable is ſeen to grow but the talk, a tree from which the lemon-coloured wood is taken which forms handles for tools. The paſſage of the deſart takes up ſome days, when the traveller finds a miſerable village, producing nothing but dates, brackiſh water, and Indian corn; from this village a day's journey conducts to the town of Sebbah, where are the remains of an ancient caſtle, and other venerable ruins, and in four days more he reaches Mourzouk, the capital of Fezzan.

This city is ſituated on the banks of a ſmall river, ſurrounded by a high wall for defence, and is diſtant from Meſurata 390 computed miles. Eaſtward of Mourzook is the town of Queela, in which are the remains of ancient buildings; the ſize of the ciſterns, and the conſtruction of the vaulted caves, exhibit inſtances of ancient ſplendour. South of which place is Jermah, diſtinguiſhed by numerous and majeſtic ruins, on which are many inſcriptions. Teſſouwa lies eaſtward, near which was a river which the ſhereef remembers, but is now overwhelmed in the moving ſands. N. E. from Mourzouk, diſtant about 120 miles, is the large town of Temmiſwa, where the caravans of pilgrims from Bornou and Nigritia, by way of Cairo to Mecca, provide their ſtores for the deſart.

In the town or province of Mendrah is a large quantity of *trona*, a ſpecies of foſſil alkali, that floats on the ſurface or ſettles on the banks of its ſpreading lakes, great quantity of which is ſent to Tripoli, and ſhipped for Turkey, Tunis, and Morocco; at the latter place it is uſed as an ingredient in the red dye of the leather. Mendrah is about 60 miles ſouth of Fezzan. The territory of Fezzan extends but little weſtward, being confined by barren mountains. The ſmaller towns of this kingdom are ſaid to be about one hundred; theſe towns are chiefly inhabited by huſbandmen and ſhepherds; in every town a market is regularly held; mutton and goat's fleſh are ſold by the quarter, uſually from thirty-two to forty grains of gold, or from four to five ſhillings Engliſh. The fleſh of camels is dearer, and divided into ſmaller parts.

The houſes are of clay, with flat roofs compoſed of branches of trees, on which earth is laid; this is ſufficient in a climate where it never rains. The heats in ſummer, from April to November, are intenſe, and the hot winds blow from the ſouth-eaſt, ſouth, and ſouth-weſt, with ſuch violence as to threaten ſuffocation; when it changes to the weſt or north-weſt a reviving freſhneſs enſues.

The dreſs of the inhabitants is like that of the Moors of Barbary, conſiſting of a large pair of trowſers, a ſhirt which hangs over the trowſers, a kind of waiſtcoat without ſleeves, and a jacket with tight ſleeves: over the jacket is a looſe robe which reaches below the knee, a girdle of crimſon, and a long cloth called a *barrakan* or *alhaicque*, like a highland plaid, is worn; ſtockings of leather, laced like half-boots, and ſlippers; on the head a red cap and turban; ſometimes over the whole they throw a long cloak with a hood, called a *burnooſe*. In ſummer they throw off all but the ſhirt and the cap.

The people bear very high degrees of heat, but any cold affects them ſenſibly. Their diſeaſes are chiefly of the inflammatory and putrid kind; the ſmall pox is common. Their old women are their principal phyſicians. For pains in the head they cup and bleed; for thoſe in the limbs, they bathe in the hot lakes. They have a multitude of noxious and loathſome animals; the air is crowded with moſquitos, and their perſons are over-run with the vermin which affect the beggars of Europe.

In their perſons they incline to the negro, of a deep ſwarthy complexion, with curly black hair; they are tall, but indolent, inactive, and weak. In their common intercourſe, diſtinction of rank ſeems to be forgotten; rich and poor, maſter and man, converſe, eat, and drink together; they are, however, generous and hoſpitable.

An extenſive plain compoſes the kingdom of Fezzan: the ſoil is generally a light ſand, the ſprings are abundant, and few regions in Africa exhibit a richer vegetation. The land produces the talk, the white thorn, date trees, the olive and lime, apricot, pomegranate, and fig: Indian corn and barley are the favourite objects of cultivation; of wheat there is little raiſed. The tame animals are, the ſheep, cow, goat, and camel; and the wild are, the oſtrich, antelopes of various kinds, one of which is called the huadee, which when chaſed plunges with addreſs from a precipice, and lights on its hams.

The food of the lower claſs conſiſts of flour of Indian corn, ſeaſoned with oil and fruit; thoſe of ſuperior rank eat wheat bread and fleſh. Fezzan produces much ſalt; the water has in general a mineral taſte, but the favourite beverage is a liquor from the date tree, which acquires, when fermented, an intoxicating ſtrength. In religion they are rigid Mahomedans, but tolerant. Their government monarchical; their preſent king is deſcended from one of the ſhereefs of Taffilet, who about 400 years ſince obtained the crown. Till the preſent century the kingdom was independent, when the Baſhaw of Tripoli conquered and made it tributary; the reigning ſovereign has nearly thrown off this yoke. In Fezzan, the deſcendants of the prophet are highly privileged, their property and perſons are inviolable; they are exempt from certain puniſhments. This claſs are in general either princes or merchants.

The revenue is compoſed of a tax on towns and villages, a tax on every camel load of goods (except proviſions) which enters the capital, fines for offences, lands of perſons dying without heirs, and a tax on gardens and date trees. Gold duſt by weight is the chief medium of payment; but for convenience they are furniſhed with ſmall papers of gold duſt of different values, from two *xarbes* or one and a half upwards; for ſmaller articles corn or flour are uſed as a medium. One grain of gold is equal to 1$\frac{1}{5}$d. ſterling. The Fezzan grain is the ſame as in England.

The juſtice of the ſovereign is highly extolled; ſmall offences are puniſhed by the baſtinado, and the puniſhments increaſe to fine, impriſonment, and death. Truſting to their natural defence, their towns are without guard, and they have no ſtanding forces. The only war the ſhereef remembered was undertaken againſt a people inhabiting the mountains of Tibeſti, which is ſeparated from the people of Fezzan by a wide and ſandy deſart. Theſe people are wild and ſavage, and had plundered a caravan belonging to the king, who ſent an army of between 3 and 4000 men againſt and ſubdued them. The country of theſe people produces much ſenna. The vales of Tibeſti are ſaid to be fertile in corn and paſture for cattle, particularly camels. The people live in huts, and profeſs various religions, ſome the Mahomedan, others are attached to their ancient idolatry.

The people of Fezzan carry on a conſiderable trade with Tripoli, Bornou, Nigritia, &c. At the end of October, when the heats are abated, the caravans depart from Mourzouk in ſmall parties of ten or twelve, unleſs in time of war. They lay in proviſions of dates, meal, and mutton ſalted, dried in the ſun, and boiled in oil or fat. The merchants have agents in the chief towns, to whom they ſend the ſlaves they purchaſe.

The caravans to Tripoli carry the *trona*, ſenna, gold and ſlaves brought from the ſouthern countries; and in return bring back cutlery, woollen, ſilks, dollars, copper, and braſs.

That to Bornou carries braſs and copper, for the currency of the country, imperial dollars, and various manufactures; but of their own produce only a preparation of dates, and meal of Indian corn; and they take in return ſlaves, gold duſt, and civet.

To Caſhna, an empire in Nigritia, they carry cowries, braſs to make rings and bracelets, horſes, ſeveral kinds of manufactures, and the Gooroo nuts; and in return take gold duſt, ſlaves, cotton cloth, dyed goats ſkins, hides, ſenna, and civet, for the countries ſouth of the Niger, where alſo they convey ſabre blades and Dutch knives, coral, braſs beads, looking glaſſes, dollars, &c. and receive back gold duſt, ſlaves, cotton cloths, goat ſkins, Gooroo nuts, cowries, and ivory.

A caravan of pilgrims ſets out likewiſe in the autumn of every ſecond or third year from Mourzouk, the capital of Fezzan, to Mecca. They proceed to Temeſſa, over the mountain of Ziltan, and thence to Sibhul, a place ſubject to Tripoli; and thence nearly in a line with the Mediterranean ſea to Cairo, and thence to Mecca by the cuſtomary route.

As not one celeſtial obſervation has been taken to determine any latitude between Benin and Tripoli, all the poſitions are fixed by eſtimation, reckoning fifteen or ſixteen miles for a day's journey. Mr Rennell places

Mourzouk, the capital of Fezzan, in lat. 27°. 20′, or 260 miles from Maſurata.

FIGURATE NUMBERS are ſuch as do or may repreſent ſome geometrical figure, ſuch as a triangle, pentagon, or pyramid, &c. Theſe numbers are treated of at great length by Maclaurin in his Fluxions; Simſon in his Algebra; and Malcolm in his Arithmetic; but the following account of them by Dr Hutton is as perſpicuous as any that we have ſeen:

Figurate numbers are diſtinguiſhed into orders, according to their place in the ſcale of their generation, being all produced one from another, viz. by adding continually the terms of any one, the ſucceſſive ſums are the terms of the next order, beginning from the firſt order, which is that of equal units 1, 1, 1, 1, &c.; then the ſecond order conſiſts of the ſucceſſive ſums of thoſe of the firſt order, forming the arithmetical progreſſion 1, 2, 3, 4, &c.: thoſe of the third order are the ſucceſſive ſums of thoſe of the ſecond, and are the triangular numbers 1, 3, 6, 10, 15, &c; thoſe of the fourth order are the ſucceſſive ſums of thoſe of the third, and are the pyramidal numbers 1, 4, 10, 20, 35, &c.; and ſo on, as below:

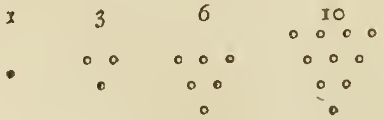
Order.	*Name.*	*Numbers,*				
1.	Equals,	1,	1,	1,	1,	1, &c.
2.	Arithmeticals,	1,	2,	3,	4,	5, &c.
3.	Triangulars,	1,	3,	6,	10,	15, &c.
4.	Pyramidals,	1,	4,	10,	20,	35, &c.
5.	2d Pyramidals,	1,	5,	15,	35,	70, &c.
6.	3d Pyramidals,	1,	6,	21,	56,	126, &c.
7.	4th Pyramidals,	1,	7,	28,	84,	210, &c.

The above are all conſidered as different ſorts of triangular numbers, being formed from an arithmetical progreſſion whoſe common difference is 1. But if that common difference be 2, the ſucceſſive ſums will be the ſeries of ſquare numbers: if it be 3, the ſeries will be pentagonal numbers, or pentagons; if it be 4, the ſeries will be hexagonal numbers, or hexagons; and ſo on. Thus:

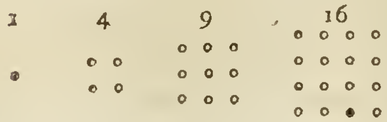
Arithmeticals.	*1ſt Sums,* or *Polygons.*	2d *Sums,* or 2d *Polygons.*
1, 2, 3, 4	Tri. 1, 3, 6, 10	1, 4, 10, 20
1, 3, 5, 7	Sqrs. 1, 4, 9, 16	1, 5, 14, 30
1, 4, 7, 10	Pent. 1, 5, 12, 22	1, 6, 18, 40
1, 5, 9, 13	Hex. 1, 6, 15, 28	1, 7, 22, 50
&c.		

And the reaſon of the names triangles, ſquares, pentagons, hexagons, &c. is, that thoſe numbers may be placed in the form of theſe regular figures or polygons, as here below:

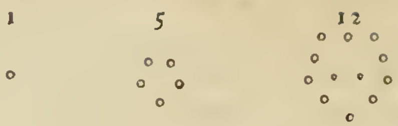
Triangles.



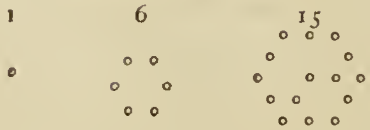
Squares.



Pentagons.



Hexagons.



But the figurate numbers of any order may alſo be found without computing thoſe of the preceding orders; which is done by taking the ſucceſſive products of as many of the terms of the arithmeticals 1, 2, 3, 4, 5, &c. in their natural order, as there are units in the number which denominates the order of figurates required, and dividing thoſe products always by the firſt product. Thus the triangular numbers are found by dividing the products 1×2, 2×3, 3×4, 4×5, &c. each by the firſt product 1×2; the firſt pyramids by dividing the products $1 \times 2 \times 3$, $2 \times 3 \times 4$, $3 \times 4 \times 5$, &c. by the firſt $1 \times 2 \times 3$. And, in general, the figurate numbers of any order n, are found by ſubſtituting ſucceſſively 1, 2, 3, 4, 5, &c. inſtead of x in this general expreſſion $\frac{x \,.\, x+1 \,.\, x+2 \,.\, x+3 \,.\, \&c.}{1 \,.\, 2 \,.\, 3 \,.\, 4 \,.\, \&c.}$; where the factors in the numerator and denominator are ſuppoſed to be multiplied together, and to be continued till the number in each be leſs by 1 than that which expreſſes the order of the figurates required.

FILTER (See *Encycl.*) It is well known that veſſels made of a particular kind of porous ſtone are employed as filtering baſins for freeing water, intended to be drunk, from various kinds of impurity. In ſea voyages ſuch filtering baſins muſt be highly uſeful; and they are frequently found uſeful at land where no water can be had but from ſtagnant pools, or ſprings flowing through clay. The ſtone, however, of which they are made is not every where to be found; and therefore different perſons have endeavoured to employ the art of the potter to ſupply their place.

In the year 1790 a patent was granted to a female potter, for her invention of the following compoſition for this purpoſe; viz. four equal parts, out of nine equal parts, of tobacco-pipe clay; and five equal parts, out of nine equal parts, of coarſe ſea, river, drift, or pit ſand; theſe two materials, in the above proportions, are ſufficient for the purpoſe of making ſmall baſins, and other veſſels, to contain a quantity not exceeding one gallon of water, or other liquid. But the compoſition, when confined to theſe two materials, and in theſe proportions, often flies or cracks in the fire, if larger baſins, or other veſſels, are attempted to be made with it. She, therefore, in the ſecond inſtance, compoſes her filtering baſins of equal parts of tobacco-pipe clay and coarſe ſea, river, drift, or pit ſand; in the third inſtance, of three equal parts, out of nine equal parts, of tobacco-pipe clay; one equal part, out of nine equal parts, of Stourbridge clay, or clay from the ſurface of coal mines, or any other clay of the ſame quality; one equal part, out of nine equal parts, of Windſor, or other loam, of the ſame quality with Windſor loam ; and four equal parts, out of nine equal parts, of coarſe river, ſea, drift, or pit ſand. Or, in the fourth inſtance, of four equal parts, out of eight equal parts, of tobacco-pipe clay ; three equal parts, out of eight equal parts, of coarſe ſea, river, drift, or pit ſand ; and one equal part, out of eight equal parts, of that burnt ground clay of which crucibles are made.

If the lady who invented, or pretends to have invented, theſe baſins, have a right to her patent, far be it from us to wiſh our readers of any deſcription to incroach upon it ; but as the uſe of the materials of which her baſins are made was known to potters before ſhe was born, they may certainly compound theſe materials in proportions different from hers, without doing her any legal injury. As ſhe varies her own proportions ſo much, we think it probable that ſome proportion differing a little from them all, may anſwer the purpoſe of filtering veſſels equally well ; and it is almoſt needleſs to add, that with this precaution any potter may make ſuch veſſels, for which he would undoubtedly have a great demand.

A patent has likewiſe been granted to Mr Joſhua Collier of Southwark for a very ingenious contrivance for filtering and ſweetening water, oil, and all other liquids. Of this contrivance, which combines the application of machinery with the antiſeptic properties of charcoal (See CHEMISTRY n° 34. *Supplement*), we ſhall give a detailed account.

Fiſh-oil is one of the liquids which he had it particularly in view to free from all its impurities in ſmell, taſte, and colour ; and the chemical proceſs employed by him for this purpoſe, conſiſts in pouring a quantity of any ſpecies of fiſh-oil, or a mixture of different ſorts of fiſh-oil, into any convenient veſſel, which is to be heated to the temperature of 110 or 120 degrees of Fahrenheit's ſcale, and then adding of cauſtic mineral alkali, of the ſpecific gravity commonly deſcribed as 1.25, or of ſuch ſtrength that a phial containing 1000 grains of diſtilled water will contain 1250 grains of theſe lees, a quantity equal to four parts of the 100 by weight of the quantity of oil ; the mixture is then to be agitated, and left to ſtand a ſufficient time for the ſalts and ſediments to ſubſide ; it is then drawn off into another veſſel, containing a ſufficient quantity of freſh burnt charcoal, finely powdered, or any other ſubſtance poſſeſſing antiſeptic properties, in a powdered or divided ſtate, with an addition of a ſmall proportion of diluted ſulphuric acid, ſufficient only to decompoſe the ſmall quantity of ſaponaceous matter ſtill ſuſpended in the oil, which appears by the oil becoming clear at the ſurface : the contents of this veſſel are alſo agitated, and the coaly ſaline and aqueous particles left to ſubſide ; after which the oil is paſſed through proper ſtrainers, herein after deſcribed, and is thereby rendered perfectly tranſparent and fit for uſe.

The principle of the improved ſtrainers, or filtering machines, conſiſts in the means applied to combine hydroſtatic preſſure, which increaſes according to the perpendicular height of the fluid, with the mode of filtering *per aſcenſum*, thereby procuring the new and peculiar advantage that the fluid and its ſediment take oppoſite directions. A great advantage attending this invention is, that the dimenſions of the chamber in which the ſediment is received, may be varied, while the filtering ſurface remains the ſame. To adapt the machines not only to the purpoſe of families, work-houſes, hoſpitals, public charities, the navy, or the merchant ſervice, but alſo to all the purpoſes of oil-men, of diſtillers, of the laboratory, the brewery, &c. chambers of various capacities muſt be provided for the ſediment and precipitated matter. With reſpect to the oil-trade, the ſpace required is very great, eſpecially for ſpermaceti, or Braſil bottoms. In the various purpoſes of the laboratory, no limits can be fixed, but all dimenſions will be occaſionally required : in diſtilleries and breweries they may be ſmaller in proportion ; and in that deſigned for water and for domeſtic uſe, a very ſmall chamber will be ſufficient. When water is to be ſweetened, or freed from any putrid or noxious particles, it paſſes, in its way to the filtering chamber, through an iron-box, or cylinder, containing charcoal finely powdered, or any other antiſeptic ſubſtance inſoluble in water, the water being forced into it by hydroſtatic preſſure, through a tube of any ſufficient height. This box has two apertures to receive and deliver the fluid, and theſe are opened and cloſed by cocks, or ſcrews, or any other method uſed for ſuch purpoſes ; and being affixed to the machine by other ſcrews, may be eaſily detached from the ſame. Thus, whenever the charcoal begins to loſe its antiſeptic properties, the box is removed and heated till it is red hot ; by which means the foreign matter eſcapes through the ſmall apertures ; after which the box is cooled, and the charcoal becomes ſweet, pure, and equally fit for uſe as at firſt, though the proceſs be ever ſo often repeated.

Another part of the invention conſiſts in filtering machines in the form of ſtills, in which charcoal may be repeatedly burned after any fluid ſubſtances have paſſed through it, for the purpoſe of freeing them either from putrid or noxious particles, or of diſcharging their colouring matter ; which filtering ſtills are ſo contrived, that the fluid may paſs through in any quantity, without diſplacing the charcoal : the part of the fluid remaining interſperſed among the charcoal, may be driven over by heat, and be employed for many inferior purpoſes of the arts or manufactures. Laſtly, the heat may be raiſed ſo as to purify the charcoal, as has been before deſcribed in the machines for water. The flue of thoſe ſtills is ſo conſtructed that water may be employed to cool them without the loſs of time requiſite for their gradually parting with their heat to the ſurrounding atmoſphere, ſo as to be fit for a ſubſequent operation.

But it was not merely to the purifying of oils and various liquids that Mr Collier turned his attention. To his filtering apparatus are attached inſtruments for aſcertaining the comparative qualities of oils, which depend in part on the principle of their ſpecific gravities ; ſpermaceti oil, contraſted with other fiſh oils, being as 875 to 920. For this purpoſe, a glaſs veſſel of any convenient ſhape is made uſe of, furniſhed with a bubble alſo of glaſs, and a thermometer. If the oil is pure, this bubble ſinks, when the mercury riſes to a certain ſtandard, by the application of the hand, or any other heat to the veſſel containing the oil. If the ſpermaceti oil is impure, the bubble will ſtill float, though it is of the temperature required ; and the degree of impure, or foreign matter, will be ſhewn by the ſtate of the thermometer at which the bubble ſinks.

Filter.

To determine what tendency oils uſed for burning have to congeal in cold weather, a freezing mixture is put in a phial of thin glaſs, or any other convenient veſſel; into this a thermometer is immerſed, and a ſingle drop of the oil, under experiment, ſuffered to fall on the outſide of the veſſel, where it immediately congeals: as the cold produced by the mixture gradually ceaſes, it is eaſy to obſerve by the thermometer at what point of temperature the oil becomes fluid, and runs down the ſide of the glaſs.

Plate XXIII.

A ſhort deſcription of this apparatus will make its principles plain to every reader. A (fig. 1.) is the ciſtern into which the water or other liquor to be filtered is put. B B is a tube opening into the bottom of the ciſtern A, and bent along the bottom of the machine conveying the fluid into CCC the filtering chamber, which is covered with leather bound down round its circular rim, and through which leather the water is percolated. DD, The baſon riſing above the level of the chamber and receiving the filtered liquor. E, The ſpout by which it runs off into a pitcher or other veſſel. F, Another ſpout furniſhed with a cock to draw off the foul water from the chamber when neceſſary. GGG, The air tube, which begins above the level of the chamber, is covered with a button, which ſaves the leather from being cut, and has a ſmall lateral aperture for the air to be carried off. This pipe paſſes along the bottom and up the ſide, and riſing above the level of the water in the ciſtern, is there cloſed, except a ſmall lateral aperture through which the air eſcapes. H, A guard or rim with croſs bars put over the leather to keep it from being forced up by the water. It is faſtened down by means of two notches on oppoſite ſides of the guard, by which it locks into two ſtaples rivetted into the bottom of the baſon. I, The lid ſliding down to cover the water from duſt, and ſuſpended at pleaſure by means of KK, two ſprings on each tube for that purpoſe. LMNO, A cylindrical box containing charcoal, which is connected with the above by means of the tube P, and a continuation of the tube B. LM, The water tube B continued below the charcoal apparatus, ſo that the fluid may paſs through the ſame into the cylinder, from whence it enters the chambers at P, ſo as to be filtered through the leather as before deſcribed. RR, Collars which may be unſcrewed at pleaſure, ſo as to detach the charcoal apparatus whenever the charcoal requires to be purified by heat. SS, Two cocks to direct the fluid through the charcoal cylinder, or immediately into the filtering chamber.

Fig. 2. A, A tub or ciſtern containing the oil to be filtered, and ſupplying a tube of ſufficient height for the hydroſtatic preſſure to operate. BB, A main tube of wood, tin, leather, or cloth, to which any number of bags, of the ſize and ſhape of corn ſacks, or any CC, convenient ſize or ſhape may be connected. Theſe are bound to DDD, ſtraight double iron bars, furniſhed with a hinge at one end and a ſcrew at the other, by opening which the bags may be emptied. F, A trough underneath, made to receive the filtered oil from the receivers EEE.

Fig. 3. A, A funnel caſk or ciſtern, into which the fluid is put which paſſes down. B, A tube fitted into the ſame, through which it enters. C, An iron ſtill, or ſtill of any other ſubſtance capable of ſuſtaining heat, full of finely powdered and ſifted charcoal, through the head of which the fluid paſſes into any receiver. D, A fire-place of any conſtruction to drive over the fluid remaining interſperſed among the charcoal, and alſo to purify the charcoal by an increaſe of temperature when required. E, A cock to let water into the flues to cool the apparatus for a ſubſequent operation.

Fire.

Fig. 4. The trial glaſs with its thermometer.

FIRE. See that article *Encycl.* and Caloric and Combustion, *Chemistry-Index* in this *Suppl.*

* *Extinction of Fire* is ſometimes a matter of ſo much conſequence, that every thing which promiſes to be effectual for that purpoſe is worthy of attention. In the nineteenth number of Mr Nicholſon's Journal of Philoſophy, Chemiſtry, and the Arts, we have the following compoſition for extinguiſhing fire, invented by M. Von Aken.

Burnt alum - - - - -	pounds	30
Green vitriol powdered - - -		40
Cinabreſe, or red ochre in powder -		20
Potter's clay, or other clay, alſo powdered		200
Water - - - - - - -		630

With 40 meaſures of this mixture an artificial fire was extinguiſhed under the direction of the inventor by three perſons, which would have required the labour of 20 men and 1500 meaſures of common water. Sig. Fabbroni was commiſſioned to examine the value of this invention, and found in his comparative trials with engines of equal power, worked by the ſame number of men, that the mixture extinguiſhed the materials in combuſtion in one ſixth part leſs time, and three eighths leſs of fluid than when common water was uſed. He obſerved, as might indeed have been imagined from the nature of the material, that the flame diſappeared wherever the mixture fell, and that the ſaline, metallic, and earthy matters, formed an impenetrable lute round the hot combuſtible matter, which prevented the acceſs of the air, and conſequently the renewal of the deſtructive proceſs.

This recipe, Mr Nicholſon informs us, is taken from N° 85. of *Giornale Letterario di Napoli*, in which it was inſerted in the form of a letter from Sig. Fabbroni to Sig. D. Luigi Targioni of Naples; and the author of the letter eſtimates the price of the compoſition at about one halfpenny per pound.

The reaſon aſſigned by Mr Nicholſon for giving this abridged account a place in his valuable work, will be admitted by him and the public as a ſufficient reaſon for our adopting it into our's. It is, that ſuch inventions are worthy of the attention of philoſophers and economiſts, even though in the firſt applications they may prove leſs advantageous than their inventors may be diſpoſed to think. It is ſcarcely probable that this practice in the large way, with an engine throwing upwards of 200 gallons (value about L. 3, 10s.) each minute, would be thought of or adopted, or that a ſufficient ſtore of the materials would be kept in readineſs; ſince at this rate the expenditure for an hour would demand a proviſion to the amount of L. 210 ſterling. But in country places the proceſs, or ſome variation of it, might be applied with ſufficient profit in the reſult; more eſpecially if it be conſidered that common ſalt or alum, or ſuch ſaline matter as can be had and mixed with the water, together with clay, chalk, or lime, ochreous earth or common mud, or even theſe laſt without any ſalt, may anſwer the purpoſe of the

the lute with more or leſs effect, and extinguiſh an accidental fire with much greater ſpeed and certainty than clear water would do.

Fire-Balls are meteors, of which ſome account has been given in the *Encyclopædia*, as well as of various hypotheſes which have been framed reſpecting their nature and their origin. Since that article was publiſhed, a new and very ſingular hypotheſis has been framed by Profeſſor Chladni of Wittenberg, who maintains it by arguments, which, however fanciful, are yet worthy of the reader's notice *.

He ſuppoſes that fire-balls, inſtead of being collections of the electrical fluid floating in the higheſt regions of our atmoſphere, are maſſes of very denſe matter formed in far diſtant parts of ſpace, and ſubjected to ſimilar laws with the planets and comets. He endeavours to prove that their component parts muſt be denſe and heavy; becauſe their courſe ſhews, in ſo apparent a manner, the effects of gravity; and becauſe their maſs, though it diſtends to a monſtrous ſize, retains ſufficient conſiſtency and weight to continue an exceedingly rapid movement through a very large ſpace, without being decompoſed or diſſolved, notwithſtanding the reſiſtance of the atmoſphere. It ſeems to him probable, that this ſubſtance is by the effect of fire reduced to a tough fluid condition; becauſe its form appears ſometimes round and ſometimes elongated, and as its extending till it burſts, as well as the burſting itſelf, allows us to ſuppoſe a previous capability of extenſion by elaſtic fluidity. At any rate, it appears to be certain, that ſuch denſe matter at ſo great a height is not collected from particles to be found in our atmoſphere, or can be thrown together into large maſſes by any power with which we are acquainted; that no power with which we are acquainted is able to give to ſuch bodies ſo rapid a projectile force in a direction almoſt parallel to the horizon; that the matter does not riſe upwards from the earth, but exiſts previouſly in the celeſtial regions, and muſt have been conveyed thence to our earth. In the opinion of Dr Chladni, the following is the only theory of this phenomenon that agrees with all the accounts hitherto given, which is not contrary to nature in any other reſpect, and which beſides ſeems to be confirmed by various maſſes found on the ſpot where fire-balls fell.

As earthy, metallic, and other particles form the principal component parts of our planets, among which iron is the prevailing part, other planetary bodies may therefore conſiſt of ſimilar, or perhaps the ſame component parts, though combined and modified in a very different manner. There may alſo be denſe matters accumulated in ſmaller maſſes, without being in immediate connection with the larger planetary bodies diſperſed throughout infinite ſpace; and which, being impelled either by ſome projecting power or attraction, continue to move until they approach the earth or ſome other body, when, being overcome by its attractive force, they immediately fall down. By their exceedingly great velocity, ſtill increaſed by the attraction of the earth and the violent friction in the atmoſphere, a ſtrong electricity and heat muſt neceſſarily be excited; by which means they are reduced to a flaming and melted condition, and great quantities of vapour and different kinds of gaſes are thus diſengaged, which diſtend the liquid maſs to a monſtrous ſize, till, by a ſtill farther expanſion of theſe elaſtic fluids, it muſt at length burſt. Dr Chladni thinks alſo, that the greater part of the *ſhooting ſtars*, as they are called, are nothing elſe than fire-balls; which differ only from the latter in this, that their peculiarly great velocity carries them paſt the earth at a greater diſtance, ſo that they are not ſo ſtrongly attracted by it as to fall down; and therefore, in their paſſage through the high regions of the atmoſphere, occaſion only a tranſient electric flaſh, or actually take fire for a moment, and are again ſpeedily extinguiſhed, when they get to ſuch a diſtance from the earth that the air becomes too much rarefied for the exiſtence of fire.

The grounds on which Dr Chladni ſupports this opinion are various relations, well authenticated, of the motions of thoſe meteors, and the phenomena which accompany their burſting. Beſides thoſe mentioned in the *Encyclopædia*, he lays a particular ſtreſs on the account which he received from *M. Baudin*, Profeſſor of philoſophy at Pau, of a remarkable fiery meteor ſeen in Gaſcony on the 24th of July 1790. On the evening of that day M. Baudin was in the court of the caſtle of Marmes with a friend, the atmoſphere being perfectly clear, when they ſuddenly found themſelves ſurrounded by a whitiſh light, which obſcured that of the full moon, then ſhining with great luſtre. On looking upwards, they obſerved, almoſt in their zenith, a fire-ball of a larger diameter than the moon, and with a tail equal in length to five or ſix times the diameter of the body. The ball and the tail were of a pale white colour, except the point of the latter, which was almoſt as red as blood. The direction of this meteor was from ſouth to north.

“Scarcely (ſays M. Baudin) had we looked at it for two ſeconds when it divided itſelf into ſeveral portions of conſiderable ſize, which we ſaw fall in different directions, and almoſt with the ſame appearance as the burſting of a bomb. All theſe different fragments became extinguiſhed in the air; and ſome of them, in falling, aſſumed that blood-red colour which I had obſerved in the point of the tail. It is not improbable that all the reſt may have aſſumed the ſame colour; but I remarked only thoſe which proceeded in a direction towards Mormes, and which were particularly expoſed to my view.

“About two minutes and a half, or three minutes after, we heard a dreadful clap of thunder, or rather exploſion, as if ſeveral large pieces of ordnance had been fired off together. The concuſſion of the atmoſphere by this ſhock was ſo great, that we all thought an earthquake had taken place. The windows ſhook in their frames, and ſome of them, which probably were laid to and not cloſely ſhut, were thrown open. We were informed next day, that in ſome of the houſes at Houga, a ſmall town about half a mile diſtant from Mormes, the kitchen utenſils were thrown from the ſhelves; ſo that the people concluded there had been an earthquake. But as no movement was obſerved in the ground below our feet, I am inclined to think that all theſe effects were produced merely by the violent concuſſion of the atmoſphere.

“We proceeded into the garden while the noiſe ſtill continued, and appeared to be in a perpendicular direction above us. Some time after, when it had ceaſed, we heard a hollow noiſe, which ſeemed to roll along

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* *Phil.Mag* os 5 and 7.

the chain of the Pyrenees in echoes, for the diſtance of 15 miles. It continued about four minutes, becoming gradually more remote, and always weaker; and at the ſame time we perceived a ſtrong ſmell of ſulphur.

"While we were endeavouring to point out to ſome perſons preſent the place where the meteor had divided itſelf, we obſerved a ſmall whitiſh cloud, which aroſe perhaps from the vapour of it, and which concealed from us the three ſtars of the Great Bear, lying in the middle of thoſe forming the ſemicircle. With ſome difficulty, however, we could at laſt diſtinguiſh theſe ſtars again behind the thin cloud. There aroſe, at the ſame time, a freſh gentle breeze.

"From the time that elapſed between the burſting of the ball and the exploſion which followed, I was inclined to think that the meteor was at the height of at leaſt ſeven or eight miles, and that it fell four miles to the north of Mormes. The latter part of my conjecture was ſoon confirmed by an account which we received, that a great many ſtones had fallen from the atmoſphere at Juliac, and in the neighbourhood of Barbotan. One of theſe places lies at the diſtance of about four miles to the north of Mormes, and the other at about the diſtance of five to the north-north-weſt."

M. de Carrits Barbotan, the friend who was with the Profeſſor in the court and garden of Mormes when the meteor firſt attracted their attention, was at Juliac two days afterwards, and confirmed to him the truth of this circumſtance. It appeared, likewiſe, from the account of ſeveral intelligent perſons, highly worthy of credit, that the meteor burſt at a little diſtance from Juliac, and that the ſtones which fell were found lying in a ſpace almoſt circular, about two miles in diameter. They were of various ſizes. Some were *ſeen to fall*, which, when found, weighed 18 or 20 pounds, and which had ſunk into the earth from two to three feet. M. de C. Barbaton tranſmitted one weighing 18 pounds to the Academy of Sciences at Paris; and M. Baudin was told, that ſome were found which weighed even 50 pounds. He examined a ſmall one, and found it very heavy in proportion to its ſize: it was black on the outſide; of a greyiſh colour in the inſide, and interſperſed with a number of ſmall ſhining metallic particles. On ſtriking it with a piece of ſteel, it produced a few ſmall dark red ſparks, not very lively. A mineralogiſt, to whom a like piece of ſtone from the ſame meteor was ſhewn at Paris, deſcribed it as a kind of grey ſlag mixed with calcareous ſpar, the ſurface of which exhibited vitrified blackiſh calx of iron. The Profeſſor was told alſo, that ſome ſtones were found totally vitrified.

Such (ſays Dr Chladni) is the account given by Baudin of this meteor; the phenomena of which he endeavours to explain from accumulations in the upper parts of the atmoſphere.

According to all the obſervations hitherto made with any accuracy on fire-balls, the height at which they were firſt perceived was always very conſiderable, and by comparing the angles under which they were ſeen from different points, often 19 German miles, and even more; their velocity, for the moſt part, ſeveral miles in a ſecond; and their ſize always very great, often a quarter of a mile, and even more, in diameter. They were all ſeen to fall moſtly in an oblique direction; not one of them ever proceeded upwards. All of them have appeared under the form of a globular maſs, ſometimes a little extended in length, and highly luminous; having behind it a tail, which, according to every appearance, was compoſed of flames and ſmoke. All of them burſt after they were ſeen to move through a large ſpace, ſometimes over ſeveral diſtricts, with an exploſion which ſhook every thing around. In every inſtance where there has been an opportunity of obſerving the fragments that fell after they burſt, and which ſometimes have ſunk to the depth of ſeveral feet into the earth, they were found to conſiſt of ſcorious maſſes, which contained iron in a metallic or calcined ſtate, pure, or elſe mixed with different kinds of earth and ſulphur. All the ancient and modern accounts, written partly by naturaliſts and partly by others, are ſo eſſentially ſimilar, that the one ſeems to be only a repetition of the other. This conformity in accounts, the authors of which knew nothing of thoſe given by others, and who could have no intereſt in fabricating ſimilar tales, can ſcarcely have ariſen from accident or fiction, and gives to the related facts, however inexplicable many of them may ſeem, every degree of credibility.

In the third volume of Pallas's Travels, we have an account of a maſs of iron diſcovered by him in Siberia, which Dr Chladni conſiders as having been undoubtedly a fire-ball, or the fragment of a fire-ball. This problematical maſs was found between Kraſnojarſk and Abekanſk in the high ſlate mountains, quite open and uncovered. It weighed 1600 pounds; had a very irregular and ſomewhat compreſſed figure like a rough granite; was covered externally with a ferruginous kind of cruſt; and the inſide conſiſted of malleable iron, brittle when heated, porous like a large ſea ſponge, and having its interſtices filled with a brittle hard vitrified ſubſtance of an amber yellow colour. This texture and the vitrified ſubſtance appeared uniformly throughout the whole maſs, and without any traces of ſlag or artificial fire.

Dr Chladni ſhews, with a great deal of ingenuity, that this maſs neither originated by the wet method, nor could have been produced by art, the burning of a foreſt, by lightning, or by a volcanic eruption. It appears to him, therefore, in the higheſt degree probable, that it is of the ſame nature with fire-balls, or, as they have ſometimes been called, *flying dragons*. The Tartars, as we are informed by Pallas, conſidered this maſs as a ſacred relic which had dropped down from heaven; and this circumſtance Dr Chladni conſiders as no ſlight confirmation of his opinion, which he farther ſupports by the following reaſonings:

"1. As fire-balls conſiſt of denſe and heavy ſubſtances, which, by their exceedingly quick movement, and the friction thence excited by the atmoſphere, become electric, are reduced to a ſtate of ignition, and melted by the heat, ſo that they extend to a great ſize, and burſt; it thence follows, that in places where fragments, produced by the burſting of a fire-ball, have been found, ſubſtances endowed with all theſe properties muſt alſo have been found. Iron, however, the principal component part of all the maſſes hitherto found (and he ſpeaks of many beſides that of Pallas), poſſeſſes all theſe properties in a very eminent degree. The weight and toughneſs of the principal component parts of fire-balls, which muſt be very conſiderable, ſince, with the greateſt poſſible diſtention, they retain conſiſtence enough to proceed with the utmoſt velocity through ſuch an immenſe ſpace without decompoſition of their maſs, and without their progreſs being obſtructed by the reſiſtance of the air, agree perfectly well with melted iron; their dazzling white light has by many obſervers been compared to that of melted iron ; iron alſo exhibits the ſame appearances of flaming, ſmoking, and throwing out ſparks, and all theſe phenomena are moſt beautiful when they take place in vital air. Of the extenſion by elaſtic fluids expanded by the heat, and of the contraction which follows from cold, traces may be diſcovered in the internal ſpongy nature of the iron maſſes which have been found, and in the globular depreſſions of the exterior hard cruſt ; the latter of which gives us reaſon to ſuppoſe, that in theſe places there have been air-bubbles, which, on cooling, ſunk down. The mixture of ſulphur found in various maſſes, agrees alſo exceedingly well with the phenomena of fire-balls, and eſpecially with the great inflammability of ſulphur in very thin impure air ; for it is well known that ſulphur in an air-pump will take fire in air in which few other bodies could do the ſame. In regard to thoſe maſſes in which no ſulphur was found, this may have ariſen from the ſulphur eſcaping in vapour, ſince ſome time after the appearance of fire-balls a ſtrong ſmell of ſulphur has been perceived. The brittleneſs of the Siberian iron maſs when heated, may ariſe from ſome ſmall remains of ſulphur, which may perhaps be the cauſe of the facility with which fragments of this maſs, as well as of another found at Aix-la-Chapelle, could be roaſted.

“ 2. The whole texture of the maſſes betrayed evident ſigns of fuſion. This, however, cannot have been occaſioned by any common, natural, or artificial fire; and particularly for this reaſon, becauſe iron ſo malleable is not fuſible in ſuch fire, and when it is fuſed with the addition of inflammable matters, loſes its malleability, and becomes like common raw iron. The vitrified ſubſtance in the Siberian maſs is equally incapable of being fuſed in a common fire. The fire, then, muſt have been much ſtronger than that produced by the common, natural, and artificial means ; or the fuſion muſt have been effected by the force of exceedingly ſtrong electricity ; or perhaps both cauſes may have been combined together.

“ 3. It is totally incomprehenſible how, on the high ſlate mountains, where the Siberian maſs was found, at a conſiderable diſtance from the iron mines ; in the chalky ſoil of the extenſive plains of America, where for a hundred miles around there are no iron mines, and not even ſo much as a ſtone to be found ; and at Aix-la-Chapelle, where, as far as the author knows, there are no iron works—ſo many ferruginous particles could be collected in a ſmall ſpace as would be neceſſary to form maſſes of 1600, 15,000, and 17,000, up to 33,600 pounds. This circumſtance ſhews that theſe maſſes could as little have been fuſed by lightning as by the burning of a foreſt or of foſſile coal. Theſe maſſes were found quite expoſed and uncovered, and not at any depth in the earth, where we can much more readily admit ſuch an accumulation of ferruginous particles to have been melted by the effects of lightning.

“ Should it be aſked how ſuch maſſes originated, or by what means they were brought into ſuch an inſulated poſition ? this queſtion would be the ſame as if it were aſked how the planets originated. Whatever hypotheſes we may form, we muſt either admit that the planets, if we except the many revolutions which they may have undergone, either on or near their ſurface, have always been ſince their firſt formation, and ever will be the ſame ; or that Nature, acting on created matter, poſſeſſes the power to produce worlds and whole ſyſtems, to deſtroy them, and from their materials to form new ones. For the latter opinion there are, indeed, more grounds than for the former, as alternations of deſtruction and creation are exhibited by all organiſed and unorganiſed bodies on our earth ; which gives us reaſon to ſuſpect that Nature, to which greatneſs and ſmallneſs, conſidered in general, are merely relative terms, can produce more effects of the ſame kind on a larger ſcale. But many variations have been obſerved on diſtant bodies, which, in ſome meaſure, render the laſt opinion probable. For example, the appearing and total diſappearing of certain ſtars, when they do not depend upon periodical changes. If we now admit that planetary bodies have ſtarted into exiſtence, we cannot ſuppoſe that ſuch an event can have otherwiſe taken place, than by conjecturing that either particles of matter, which were before diſperſed through infinite ſpace in a more ſoft and chaotic condition, have united together in large maſſes by the power of attraction ; or that new planetary bodies have been formed from the fragments of much larger ones that have been broken to pieces, either perhaps by ſome external ſhock, or by an internal exploſion. Let whichever of theſe hypotheſes be the trueſt, it is not improbable, or at leaſt not contrary to nature, if we ſuppoſe that a large quantity of ſuch material particles, either on account of their too great diſtance, or becauſe prevented by a ſtronger movement in another direction, may not have united themſelves to the larger accumulating maſs of a new world ; but have remained inſulated, and, impelled by ſome ſhock, have continued their courſe through infinite ſpace, until they approached ſo near to ſome planet as to be within the ſphere of its attraction, and then by falling down to occaſion the phenomena before mentioned.”

Whether Chladni be a philoſopher of the French ſchool we know not ; but ſome parts of his theory tend ſtrongly towards materialiſm ; and the arguments by which he attempts to prop thoſe parts are peculiarly weak. When he talks of *Nature* producing worlds, he either ſubſtitutes Nature for Nature's God, or utters jargon which has no meaning. In what ſenſe the word Nature is uſed by every philoſopher of a ſound mind, we have elſewhere been at ſome pains to ſhew (ſee River, n° 116. *Encycl.*); but how abſurd would it be to ſay, that the ſyſtem of general laws, by which the Author and Governor of the univerſe connects together its various parts, and regulates all their operations, poſſeſſes, independently of Him, “ the power to produce worlds and whole ſyſtems, to deſtroy them, and from their materials to form new ones !”

As Chladni admits, or talks as if he admitted, the creation of matter, it would be wrong to impute to him this abſurdity ; but if by *Nature* he means God, and he can conſiſtently mean nothing elſe, we beg leave to affirm, that it is *directly contrary* to every notion which we can form of Nature in *this ſenſe*, "to ſuppoſe that a large quantity of material particles, either on account of the *diſtance*, or becauſe prevented by a *ſtronger movement* in another direction, have not united themſelves to the larger accumulating maſs of a new world, but remained inſulated, and impelled by ſome ſhock, have continued their courſe through infinite ſpace, &c." Is there any diſtance to which God cannot reach, or any movement ſo ſtrong as to reſiſt his power? Our author's language is indeed confuſed, and probably his ideas were not very clear. When he ſpeaks of the particles of matter being at firſt diſperſed through infinite ſpace, and afterwards united by the power of attraction, he revives the queſtion which was long ago diſcuſſed between Newton and Bentley, and diſcuſſed in ſuch a manner as ſhould have ſilenced for ever the bablings of thoſe who form worlds by attraction.

"The hypotheſis (ſays Newton) of matter's being at firſt evenly ſpread through the heavens, is, in my opinion, inconſiſtent with the hypotheſis of innate gravity without a ſupernatural power to reconcile them; and therefore infers a Deity. For if there be innate gravity, it is impoſſible now for the matter of the earth, and all the planets and ſtars, to fly up from them, and become evenly ſpread through all the heavens, without a ſupernatural power; and certainly that which can never be hereafter without a ſupernatural power, could never be heretofore without the ſame power." Dr Chladni, indeed, does not ſay that his particles of matter were *evenly* diſperſed through infinite ſpace; but ſuch muſt be his meaning, if he has any meaning: for matter *unevenly* diſperſed muſt, by an innate attraction, be united as ſoon as it exiſts, and ſo united as not to leave ſmall fragments of it to wander, we know not why, through the trackleſs void. Turn matter on all ſides, make it eternal or of late production, finite or infinite, there can be no regular ſyſtem produced but by a voluntary and meaning agent; and therefore, if it be true that fire-balls are maſſes of denſe matter, coeval with the planetary ſyſtem, exiſting in the celeſtial regions, and thence conveyed to our earth, they muſt have been formed, and their motions impreſſed upon them, by the Author of Nature for ſome wiſe purpoſe, though by us that purpoſe may never be diſcovered. One thing ſeems pretty clear, that wherever they may be formed, the phenomena attending their burſting, account ſufficiently for the notions of thunderbolts which have been generally entertained in all ages, and in every country.

Greek-Fire (ſee *Wild-Fire*, *Encycl.*). In the ſecond volume of Mr Nicholſon's Philoſophical Journal, we have the following receipt for making this compoſition, taken from ſome manuſcripts of Leonard de Vinci, who flouriſhed in the end of the fifteenth and beginning of the ſixteenth centuries, and who appears to have advanced far before his contemporaries in phyſical ſcience. Take the charcoal of willow, nitre, brandy, reſin, ſulphur, pitch, and camphor. Mix the whole together over the fire. Plunge a woollen cord in the mixture, and form it into balls, which may afterwards be provided with ſpikes. Theſe balls, being ſet on fire, are thrown into the enemy's veſſels. It is called the Greek fire, and is a ſingular compoſition, for it burns even upon the water. Callinicus the architect taught this compoſition to the Romans (of Conſtantinople), who derived great advantage from it, particularly under the emperor Leo, when the Orientals attacked Conſtantinople. A great number of their veſſels were burned by means of this compoſition.

The compoſition of the Greek fire thus given by Vincini is found in nearly the ſame words in ſome of the writings of Baptiſta Porta; whence it appears that both authors derived their information from the ſame ſource. A compoſition which burnt without acceſs to the atmoſphere could not fail to fill the minds of our forefathers with wonder; but the modern diſcoveries in chemiſtry have diſcloſed the ſecret, by ſhewing, that the combuſtion is carried on by means of the oxygen contained in the nitre.

Raſant or *Razant Fire*, is a fire from the artillery and ſmall arms, directed parallel to the horizon, or to thoſe parts of the works of a place that are defended.

Running Fire is when ranks of men fire one after another; or when the lines of an army are drawn out to fire on account of a victory; in which caſe each ſquadron or battalion takes the fire from that on its right, from the right of the firſt line to the left, and from the left to the right of the ſecond line, &c.

FISHING, the art of catching fiſh. See Angling, Fishery, and Fishing, &c. *Encycl.*

Chineſe Fishing. We venture to give this appellation to ſome very ingenious contrivances of the people of China for catching in their lakes, not only fiſh, but water-fowl. For the purpoſe of catching fiſh they have trained a ſpecies of pelican, reſembling the common corvorant, which they call the *Leu-tze*, or fiſhing-bird. It is brown, with a white throat, the body whitiſh beneath, and ſpotted with brown; the tail is rounded, the irides blue, and the bill yellow. Sir George Staunton, who, when the embaſſy was proceeding on the ſouthern branch of the great canal, ſaw thoſe birds employed, tells us, that on a large lake, cloſe to the eaſt ſide of the canal, are thouſands of ſmall boats and rafts, built entirely for this ſpecies of fiſhery. On each boat or raft are ten or a dozen birds, which, at a ſignal from the owner, plunge into the water; and it is aſtoniſhing to ſee the enormous ſize of fiſh with which they return, graſped within their bills. They appeared to be ſo well trained, that it did not require either ring or cord about their throats to prevent them from ſwallowing any portion of their prey, except what their maſter was pleaſed to return to them for encouragement and food. The boat uſed by theſe fiſhermen is of a remarkable light make, and is often carried to the lake, together with the fiſhing birds, by the men who are there to be ſupported by it.

The ſame author ſaw the fiſhermen buſy on the great lake Wee-chaung hee; and he gives the following account of a very ſingular method practiſed by them for catching the fiſh of the lake without the aid of birds, of net, or of hooks.

To one ſide of a boat a flat board, painted white, is fixed, at an angle of about 45 degrees, the edge inclining towards the water. On moonlight nights the boat is ſo placed that the painted board is turned to the moon, from whence the rays of light ſtriking on the whitened ſurface, give to it the appearance of moving water; on which the fiſh being tempted to leap as on their element, the boatmen, riſing with a ſtring the board, turn the fiſh into the boat.

Water-fowl are much ſought after by the Chineſe and are taken upon the ſame lake by the following ingenious device. Empty jars or gourds are ſuffered to float about upon the water, that ſuch objects may become familiar to the birds. The fiſherman then wades into the lake with one of thoſe empty veſſels upon his head, and walks gently towards a bird; and lifting up his arm, draws it down below the ſurface of the water without any diſturbance or giving alarm to the reſt, ſeveral of whom he treats in the ſame manner, until he fills the bag he had brought to hold his prey. The contrivance itſelf is not ſo ſingular, as it is that the ſame exactly ſhould have occurred in the new continent, as Ulloa aſſerts, to the natives of Carthagena, upon the lake Cienega de Teſias.

FISTULA Lachrymalis is a diſeaſe which, in all its ſtages, has been treated of in the article Surgery, chap. xiv. *Encycl.* A work, however, has been lately publiſhed by James Ware ſurgeon, in which there is the deſcription of an operation for its cure conſiderably different from that moſt commonly uſed, and which, while it is ſimple, the author's experience has aſcertained to be ſucceſsful.

In the cure of this diſeaſe, which is very troubleſome, and not very uncommon, it is a well known practice to inſert a metallic tube in the naſal duct of the lachrymal canal: but the advantage derived from this operation is not at all times laſting. Among other cauſes of failure, Mr Ware notices the lodgment of inſpiſſated mucus in the cavity of the tube. To remedy this defect, he recommends the following operation.

“ If the diſeaſe has not occaſioned an aperture in the lachrymal ſac, or if this aperture be not ſituated in a right line with the longitudinal direction of the naſal duct, a puncture ſhould be made into the ſac, at a ſmall diſtance from the internal juncture of the palpebræ, and nearly in a line drawn horizontally from this juncture towards the noſe with a ſpear-pointed lancet. The blunt end of a ſilver probe, of a ſize rather ſmaller than the probes that are commonly uſed by ſurgeons, ſhould then be introduced through the wound, and gently, but ſteadily, puſhed on in the direction of the naſal duct, with a force ſufficient to overcome the obſtruction in this canal, and until there is reaſon to believe that it has freely entered into the cavity of the noſe. The poſition of the probe, when thus introduced, will be nearly perpendicular; its ſide will touch the upper edge of the orbit; and the ſpace between its bulbous end in the noſe and the wound in the ſkin will uſually be found, in a full-grown perſon, to be about an inch and a quarter, or an inch and three-eighths. The probe is then to be withdrawn, and a ſilver ſtyle, of a ſize nearly ſimilar to that of the probe, but rather ſmaller, about an inch and three-eighths in length, with a flat head, like that of a nail, but placed obliquely, that it may ſit cloſe on the ſkin, is to be introduced through the duct, in place of the probe, and to be left conſtantly in it. For the firſt day or two after the ſtyle has been introduced, it is ſometimes adviſable to waſh the eye with a weak ſaturnine lotion, in order to obviate any tendency to inflammation which may have been excited by the operation; but this in general is ſo ſlight, that our author has rarely had occaſion to uſe any application to remove it. The ſtyle ſhould be withdrawn once every day for about a week, and afterwards every ſecond or third day. Some warm water ſhould each time be injected through the duct into the noſe, and the inſtrument be afterwards replaced in the ſame manner as before. Mr Ware formerly uſed to cover the head of the ſtyle with a piece of diachylon plaſter ſpread on black ſilk, but has of late obviated the neceſſity for applying any plaſter by blackening the head of the ſtyle with ſealing wax.

“ The effect (ſays he) produced by the ſtyle, when introduced in the way above mentioned, at firſt gave me much ſurpriſe. It was employed with a view ſimilar to that with which Mr Pott recommends the introduction of a bougie; viz. to open and dilate the naſal duct, and thus to eſtabliſh a paſſage, through which the tears might afterwards be conveyed from the eye to the noſe. I expected, however, that whilſt the ſtyle continued in the duct the obſtruction would remain, and of courſe that the watering of the eye, and the weakneſs of the ſight, would prove as troubleſome as they had been before the inſtrument was introduced. I did not imagine that any eſſential benefit could reſult from the operation until the ſtyle was removed, and the paſſage thereby opened. It was an agreeable diſappointment to me to find that the amendment was much more expeditious. The watering of the eye almoſt wholly ceaſed as ſoon as the ſtyle was introduced; and in proportion as the patient amended in this reſpect, his ſight alſo became more ſtrong and uſeful. The ſtyle, therefore, ſeems to act in a twofold capacity: firſt, it dilates the obſtructed paſſage; and then, by an attraction ſomewhat ſimilar to that of a capillary tube, it guides the tears through the duct into the noſe.

“ The wound that I uſually make into the ſac, if the ſupperative proceſs has not formed a ſuitable aperture in this part, is no larger than is juſt ſufficient to admit the end of the probe or ſtyle; and this, in general, in a little time, becomes a fiſtulous orifice, through which the ſtyle is paſſed without occaſioning the ſmalleſt degree of pain. The accumulation of matter in the lachrymal ſac, which, previous to the operation, is often copious, uſually abates ſoon after the operation has been performed; and, in about a week or ten days, the treatment of the caſe becomes ſo eaſy, that the patient himſelf, or ſome friend or ſervant who is conſtantly with him, is fully competent to do the whole that is neceſſary. It conſiſts ſolely in withdrawing the ſtyle two or three times in the week, occaſionally injecting ſome warm water, and then replacing the inſtrument in the ſame way in which it was done before.

“ It is not eaſy to aſcertain the exact length of time that the ſtyle ſhould be continued in the duct. Some have worn it many years, and, not finding any inconvenience from the inſtrument, are ſtill afraid and unwilling to part from it. Others, on the contrary, have diſuſed it at the end of about a month or ſix weeks, and have not had the ſmalleſt return of the obſtruction afterwards.”

The author relates ſo many ſucceſsful caſes of this operation, that we thought it our duty to record his method in this Supplementary volume of our general repoſitory of arts and ſciences; for a ſucceſsful practice, as well in ſurgery as in phyſic, muſt reſt on the baſis of experience.

Oblique or Second FLANK, or *Flank of the Curtain*, is that part of the curtain from whence the face of the oppoſite baſtion can be ſeen, being contained between the lines raſant and fichant, or the greater and leſs lines of defence; or the part of the curtain between the flank and the point where the fichant line of defence terminates.

Covered, Low, or *Retired* FLANK, is the platform of the caſemate, which lies hid in the baſtion, and is otherwiſe called the *orillon*.

Fichant FLANK,' is that from whence a cannon playing, fires directly on the face of the oppoſite baſtion.

Raſant or *Razant* FLANK, is the point from whence the line of defence begins, from the conjunction of which with the curtain the ſhot only raſeth the face of the next baſtion, which happens when the face cannot be diſcovered but from the flank alone.

FLIE or FLY, that part of the mariner's compaſs on which the thirty-two points of the wind are drawn, and over which the needle is placed, and faſtened underneath.

FLOATING BODIES are ſuch as ſwim on the ſurface of a fluid, of which the moſt important are ſhips, and all kinds of veſſels employed in war and in commerce. Every ſeaman knows of how much conſequence it is to determine the ſtability of ſuch veſſels, and the poſitions which they aſſume when they float freely and at reſt on the water. To accompliſh this, it is neceſſary to ſtate the principles on which that ſtability and theſe poſitions depend; and this has been done with ſo much ingenuity and ſcience by GEORGE ATWOOD, Eſq; F. R. S. in the Philoſophical Tranſactions for the year 1796, that we are perſuaded a large claſs of our readers will thank us for inſerting an abſtract of his memoir in this place.

A floating body is preſſed downwards by its own weight in a vertical line that paſſes through its centre of gravity; and it is ſuſtained by the upward preſſure of a fluid, acting in a vertical line that paſſes through the centre of gravity of the immerſed part; and unleſs theſe two lines be coincident, ſo that the two centres of gravity may be in the ſame vertical line, the ſolid will revolve on an axis, till it gains a poſition in which the equilibrium of floating will be permanent. Hence it appears, that it is neceſſary, in the firſt place, to aſcertain the proportion of the part immerſed to the whole; for which purpoſe the ſpecific gravity of the floating body muſt be known; and then it muſt be determined, by geometrical or analytical methods, in what poſitions the ſolid can be placed on the ſurface of the fluid, ſo that the two centres of gravity already mentioned may be in the ſame vertical line when a given part of the ſolid is immerſed under the ſurface of the fluid. When theſe preliminaries are ſettled, ſomething ſtill remains to be done. Poſitions may be aſſumed in which the circumſtances juſt recited concur, and yet the ſolid will aſſume ſome other poſition in which it will permanently float. If a cylinder, *e. g.* having its ſpecific gravity to that of the fluid on which it floats as 3 to 4, and its axis to the diameter of the baſe as 2 to 1, be placed on the fluid with its axis vertical, it will ſink to a depth equal to a diameter and a half of the baſe; and while its axis is preſerved in a vertical poſition by external force, the centres of gravity of the whole ſolid and of the immerſed part will remain in the ſame vertical line: but when the external force that ſuſtained it is removed, it will decline from its upright poſition, and will permanently float with its axis horizontal. If the axis be ſuppoſed to be half of the diameter of the baſe, and be placed vertically, the ſolid will ſink to the depth of three-eighths of its diameter; and in that poſition it will float permanently. If the axis be made to incline to the vertical line, the ſolid will change its poſition until it ſettles permanently with the axis perpendicular to the horizon.

Whether, therefore, a ſolid floats permanently, or overſets when placed on the ſurface of a fluid, ſo that the centre of gravity of the ſolid and that of the part immerſed ſhall be in the ſame vertical line, it is ſaid to be in a poſition of equilibrium; and of this equilibrium there are three ſpecies, viz. the equilibrium of ſtability, in which the ſolid floats permanently in a given poſition; the equilibrium of inſtability, in which the ſolid, though the two centres of gravity already mentioned are in the ſame vertical line, ſpontaneouſly overſets, unleſs ſupported by external force; and the equilibrium of indifference, or the inſenſible equilibrium, in which the ſolid reſts on the fluid indifferent to motion, without tendency to right itſelf when inclined, or to incline itſelf farther.

If a ſolid body floats permanently on the ſurface of a fluid, and external force be applied to incline it from its poſition, the reſiſtance oppoſed to this inclination is termed the ſtability of floating. Among various floating bodies, ſome loſe their quieſcent poſition, and ſome gain it, after it has been interrupted, with greater facility and force than others.

Some ſhips at ſea (*e. g.*) yield to a given impulſe of the wind, and ſuffer a greater inclination from the perpendicular than others. As this reſiſtance to heeling or pitching, duly regulated, has been deemed of importance in the conſtruction of veſſels, ſeveral eminent mathematicians have inveſtigated rules for determining the ſtability of ſhips from their known dimenſions and weight, without recurring to actual trial. To this claſs we may refer Bouguer, Euler, Fred. Chapman, and others; who have laid down theorems for this purpoſe, founded on a ſuppoſition that the inclinations of ſhips from their quieſcent poſitions are evaneſcent, or, in a practical ſenſe, very ſmall.

"But ſhips at ſea (ſays our ingenious author) are known to heel through angles of 10°, 20°, or even 30°; and therefore a doubt may ariſe how far the rules, demonſtrated on the expreſs condition that the angles of inclination are of evaneſcent magnitude, ſhould be admitted as practically applicable in caſes where the inclinations are ſo great."—"If we admit that the theory of ſtatics can be applied with any effect to the practice of naval architecture, it ſeems to be neceſſary that the rules, inveſtigated for determining the ſtability of veſſels, ſhould be extended to thoſe caſes in which the angles of inclination are of any magnitude likely to occur in the practice of navigation."

A ſolid body placed on the ſurface of a lighter fluid, at the depth correſponding to the relative gravities, cannot change its poſition by the combined actions of its weight and the preſſure of the fluid, except by revolving on ſome horizontal axis which paſſes through the centre of gravity: but as many axes may be drawn through this point of the floating body in a direction parallel to the horizon, and the motion of the ſolid reſpects one axis only, this axis muſt be determined by the figure of the body and the particular nature of the caſe. When this axis of motion, as it is called, is determined,

termined, and the ſpecific gravity of the ſolid is known, "the poſitions of permanent floating will be obtained, firſt by finding the ſeveral poſitions of equilibrium through which the ſolid may be conceived to paſs, while it revolves round the axis of motion; and ſecondly, by determining in which of thoſe poſitions the equilibrium is permanent, and in which of them it is momentary and unſtable."

Such as we have now briefly ſtated are the general principles on which are founded Mr Atwood's inveſtigations for determining the poſitions aſſumed by homogeneous bodies, floating on a fluid ſurface; and alſo for determining the ſtability of ſhips and of other floating bodies. We cannot farther accompany him in his elucidation of them, in the problems to the ſolution of which they lead, and in the important practical purpoſes of naval architecture to which they are referred. The whole paper, comprehending no leſs than 85 pages, is curious and valuable; it abounds with analytical and geometrical diſquiſitions of the moſt elaborate kind; and it ſerves to enlarge our acquaintance with a ſubject that is not only highly intereſting to the ſpeculative mathematician, but extremely uſeful in its practical application.

With this latter view, the author ſeems to have directed his attention to the various objects of inquiry which this article comprehends. They are ſuch as intimately relate to the theory of naval architecture, ſo far as it depends on the pure laws of mechanics, and they contribute to extend and improve this theory. The union of thoſe principles that are deduced from the laws of motion, with the knowledge which is derived from obſervation and experience, cannot fail to eſtabliſh the art of conſtructing veſſels on its true baſis, and gradually to lead to farther improvements of the greateſt importance and utility. To this purpoſe, the author obſerves, that

"If the proportions and dimenſions adopted in the conſtruction of individual veſſels are obtained by exact geometrical menſurations, and calculations founded on them, and obſervations are made on the performance of theſe veſſels at ſea; experiments of this kind, ſufficiently diverſified and extended, ſeem to be the proper grounds on which theory may be effectually applied in developing and reducing to ſyſtem thoſe intricate, ſubtil, and hitherto unperceived cauſes, which contribute to impart the greateſt degree of excellence to veſſels of every ſpecies and deſcription. Since naval architecture is reckoned amongſt the practical branches of ſcience, every voyage may be conſidered as an experiment, or rather as a ſeries of experiments, from which uſeful truths are to be inferred towards perfecting the art of conſtructing veſſels: but inferences of this kind, conſiſtently with the preceding remark, cannot well be obtained, except by acquiring a perfect knowledge of all the proportions and dimenſions of each part of the ſhip; and ſecondly, by making and recording ſufficiently numerous obſervations on the qualities of the veſſel, in all the varieties of ſituation to which a ſhip is uſually liable in the practice of navigation."

In the valuable miſcellany entitled the *Philoſophical Magazine*, there is a paper on this ſubject by Mr John George Engliſh, teacher of mathematics and mechanical philoſophy; which, as it is not long, and is eaſily underſtood, we ſhall take the liberty to tranſcribe.

"However operoſe and difficult the calculations neceſſary to determine the ſtability of nautical veſſels may, in ſome caſes, be, yet they all depend, ſays this author, upon the four following ſimple and obvious theorems, accompanied with other well-known ſtereometrical and ſtatical principles.

"*Theorem* 1. Every floating body diſplaces a quantity of the fluid in which it floats, equal to its own weight: and conſequently, the ſpecific gravity of the fluid will be to that of the floating body, as the magnitude of the whole is to that of the part immerſed.

"*Theorem* 2. Every floating body is impelled downward by its own eſſential power, acting in the direction of a vertical line paſſing through the centre of gravity of the whole; and is impelled upward by the reaction of the fluid which ſupports it, acting in the direction of a vertical line paſſing through the centre of gravity of the part immerſed: therefore, unleſs theſe two lines are coincident, the floating body thus impelled muſt revolve round an axis, either in motion or at reſt, until the equilibrium is reſtored.

"*Theorem* 3. If by any power whatever a veſſel be deflected from an upright poſition, the perpendicular diſtance between two vertical lines paſſing through the centres of gravity of the whole, and of the part immerſed reſpectively, will be as the ſtability of the veſſel, and which will be poſitive, nothing, or negative, according as the metacentre is above, coincident with, or below, the centre of gravity of the veſſel.

"*Theorem* 4. The common centre of gravity of any ſyſtem of bodies being given in poſition, if any one of theſe bodies be moved from one part of the ſyſtem to another, the correſponding motion of the common centre of gravity, eſtimated in any given direction, will be to that of the aforeſaid body, eſtimated in the ſame direction, as the weight of the body moved is to that of the whole ſyſtem.

"From whence it is evident, that in order to aſcertain the ſtability of any veſſel, the poſition of the centres of gravity of the whole, and of the part immerſed, muſt be determined; with which, and the dimenſions of the veſſel, the line of floatation, and angle of deflection, the ſtability or power either to right itſelf or overturn, may be found.

"In ſhips of war and merchandiſe, the calculations neceſſary for this purpoſe become unavoidably very operoſe and troubleſome; but they may be much facilitated by the experimental method pointed out in the New Tranſactions of the Swediſh Academy of Sciences, firſt quarter of the year 1787, page 48.

"In river and canal boats, the regularity and ſimplicity of the form of the veſſel itſelf, together with the compact diſpoſition and homogeneal quality of the burden, render that method for them unneceſſary, and make the requiſite calculations become very eaſy. Veſſels of this kind are generally of the ſame tranſverſe ſection throughout their whole length, except a ſmall part in prow and ſtern, formed by ſegments of circles or other ſimple curves; therefore a length may eaſily be aſſigned ſuch, that any of the tranſverſe ſections being multiplied thereby, the product will be equal to the whole ſolidity of the veſſel. The form of the ſection ABCD is for the moſt part either rectangular, as in fig. 1. trapezoidal as in fig. 2. or mixtilineal

Plate XXVIII.

tilineal as in fig. 3. in all which MM repreſents the line of floatation when upright, and EF that when inclined at any angle MXE; alſo G repreſents the centre of gravity of the whole veſſel, and R that of the part immerſed.

“ If the veſſel be loaded quite up to the line AB, and the ſpecific gravity of the boat and burden be the ſame, then the point G is ſimply the centre of gravity of the ſection ABCD; but if not, the centres of gravity of the boat and burden muſt be found ſeparately, and reduced to one by the common method, namely, by dividing the ſum of the momenta by the ſum of weights, or areas, which in this caſe are as the weights. The point R is always the centre of gravity of the ſection MMCD, which, if conſiſting of different figures, muſt alſo be found by dividing the ſum of the momenta by the ſum of the weights as common. Theſe two points being found, the next thing neceſſary is to determine the area of the two equal triangles MXE, MXF, their centres of gravity *o*, *o*, and the perpendicular projected diſtance *n n* of theſe points on the water line EF. This being done, through R, and parallel to EF, draw RT = a fourth proportional to the whole area MMCD, either triangle MXE or MXF, and the diſtance *n n*; through T, and at right angles to RT or EF, draw TS meeting the vertical axis of the veſſel in S the metacentre; alſo through the points G, B, and parallel to ST, draw NGW and BV; moreover through S, and parallel to EF, draw WSV, meeting the two former in V and W; then SW is as the ſtability of the veſſel, which will be poſitive, nothing, or negative, according as the point S is above, coincident with, or below, the point G. If now we ſuppoſe W to repreſent the weight of the whole veſſel and burden (which will be equal to the ſection MMCD multiplied by the length of the veſſel), and P to repreſent the required weight applied at the gunwale B to ſuſtain the veſſel at the given angle of inclination; we ſhall always have this proportion: as VS : SW : : W : P; which proportion is general, whether SW be poſitive or negative; it muſt only, in the latter caſe, be ſuppoſed to act upward to prevent an overturn.

“ In the rectangular veſſel, of given weight and dimenſions, the whole proceſs is ſo evident, that any farther explanation would be unneceſſary. In the trapezoidal veſſel, after having found the points G and R, let AD, BC be produced until they meet in K. Then, ſince the two ſections MMCD, EFDC are equal, the two triangles MMK, EFK are alſo equal; and therefore the rectangle EK × KF = KM × KM = $\overline{\text{KM}^2}$; and ſince the angle of inclination is ſuppoſed to be known, the angles at E and F are given. Conſequently, if a mean proportional be found between the ſines of the angles at E and F, we ſhall have the following proportions:

“ As the mean proportional thus found : ſine ∠ E : : KM : KF, and as the ſaid mean proportional : ſine ∠F : : KM : KE; therefore ME, MF become known: from whence the area of either triangle MXE or MXF, the diſtance *n n*, and all the other requiſites, may be found.

“ In the mixtilineal ſection, let AB = 9 feet = 108 inches, the whole depth = 6 feet = 72 inches, and the altitude of MM the line of floatation 4 feet or 48 inches; alſo let the two curvelinear parts be circular quadrants of two feet, or 24 inches radius each. Then the area of the two quadrants = 904·7808 ſquare inches, and the diſtance of their centres of gravity from the bottom = 13·8177 inches very nearly; alſo the area of the included rectangle *a b i e* = 1440 ſquare inches, and the altitude of its centre of gravity 12 inches; in like manner, the area of the rectangle AB *c d* will be found = 5184 ſquare inches, and the altitude of its centre of gravity 48 inches: therefore we ſhall have

Momentum of the two quad.	= 904·7808	×	13·8177	= 12501·98966016
Moment. of the rectan. *a b i e*	= 1440·	×	12	= 17280·
Moment. of the rectan. AB*c d*	= 5184·	×	48	= 248832· .
	7528·7808			278613·98966016

“ Now the ſum of the momenta, divided by the ſum of the areas, will give $\frac{278613\cdot98966016}{7528\cdot7808} = 37\cdot006$ inches, the altitude of G, the centre of gravity of the ſection ABCD above the bottom. In like manner, the altitude of R, the centre of gravity of the ſection MMCD, will be found to be equal $\frac{123093\cdot98966016}{4936\cdot7808}$ = 24·934 inches; and conſequently their difference, or the value of GR = 12·072 inches, will be found.

Suppoſe the veſſel to heel 15°, and we ſhall have the following proportion; namely, As radius : tangent of 15 : : MX = 54 inches : 14.469 inches = ME or MF; and conſequently the area of either triangle MXE or MXF = 390·663 ſquare inches. Therefore, by theorem 4th, as 4936·7808 : 390·663 : : 72 = *n n* = $\frac{2}{3}$ AB : 5·6975 inches = RT; and, again, as radius : ſine of 15° : : 12.072 = GR : 3·1245 inches = RN; conſequently RT—RN = 5·6975—3·1245 = 2·573 inches = SW, the ſtability required.

“ Moreover, as the ſine of 15° : radius : : 5·6975 = RT : 22·013 = RS, to which, if we add 24·934, the altitude of the point R, we ſhall have 46·947 for the height of the metacentre, which taken from 72, the whole altitude, there remains 25·053; from which, and the half width = 54 inches, the diſtance BS is found = 59·529 inches very nearly, and the angle SBV = 80°—06′—42″; from whence SV = 58·645 inches.

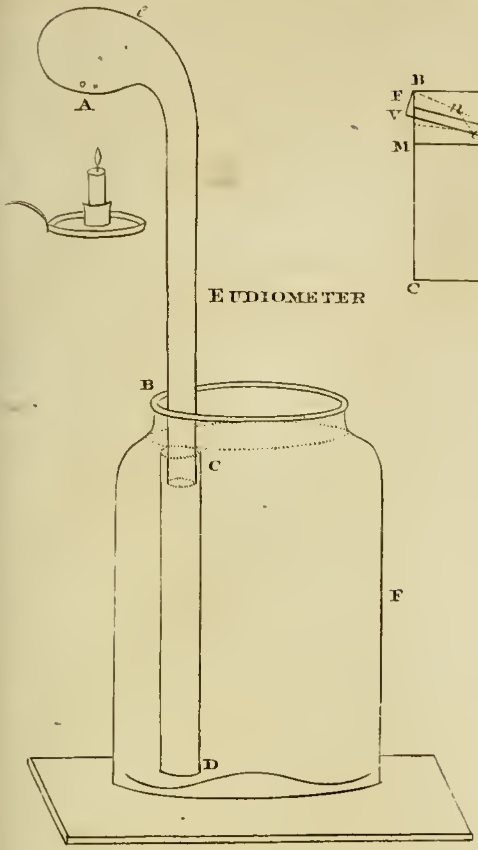
Again: Let us ſuppoſe the mean length of the veſſel to be 40 feet, or 480 inches, and we ſhall have the weight of the whole veſſel equal to the area of the ſection MMCD = 4936.7808 multiplied by 480 = 2369654·784 cubic inches of water, which weighs exactly 85708 pounds avoirdupois, allowing the cubic foot to weigh 62.5 pounds.

“ And, finally, as SV : SW (*i. e.*) as 58·645 : 2·573 : : 85708 : 3760 +, the weight on the gunwale which will ſuſtain the veſſel at the given inclination. Therefore a veſſel of the above dimenſions, and weighing 38 tons, 5 cwts. 28 lbs. will require a weight of 1 ton, 13 cwts. 64 lbs. to make her incline 15°.

“ In this example, the deflecting power has been ſuppoſed to act perpendicularly on the gunwale at B; but if the veſſel is navigated by ſails, the centre velique muſt be found; with which, and the angle of deflection, the projected diſtance thereof on the line SV may be obtained; and then the power, calculated as above

neceſſary

PLATE XXVIII.


EUDIOMETER

FLOATING BODIES

Fig. 1.

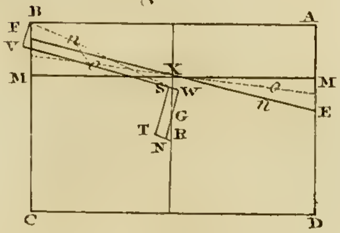


Fig. 2.

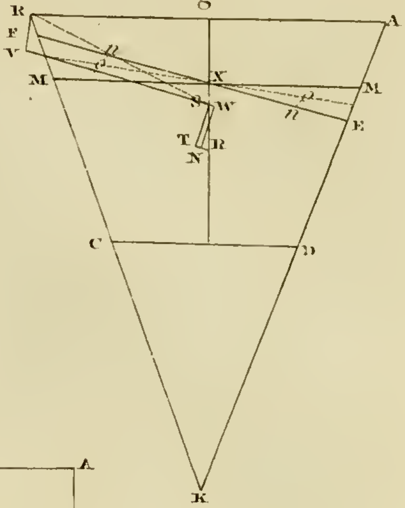
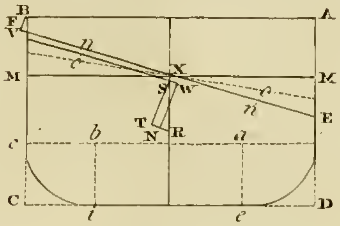


Fig. 3.



EUPHORBIA

Fig. 1.

Fig. 2.

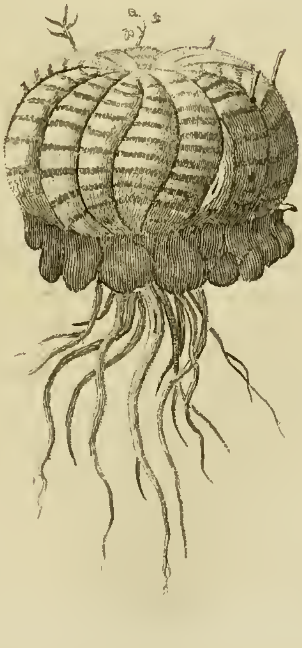
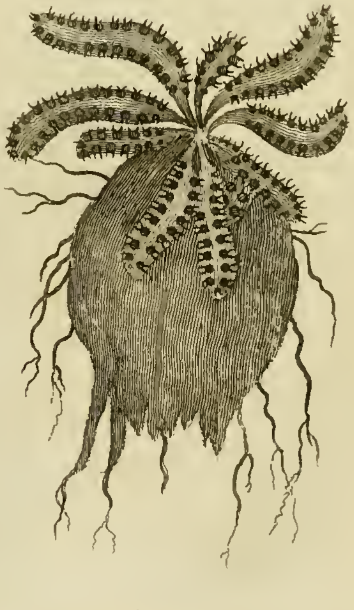


Fig. 3.



neceſſary to be applied at the projected point, will be that part of the wind's force which cauſes the veſſel to heel. And converſely, if the weight and dimenſions of the veſſel, the area and altitude of the ſails, the direction and velocity of the wind be given, the angle of deflection may be found."

FLUENT, or FLOWING QUANTITY, in the doctrine of fluxions, is the variable quantity which is conſidered as increaſing and decreaſing; or the fluent of a given fluxion, is that quantity whoſe fluxion being taken, according to the rules of that doctrine, ſhall be the ſame with the given fluxion. See FLUXIONS, *Encycl.*

FLUIDS (MOTION IN). See HYDROSTATICS and RESISTANCE OF FLUIDS, *Encycl.* and MOTION in this *Supplement*.

FOGEDAR, the military governor of a ſubordinate diſtrict in India, who has ſometimes the additional office of collecting the revenues.

FOLIATE, a name given by ſome to a curve of the 2d order, expreſſed by the equation $x^3+y^3=axy$, being one ſpecies of defective hyperbolas, with one aſymptote, and conſiſting of two infinite legs croſſing each other, forming a ſort of leaf. It is the 42d ſpecies of Newton's Lines of the 3d Order.

FORCER, in mechanics, is properly a piſton without a valve. For, by drawing up ſuch a piſton, the air is drawn up, and the water follows; then puſhing the piſton down again, the water, being prevented from deſcending by the lower valve, is forced up to any height above, by means of a ſide branch between the two.

FORDYCE (James, D. D.), ſo well known to ſerious readers by his ſermons to young women, and other ſpecimens of pulpit eloquence, was born at Aberdeen in the year 1720. His father was a man much eſteemed, and held, more than once, the office of chief magiſtrate in his native city; and his mother was a woman of good ſenſe, amiable temper, and exemplary piety. This reſpectable pair had the ſingular felicity of tranſmitting ſuperior talents to almoſt every individual of a numerous family; of one of which, viz. David Fordyce, the reader will find ſome account in the *Encyclopædia*.

The ſubject of this memoir, who was their fourth ſon, acquired, as well as his brother, the rudiments of claſſical learning at the grammer ſchool of Aberdeen, whence he was removed to the Mariſchal college and univerſity in the ſame city. Having completed a regular courſe of ſtudy both in philoſophy and theology, he was licenſed, when very young, according to the forms of the church of Scotland, to be a preacher of the goſpel; and was ſoon afterwards preferred to the place of ſecond miniſter in the collegiate church of Brechin in the county of Angus. After remaining there for ſome years, he received a preſentation to the church of Alloa near Stirling; and though the inhabitants of that pariſh were prepoſſeſſed in favour of another miniſter whom they knew, and prejudiced againſt Mr Fordyce whom they did not know; ſo narrow minded and totally deſtitute of taſte was his colleague in Brechin, that he judged it expedient to hazard the conſequences of a removal. He was aware that he entered on his new charge under a conſiderable degree of popular odium; but he thought it more probable that he ſhould be able to overcome that odium, than conciliate the affections of a ſour fanatic. In this expectation he was not deceived. The prejudices of the good people in Alloa were very quickly removed, not more by the able and impreſſive manner in which he conducted the public ſervices of the Lord's day, than by the amiable and condeſcending ſpirit with which he performed the more private duties of viſiting and catechiſing in the different diſtricts of his pariſh; duties which, as they were wont to be performed by the Scotch clergy, contributed much more than preaching to the religious inſtruction of the lower claſſes of the people.

It was during his reſidence at Alloa that Mr Fordyce firſt diſtinguiſhed himſelf as an author by the ſucceſſive publication of the three following ſermons. The firſt, upon the eloquence of the pulpit, was annexed to "the Art of Preaching" by his brother David; the ſecond, upon the methods of promoting edification by public inſtitutions, was preached at the ordination of the Rev. Mr Gibſon miniſter of St Ninian's, a neighbouring pariſh, in the year 1754, and publiſhed, with the charge and notes, in 1755; and the third, upon the deluſive and perſecuting ſpirit of popery, was preached the ſame year before the ſynod of Stirling and Perth; and being publiſhed, came very quickly to a ſecond edition. But the ſermon which moſt ſtrongly arreſted the attention, both of the audience before which it was delivered, and of the public to which, in 1760, it was given from the preſs, was that on the *folly, infamy, and miſery of unlawful pleaſure*, preached before the General Aſſembly of the Church of Scotland. The choice of ſuch a ſubject, on ſuch an occaſion, excited the ſurpriſe of all his hearers, and tempted the younger part of them to ſmile at the very reading of the text; but this unſeaſonable mirth was ſoon converted into ſerioufneſs. The picture exhibited in this ſermon is the work of a maſter; and we have been aſſured by a friend who heard it preached, that the ſpirit and elegance of the compoſition was ſo ſeconded by the ſolemnity and animation with which it was delivered, that it made a very ſtriking impreſſion, not only upon the more reſpectable part of the audience, but upon minds of noted levity: It raiſed indeed its writer's fame as a pulpit orator to an unrivalled eminence among his brethren in Scotland.

About this time, and we believe in conſequence of this ſermon, Mr Fordyce received from the univerſity of Glaſgow a diploma, creating him Doctor in Divinity; and if there is yet any thing honourable in academical degrees, proſtituted as they have long been by an undiſtinguiſhing diſtribution, the honour could not have been conferred with greater propriety on any man in the church to which he then belonged.

In that church he did not long remain. Soon after the publication of this ſingular ſermon, and his conſequent acquiſition of academical honours, he accepted of an invitation from a ſociety of Proteſtant diſſenters, who had their place of meeting in Monkwell-ſtreet, London, to become colleague and ſucceſſor to their paſtor, who was then old and infirm, and who died, indeed, in the ſpace of a few months. This gave occaſion to the Doctor to diſplay his oratory once more both from the pulpit and the preſs in a ſermon on the death of Dr Lawrence. He was now ſole paſtor to the congregation of Monkwell-ſtreet; and preached for many years with great powers of eloquence and fervour of piety, to an audience always crowded and often overflowing.

When a preacher obtains, with or without merit, an uncommon ſhare of popularity, a conſiderable proportion of his hearers will ever conſiſt of thoſe, who are guided in their choice rather by curioſity and faſhion, than by ſound judgment. The attachments of ſuch people are as capricious and variable as their minds; and they change their preacher as they change their dreſs, not from their own taſte, for in general they have none; but from the deſire of being where others are, of doing what others do and of admiring what others admire. Dr Fordyce appreciated juſtly the value of ſuch mens approbation, and knew it eventually by experience; but he was more than compenſated for the loſs of hearers of this deſcription by the ſteady adherence of others, whoſe eſteem was moſt deſirable, becauſe it was grounded upon the dictates of a ſound underſtanding.

At laſt, about Chriſtmas 1782, when his health, which had long been declining, rendered it neceſſary, in his own opinion, and in the opinion of his phyſicians, to diſcontinue his public ſervices, he reſigned his charge in Monkwell-ſtreet, and retired to a villa in Hampſhire, in the neighbourhood of the Earl of Bute, who honoured him with his friendſhip, and to whoſe valuable library he had free acceſs. Afterwards he removed to Bath, where having, with Chriſtian patience, ſuffered much from an aſthmatic complaint, to which he had been ſubject for ſome years, on the 1ſt of October 1796 he expired without a groan.

Were we to hazard an opinion of Dr Fordyce's intellectual powers from ſuch a peruſal of his works as we muſt acknowledge to have been haſty, we would ſay that he was a man of genius rather than of judgment; that his imagination was the predominant faculty of his mind; and that he was better fitted, by an addreſs to the paſſions, to enforce the practice of virtue, than, by the exertions of his own underſtanding, to vindicate ſpeculative truth, or to detect the ſophiſtry of error. From this remark, we cannot be ſuſpected of a wiſh to leſſen his character in the public eſteem; for his talents, as they appear to us, are ſurely of more value to a preacher than thoſe which are perhaps better adapted to literary or ſcientific purſuits. In none of his works indeed do we perceive any evidence either of profound ſcience, or of various erudition; though we doubt not but thoſe works are every thing which their author intended them to be. Of his ſermons to young women, which have attracted moſt general notice, it would be preſumptuous in us to give a character; for though we ſat down many years ago to read them, we could not get through; and we have never made a ſecond attempt. As far as we can depend upon what we recollect of theſe far-famed diſcourſes, the cenſure paſſed on them by Mrs Wolſtoncraft ſeems to be juſt. Their author, however, was certainly qualified to excel, and actually did excel as a preacher. We have already mentioned with approbation three or four of his occaſional ſermons; but perhaps the fineſt ſpecimen of pulpit oratory which ever fell from his pen, is the charge which he delivered at the ordination of his ſucceſſor in the meeting of Monkwell-ſtreet. It is indeed one of the moſt valuable diſcourſes of the kind that we have ſeen, and ſhould be read with attention by every clergyman of every denomination, who wiſhes to diſcharge his duty with credit to himſelf and with advantage to his people.

The effect of Dr Fordyce's addreſſes from the pulpit was much heightened, not only by an action and an elocution, which he ſtudied with care and practiſed with ſucceſs; but by the figure of his perſon, which was peculiarly dignified, and by the expreſſion of his countenance, which was animated at all times, but animated moſt of all when lighted up by the ardour of his ſoul in the ſervice of God. By ſome of his hearers, it was obſerved that, on many occaſions, he ſeemed not merely to ſpeak, but to look conviction to the heart. His eye, indeed, was particularly bright and penetrating, and he had carefully attended to the effect which an orator may often produce upon an audience by the judicious uſe of that little, but invaluable organ.

With reſpect to his theological ſentiments, we are aſſured (A) they were in no extreme, but liberal, rational, and manly. He ſeems to have been untainted by that rage of innovation, which of late has ſo completely disfigured the creed, as well religious as political, of the great body of Engliſh diſſenters. The conſequence was, that he lived on terms of friendſhip with men of very oppoſite ſentiments; with Price a republican and Arian, and with Johnſon, who, though he hated a whig and a Preſbyterian, reſpected talents and worth wherever he found them.

We ſhall conclude this ſhort ſketch of Dr Fordyce's life and character with the following liſt of his works, of which ſome have been tranſlated into ſeveral languages. 1. A Sermon and Charge, at the ordination of the Rev. Mr Gibſon Miniſter of St Ninian's, 1754. 2. Another Ordination Sermon on the Eloquence of the Pulpit, annexed to his brother's "Art of Preaching," 1754. 3. A Sermon on the Spirit of Popery, 1754. 4. A Sermon on the Folly, Infamy, and Miſery of Unlawful Pleaſure, 1760. 5. A Sermon on the Death of Dr Lawrence, 1760. 6. Sermons to Young Women, 2 vols. 1765. 7. A Sermon on the Character and Conduct of the Female Sex, 1776. 8. Addreſſes to Young Men, 2 vols. 1777. 9. A Charge at the Ordination of the Rev. James Lindſay, in Monkwell-ſtreet, 1783. 10. Addreſſes to the Deity, 1785. 11. Poems, 1786. 12. A Diſcourſe on Pain, 1791. He alſo re-publiſhed, with an additional character, "The Temple of Virtue, a Dream," written by his brother David.

FORMULA, a theorem or general rule or expreſſion, for reſolving certain particular caſes of ſome problem, &c. So $\frac{1}{2}s + \frac{1}{2}d$ is a general formula for the greater of two quantities whoſe ſum is s and difference d; and $\frac{1}{2}s - \frac{1}{2}d$ is the formula, or general value, for the

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(A) By his ſucceſſor in Monkwell-ſtreet, to whoſe ſermon, preached on occaſion of the Doctor's death, our readers are indebted for every thing valuable in this ſhort memoir.

the leſs quantity. Alſo $\sqrt{dx - x^2}$ is the formula, or general value of the ordinate to a circle, whoſe diameter is *d*, and abſciſs *x*.

FORSTER (John Reinhold, LL. D.) profeſſor of natural hiſtory in the univerſity of Halle, member of the academy of ſciences at Berlin, and of other learned ſocieties, was born at Dirſchau, in Weſt Pruſſia, in the month of October 1729, and was formerly a Proteſtant clergyman at Dantzick. He had a numerous family, and the emoluments of his office were ſlender. He therefore quitted Dantzick, and went, firſt to Ruſſia, and thence to England, in queſt of a better ſettlement than his own country afforded. In the diſſenting academy at Warrington he was appointed tutor in the modern languages, with the occaſional office of lecturing in various branches of natural hiſtory. For the firſt department he was by no means well qualified; his extraordinary knowledge of languages, ancient and modern, being unaccompanied by a particle of taſte; and his uſe of them being all barbarous, though fluent. As a natural hiſtorian, a critic, geographer, and antiquary, he ranked much higher; but unfortunately theſe were acquiſitions of little value in his academical department.

At length he obtained the appointment of naturaliſt and *philoſopher* (if the word may be ſo uſed) to the ſecond voyage of diſcovery undertaken by Capt. Cook; and from 1772 to 1775 he accompanied that immortal navigator round the world. On his return he reſided in London till the improper conduct of himſelf and his ſon made it expedient for them both to leave the kingdom. Fortunately he received an invitation to Halle, where, for 18 years, he was a member of the philoſophical and medical faculties. Among his works are: An Introduction to Mineralogy, or, An accurate Claſſification of Foſſils and Minerals, &c. London, 1768, 8vo. A Catalogue of the Animals of North America, with ſhort Directions for collecting, preſerving, and tranſporting all kinds of Natural Curioſities, London, 1771, 8vo. Obſervations made during a Voyage round the World, on Phyſical Geography, &c. London, 1778. He was the author of a great many productions in Engliſh, Latin, or German, and of ſeveral papers in the Philoſophical Tranſactions. He tranſlated into Engliſh, Bougainville's Voyage round the World, and Kalm's, Boſſu's, and Reidſel's Travels. He was employed likewiſe, when in England, in the Critical Review; and he wrote various detached papers on different ſubjects, which have been inſerted in foreign journals and the tranſactions of learned academies.

He died at Halle on the 16th of December 1798, in the 70th year of his age.

FORSTER (George), the ſon of the preceding, was born at Dantzick, and accompanied his father to England when he was about twelve years of age. He was entered a ſtudent in the academy at Warrington, and ſoon acquired a very perfect uſe of the Engliſh tongue. He alſo diſtinguiſhed himſelf greatly by his attainments in ſcience and literature in general; adding to an excellent memory, quick parts and a fertile imagination. His temper was mild and amiable; in which he much differed from his father, one of the moſt quarrelſome and irritable of men; by which diſpoſition, joined to a total want of prudence in common concerns, he loſt almoſt all the friends his talents had acquired him, and involved himſelf and family in perpetual difficulties.

The caſe was very different with the ſubject of this memoir; for when Dr Forſter was appointed naturaliſt to Captain Cook, his ſon, through the intereſt of the friends whom his good nature had made, was aſſociated with him in his office. The voyage continued during the ſpace of three years; and on their return the two Forſters publiſhed jointly a botanical work in Latin, containing the characters of a number of new *genera* of plants, diſcovered by them in their circumnavigation. Thus far they acted properly in the ſervice of government for the advancement of ſcience; but in publiſhing another work their conduct was not proper.

The father had come under an engagement not to publiſh ſeparately, from the authoriſed narrative, any account of the voyage; and this engagement he and his ſon were determined to violate. An account of the voyage, therefore, was publiſhed in Engliſh and German by *George*; and the language, which is correct and elegant, was undoubtedly his; but thoſe who knew both him and his father, are ſatisfied that the matter proceeded from the joint ſtock of their obſervations and reflections. Several parts of the work, and particularly the elaborate inveſtigations relative to the languages ſpoken by the natives of the South Sea Iſlands, and the ſpeculations concerning their ſucceſſive migrations, are thought to be ſtrongly impreſſed with the genius of the elder Forſter.

That a work thus ſurreptitiouſly uſhered into the world was not patroniſed by thoſe with whom the authors had ſo ungratefully broken faith, could excite no wonder, even though the publication itſelf had been otherwiſe unexceptionable; but this was far from being the caſe. It abounds with reflections injurious to the government whoſe ſervants they had been, and not juſt to the navigators employed on voyages of diſcovery. The younger Forſter, too, had ſome time before publiſhed a book replete with factious ſentiments; and the coldneſs with which he and his father were both treated in conſequence of ſuch conduct, determined them to leave London.

We have already related all that we know of the father, who was recommended to our notice only by his connection with the illuſtrious Cook; and of the ſon, there is a ſhort account in the Monthly Magazine, by Charles Pougens, fraught with thoſe impious and ſeditious reflections which ſo frequently diſgrace a miſcellany, which would otherwiſe be highly valuable. According to this author, George Forſter was deſirous to ſettle in France. Avaricious of glory, and an idolator of liberty, Paris was the city moſt ſuitable to his taſte and character of any in Europe. Notwithſtanding this, he was ſoon conſtrained to leave it: the intereſt of his family demanded this ſacrifice; for a learned man, who ſails round the world, may enrich his memory, but he will not better his fortune. He was accordingly obliged to accept the place of profeſſor of natural hiſtory in the univerſity of Caſſel. But his factious ſpirit accompanied him whitherſoever he went. It is well known, that the petty princes of Germany have long been in the practice of hiring out their troops to more opulent ſovereigns engaged in war. This practice, which we are not diſpoſed to defend, not only ſcandalized our Coſmopolite, but ſo irritated

ritated his temper and offended his pride, becauſe, forſooth, the Prince of Heſſe-Caſſel would not by *him* be perſuaded to relinquiſh it, that he did every thing in his power, we are told, to withdraw himſelf from a ſituation ſo unſuitable to a thinking being. Every thing in his power! Did the Prince retain him in the univerſity contrary to his inclination? The univerſity of Caſſel muſt be contemptible indeed, if the prelections of ſuch a man as George Forſter were of ſuch conſequence to it.

He got away, however; and the ſenate of Poland having offered him a chair in the univerſity of Wilna, Forſter accepted of the invitation. But although this office was very lucrative, and the enlightened patriots of that country did not neglect to procure him all the literary ſuccours of which he ſtood in need, he could not be long happy in a ſemi-barbarous nation, in which liberty was ſuffered to expire under the intrigues of Ruſſia and Pruſſia.

On this, with wonderful conſiſtency, the man who could not endure the deſpotiſm of Heſſe, or even the ariſtocracy of England, accepted of the propoſitions of that friend to liberty Catharine II.; who, jealous of every ſpecies of glory, wiſhed to ſignalize her reign, by procuring to the Ruſſian nation the honour of undertaking, after the example of England and France, a new voyage of diſcovery round the world. Unfortunately for the progreſs of knowledge, the war with the Ottoman Porte occaſioned the miſcarriage of this uſeful project.

But Forſter could not long remain in obſcurity. The different publications with which he occaſionally enriched natural hiſtory and literature, encreaſed his reputation. The Elector of Mentz accordingly appointed him preſident of the univerſity of the ſame name; and he was diſcharging the functions of his new office when the French troops took poſſeſſion of the capital. This philoſophical traveller, who had ſtudied ſociety under all the various aſpects ariſing from different degrees of civilization; who had viewed man ſimple and happy at Otaheite;—an eater of human fleſh in New Zealand, corrupted by commerce in England, depraved in France by luxury and atheiſm, in Brabant by ſuperſtition, and in Poland by anarchy;—beheld with wild enthuſiaſm the dawnings of the French revolution, and was the firſt, ſays M. Pougens, to promulgate republicaniſm in Germany.

The *Mayencois*, who had formed themſelves into a national convention, ſent him to Paris, in order to ſolicit their *reunion* with the French republic. But, in the courſe of his miſſion, the city of Mentz was beſieged and retaken by the Pruſſian troops. This event occaſioned the loſs of all his property; and what was ſtill more diſaſtrous, that of his numerous manuſcripts, which fell into the hands of the Prince of Pruſſia.

Our biographer, after conducting his hero through theſe ſcenes of public life, proceeds to give us a view of his domeſtic habits and private principles. He tells us, that he formed a connection (whether a marriage or not, the ſtudied ambiguity of his language leaves rather uncertain) with a young woman named *Thereſa Hayne*, who, by the illumination of French philoſophy, had diveſted herſelf of all the prejudices which, we truſt, the ladies of this country ſtill conſider as their honour, as they are certainly the guardians of domeſtic peace. Miſs Hayne was indignant at the very *name of duty*. With Eloiſa ſhe had taken it into her head that

> Love, free as air, at ſight of human ties,
> Spreads his light wings, and in a moment dies.

She was frank enough, however, ſays our author, to acknowledge the errors of her imagination; and from this expreſſion, and his calling her afterwards Forſter's wife, we are led to ſuppoſe that ſhe was actually married to him. But their union, of whatever kind, was of ſhort duration. Though the lady is ſaid to have been paſſionately attached to celebrated names, the *name* of George Forſter was not ſufficient to ſatisfy her. He ſoon ceaſed, we are informed, to *pleaſe* her; ſhe therefore transferred her affections to another; and, as was very natural for a woman who was indignant at the name of duty, ſhe proved falſe to her huſband's bed. Forſter, however, pretended to be ſuch a friend to the *modern* rights of men and women, that he defended the character of his Thereſa againſt crowds who condemned her conduct. Nay, we are told, that he conſidered himſelf, and every other huſband who ceaſes to pleaſe, as the *adulterer of nature*. He therefore laboured ſtrenuouſly to obtain a divorce, to enable Thereſa Hayne to eſpouſe the man whom ſhe preferred to himſelf. Strange, however, to tell, the prejudices even of this Coſmopolite were too ſtrong for his principles. While he was endeavouring to procure the divorce, he made preparations at the ſame time, by the ſtudy of the oriental languages, to undertake a journey to Thibet and Indoſtan, in order to remove from that part of the world, in which both his heart and his perſon had experienced ſo ſevere a ſhock. But the chagrin occaſioned by his misfortunes, joined to a ſcorbutic affection, to which he had been long ſubject, and which he had contracted at ſea during the voyage of circumnavigation, abridged his life, and prevented him from realiſing this double project. He died at Paris, at the age of 39, on the 13th of February 1792.

This is a ſtrange tale; but we truſt it will not prove uſeleſs. The latter part of it at leaſt ſhows, that when men diveſt themſelves of the principles of religion, they ſoon degenerate from the dignity of philoſophers to the level of mere ſenſualiſts; and that the woman who can, in defiance of decorum and honour, transfer her affections and her perſon from man to man, ranks no higher in the ſcale of being than a female brute of more than common ſagacity. It ſhews likewiſe, that the contempt of our modern ſages for thoſe partial attachments which unite individuals in one family, is a mere pretence; that the dictates of nature will be heard; and the laws of nature's God obeyed. George Forſter, though he was ſuch a zealous advocate for liberty and equality, as to vindicate the adultery of his wife; yet felt ſo ſenſibly the wound which her infidelity inflicted on his honour, that he could not ſurvive it, but periſhed, in conſequence, in the flower of his age.

Royal FORT, is one whoſe line of defence is at leaſt 26 fathoms long.

Star Fort, is a ſconce or redoubt, conſtituted by re-entering and ſaliant angles, having commonly from five to eight points, and the ſides flanking each other.

FOSSIL-Meal, otherwiſe called *lac lune*, mineral argaric,

argaric, and guhr, is, according to M. Fabbroni, a mixed earth, which exhales an argillaceous odour, and throws out a light whitiſh ſmoke when ſprinkled with water. It is abundant in Tuſcany, where it is employed for cleaning plate. It does not efferveſce with acids; is infuſible in the fire, in which it loſes an eighth part of its weight, though it becomes ſcarcely diminiſhed in bulk; and, according to the analyſis made by M. Fabbroni, conſiſts of the following component parts: Siliceous earth 55, magneſia 15, water 14, argil 12, lime 3, iron 1. With this earth, which is found near Caſteldelpiano in the territories of Sienna, M. Fabbroni compoſed bricks, which, either baked or unbaked, floated in water. Hence he infers, that the floating bricks, which Pliny mentions as peculiar to Maſſilua and Calento, two cities in Spain, muſt have been made of foſſil meal. Bricks made of that ſubſtance reſiſt water exceedingly well, and unite perfectly with lime; they are ſubject to no alteration either by heat or cold; and about a twentieth part of argil may be added with advantage to their compoſition, without depriving them of the property of floating. M. Fabbroni tried their reſiſtance, and found it very little inferior to that of common bricks; but it is much greater in proportion to their lightneſs. One of theſe bricks, ſeven inches in length, four and a half in breadth, and one inch eight lines in thickneſs, weighed only 14¼th ounces; whereas a common brick weighed 5 pounds 6¾ths ounces.

Bricks of foſſil-meal may be of important benefit in the conſtruction of reverberating furnaces; as they are ſuch bad conductors of heat, that a perſon may bring one half of them to a red heat, while the other is held in the hand. They may be employed alſo for buildings that require to be light; for conſtructing cooking places on board ſhips; and alſo floating batteries, the parapets of which, if made of theſe bricks, would be proof againſt red hot bullets; and, laſtly, for conſtructing powder magazines.

FOULAHS, or Foolahs, a people in Africa, inhabiting a country on the confines of the great deſert (ſee Sahara in this *Suppl.*), along the parallel of nine degrees north. They partake much of the negro form and complexion; but have neither the *jetty* colour, *thick* lips, nor *criſped* hair of the negroes. They have alſo a language diſtinct from the Mandinga, which is the prevailing one in this quarter. The Foulahs occupy, at leaſt as ſovereigns, ſeveral provinces or kingdoms, interſperſed throughout the tract comprehended between the mountainous border of the country of Sierra Leona on the weſt, and that of Tombuctoo on the eaſt; as alſo a large tract on the lower part of the Senegal river; and theſe provinces are inſulated from each other in a very remarkable manner. Their religion is Mahomedaniſm; but with a great mixture of Paganiſm, and with leſs intolerance than is practiſed by the Moors.

The principal of the Foulah ſtates is that within Sierra Leona; and of which Teemboo is the capital. The next in order appears to be that bordering on the ſouth of the Senegal river, and on the Jaloffs; this is properly named Siratik. Others of leſs note are Bondou, with Foota-Torra adjacent to it, lying between the rivers Gambia and Falemé; Foola-doo and Brooko along the upper part of the Senegal river; Waſſela beyond the upper part of the Niger; and Maſſina lower down on the ſame river, and joining to Tombuctoo on the weſt.

The kingdom of the Foulahs, ſituated between the upper part of the Gambia river and the coaſt of Sierra Leona, and along the Rio Grande, is governed by a Mahometan ſovereign; but the bulk of the people appear to be Pagans. From the circumſtances of their long hair, their lips, and comparatively light colour, Major Rennel is decidedly of opinion, that the Foulah's are the Leucæthiops of Ptolemy and Pliny. The former, as he obſerves, places the Leucæthiops in the ſituation occupied by the Foulahs; and by the name which he gave them, he evidently meant to deſcribe a people *leſs* black than the generality of the Ethiopians. Hence it may be gathered that this nation had been traded with, and that ſome notices reſpecting it had been communicated to Ptolemy. It may alſo be remarked, that the navigation of Hanno terminated on this coaſt; and as this was alſo the term of Ptolemy's knowledge, it may juſtly be ſuſpected that this part of the coaſt was deſcribed from Carthaginian materials.

Thoſe who have peruſed the Journal of Meſſrs Watt and Winterbottom through the Foulah country in 1794, and recollect how flattering a picture they give of the urbanity and hoſpitality of the Foulah's, will be gratified on finding that this nation was known and diſtinguiſhed from the reſt of the Ethiopians at a remote period of antiquity.

The contraſt between the Mooriſh and Negro characters is as great as that between the nature of their reſpective countries, or between their form and complexion. The Moors appear to poſſeſs the vices of the Arabs without their virtues; and to avail themſelves of an intolerant religion, to oppreſs ſtrangers: whilſt the Negroes, and eſpecially the Mandingas, unable to comprehend a doctrine that ſubſtitutes opinion or belief for the ſocial duties, are content to remain in their humble ſtate of ignorance. The hoſpitality ſhewn by theſe good people to Mr Park, a deſtitute and forlorn ſtranger, raiſes them very high in the ſcale of humanity: and I know of no fitter title, ſays Mr Rennel, to confer on them than that of the *Hindoos of Africa*; at the ſame time, by no means intending to degrade the Mahomedans of India by a compariſon with the African Moors.—See *Major Rennels Geographical Illuſtrations of Mr Park's Journey, and of North Africa at large*, printed for the African Aſſociation.

FRANCAIS (Port des), the name given by Perouſe to a bay, or rather harbour, which he undoubtedly diſcovered on the north-weſt coaſt of America. It is ſituated, according to him, in 58° 37′ N. Lat. and in 139° 50′ W. Long. from Paris. When the two frigates which he commanded approached it, as they were ſtretching along the coaſt from ſouth to north, he perceived from his ſhip a great reef of rocks, behind which the ſea was very calm. This reef appeared to be about three or four hundred toiſes in length from eaſt to weſt, and to be terminated, at about two cables length, by the point of the continent, leaving a pretty large opening; ſo that Nature ſeemed to have made, at the extremity of America, a harbour like that of Toulon, only more vaſt in her deſigns and in her means: this new harbour was three or four leagues deep.

Some officers, who had been diſpatched in boats to reconnoitre this harbour, gave a report of it extremely favourable;

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favourable; and on the 3d of July 1786, the two frigates entered it, and anchored near its mouth in three fathoms and a half, rocky bottom. The bay, however, was quickly ſounded, and much better anchoring ground diſcovered at an iſland in the middle of it, where the ſhips might ride in 20 fathoms water with muddy bottom. This ground was taken poſſeſſion of, an obſervatory erected on the iſland, which was only a muſket ſhot from the ſhips, and a ſettlement formed for their ſtay in the harbour. From a report made by one of the officers who had penetrated towards the bottom of the bay, Perouſe had conceived the idea of finding perhaps a channel by which he might proceed into the interior of America; but he was diſappointed. The bottom of the bay, indeed, according to him, is one of the moſt extraordinary places in the world. It is a baſon of water, of a depth in the middle that could not be fathomed, bordered by peaked mountains of an exceſſive height, covered with ſnow, without a blade of graſs upon this immenſe collection of rocks, condemned by Nature to perpetual ſterility. "I never (ſays he) ſaw a breath of air ruffle the ſurface of this water; it is never troubled but by the fall of enormous pieces of ice, which continually detach themſelves from five different glaciers, and which in falling make a noiſe that reſounds far in the mountains. The air is in this place ſo very calm, and the ſilence ſo profound, that the mere voice of a man may be heard half a league off, as well as the noiſe of ſome ſea birds which lay their eggs in the cavities of theſe rocks."

It was at the extremity of this bay that he was in hopes of finding a paſſage into the interior of America. He imagined that it might terminate in a great river, of which the courſe might lie between two mountains; and that this river might take its ſource in the great lakes to the northward of Canada. Two channels were indeed found, ſtretching, the one to the eaſt, and the other to the weſt; but both were very ſoon terminated by immenſe glaciers.

In Port des Français the variation of the compaſs is 28° eaſt, and the dip of the needle 74°. The ſea riſes there ſeven feet and a half at full and change of the moon, when it is high water at one o'clock. The ſea breezes, or perhaps other cauſes, act ſo powerfully upon the current of the channel, that M. Perouſe ſaw the flood come in there like the moſt rapid river; while, in other circumſtances, at the ſame period of the moon, it may be ſtemmed by a boat. In this channel he loſt two ſhallops and twenty men. In his different excurſions, he found the high water mark to be about 15 feet above the ſurface of the ſea. Theſe tides are probably incident to the bad ſeaſon. When the winds blow with violence from the ſouthward, the channel muſt be impracticable, and at all times the currents render the entrance difficult; the going out of it alſo requires a combination of circumſtances, which may retard the departure of a veſſel many weeks; there is no getting under way but at the top of high water; the breeze from the weſt to the north-weſt does not often riſe till toward eleven o'clock, which does not permit the taking advantage of the morning tide; finally, the eaſterly winds, which are contrary, appeared to him to be more frequent than thoſe from the weſt, and the vaſt height of the ſurrounding mountains never permits the land breezes, or thoſe from the north, to penetrate into the road.

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As this port poſſeſſes great advantages, M. Perouſe thought it a duty incumbent on him to make its inconveniences alſo known. It ſeemed to him that this anchorage is not convenient for thoſe ſhips which are ſent out at a venture for trafficking in ſkins; ſuch ſhips ought to anchor in a great many bays, and always make the ſhorteſt ſtay poſſible in any of them; becauſe the Indians have always diſpoſed of their whole ſtock in the firſt week, and all loſt time is prejudicial to the intereſts of the owners: but a nation which ſhould form the project of eſtabliſhing factories ſimilar to thoſe of the Engliſh in Hudſon's Bay, could not make choice of a place more proper for ſuch a ſettlement. A ſimple battery of four heavy cannon, placed upon the point of the continent, would be fully adequate to the defence of ſo narrow an entrance, which is alſo made ſo difficult by the currents. This battery could not be turned or taken by land, becauſe the ſea always breaks with ſuch violence upon the coaſt, that to diſembark is impoſſible. The fort, the magazines, and all the ſettlements for commerce, ſhould be raiſed upon Cenotaph Iſland (A), the circumference of which is nearly a league: it is capable of being cultivated, and there is plenty of wood and water. The ſhips not having their cargo to ſeek, but being certain of having it collected to a ſingle point, would not be expoſed to any delay: ſome buoys, placed for the internal navigation of the bay, would make it extremely ſafe and eaſy. The ſettlement would form pilots, who, better verſed than we are in the ſet and ſtrength of the current at particular times of tide, would enſure the entrance and departure of the ſhips. Finally, continues the author, our traffic for otters ſkins has been ſo very conſiderable, that I may fairly preſume there could not, in any part of America, be a greater quantity of them collected.

The climate of this coaſt ſeemed to Perouſe much milder than that of Hudſon's Bay in the ſame latitude. Pines were meaſured of ſix feet diameter, and 140 high; while thoſe of the ſame ſpecies at Prince of Wales's Fort and Fort York, are of a dimenſion ſcarce ſufficient for ſtudding ſail-booms. Vegetation is alſo very vigorous during three or four months of the year; and our author thinks, that Ruſſian corn, as well as many common plants, might thrive exceedingly at Port des Français, where was found great abundance of celery, lupine, the wild pea, yarrow, and andive. Among theſe pot herbs were ſeen almoſt all thoſe of the meadows and mountains of France; ſuch as the angelica, the butter cup, the violet, and many ſpecies of graſs proper for fodder. The woods abound in gooſeberries, raſpberries, and ſtrawberries; cluſters of elder trees, the dwarf willow, different ſpecies of briar which grow in the ſhade, the gum poplar tree, the poplar, the ſallow, the horn-beam; and, finally, ſuperb pines, fit for the maſts.

(A) This name was given to the iſland in the bay from the monument erected on it to the memory of their unfortunate companions.

moſts of our largeſt ſhips. Not any of the vegetable productions of this country are unknown in Europe. M. de Martinière, in his different excurſions, met with only three plants which he thought new; and it is well known, that a botaniſt might do the ſame in the vicinity of Paris.

The rivers were filled with trout and ſalmon; and as the Indians ſold theſe fiſh to the French in greater quantities than they could conſume, they had very little fiſhing in the bay, and that only with the line. They caught ſome ling, a ſingle thornback, ſome plaice, *fletans* or *faitans*, of which ſome were more than 100 pounds in weight (b), and a fiſh reſembling the whiting, but a little larger, which abounds on the coaſt of Provence, where it is known by the name of *poor prieſt*. Perouſe calls theſe fiſh *capelans*. In the woods they met with bears, martens, and ſquirrels; but they ſaw no great variety of birds, though the individuals were very numerous.

" If the animal and vegetable productions of this country reſemble thoſe of a great many others, its appearance (ſays our author) can be compared to nothing. The views which it preſents are more frightful than thoſe of the Alps and the Pyrenees; but at the ſame time ſo pictureſque, that they would deſerve the viſits of the curious, were they not at the extremity of the world. The primitive mountains of granite or ſchiſtus, perpetually covered with ſnow, upon which are neither trees nor plants, have their foundation in the ſea, and form upon the ſhore a kind of quay; their ſlope is ſo rapid, that after the firſt two or three hundred toiſes, the wild goats cannot climb them; and all the gullies which ſeparate them are immenſe glaciers, of which the tops cannot be diſcerned, while the baſe is waſhed by the ſea. At a cable's length from the land there is no bottom at leſs than 160 fathoms. The ſides of the harbour are formed by ſecondary mountains, the elevation of which does not exceed from 800 to 900 toiſes; they are covered with pines, and overſpread with verdure, and the ſnow is only ſeen on their ſummits: they appeared to be entirely formed of ſchiſtus, which is in the commencement of a ſtate of decompoſition; they are extremely difficult to climb, but not altogether inacceſſible.

" Nature aſſigns inhabitants to ſo frightful a country, who as widely differ from the people of civilized countries as the ſcene which has juſt been deſcribed differs from our cultivated plains; as rude and barbarous as their ſoil is rocky and barren, they inhabit this land only to deſtroy its population: at war with all the animals, they deſpiſe the vegetable ſubſtances that grow around them. I have ſeen (ſays our author) women and children eat ſome raſpberries and ſtrawberries; but theſe are undoubtedly viands far too inſipid for men, who live upon the earth like vultures in the air, or wolves and tigers in the foreſts.

" Their arts are ſomewhat advanced, and in this reſpect civilization has made conſiderable progreſs; but that which ſoftens their ferocity, and poliſhes their manners, is yet in its infancy. The mode of life they purſue excluding all kind of ſubordination, they are continually agitated by fear or revenge; prone to anger, and eaſily irritated, they are continually attacking each other dagger in hand. Expoſed in the winter to periſh for want, becauſe the chaſe cannot be ſucceſsful, they live during the ſummer in the greateſt abundance, as they can catch in leſs than an hour a ſufficient quantity of fiſh for the ſupport of their family; they remain idle during the reſt of the day, which they paſs at play, to which they are as much addicted as ſome of the inhabitants in our great cities. This gaming is the great ſource of their quarrels. If to all theſe deſtructive vices they ſhould unfortunately add a knowledge of the uſe of any inebriating liquor, M. Perouſe does not heſitate to pronounce, that this colony would be entirely annihilated."

Like all other ſavages, they are incorrigible thieves; and when they aſſumed a mild and placid appearance, the Frenchmen were ſure that they had ſtolen ſomething. Iron, of which they appeared to know the uſe, and of courſe the value, moſt excited their cupidity; and when our navigators were engaged in careſſing a child, the father was ſure to ſeize the opportunity of taking up, and concealing under his ſkin-garment, every thing of that metal which lay within his reach, and was not too heavy to be carried off.

M. Rollin, ſurgeon major of one of the frigates, thus deſcribes theſe people. " They have very little ſimilarity to the Californians; they are taller, ſtouter, of a more agreeable figure, and greater vivacity of expreſſion: they are alſo much their ſuperiors in courage and ſenſe. They have rather a low forehead, but more open than that of the Southern Americans; their eyes are black and very animated; their eyebrows much fuller; their noſe of the uſual ſize, and well formed, except being a little widened at the extremity; their lips thinner; their mouth moderately large; their teeth fine and very even; their chin and ears very regular.

" The women alſo have an equal advantage over thoſe of the preceding tribes; they have much more mildneſs in their features and grace in their limbs.—Their countenance would be even very agreeable, if, in order to ſet it off, they did not make uſe of a ſtrange cuſtom of wearing in the lower lip an elliptical piece of wood, lightly grooved on its circumference and both its ſides, and which is commonly half an inch thick, two in diameter, and three in length.

" This ſingular ornament, beſides being a great deformity, is the cauſe of a very troubleſome as well as diſguſting involuntary flow of ſaliva. This appendage is peculiar to the women; and female children are made to undergo the preparatory operations from the time of their birth. For this purpoſe, the lower lip is pierced with a kind of pin of copper or gold, which is either left in the opening, or its place ſupplied with a ring of the ſame material, till the period of puberty. The aperture is then gradually enlarged, by ſubſtituting firſt a ſmall piece of wood of the form mentioned above, then a larger one; and ſo on, increaſing its ſize by degrees till it reaches the dimenſions juſt ſtated.

" This extraordinary cuſtom ſhews the great power of dilatation in the lip, and may encourage medical prac-

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(b) This is a flat fiſh, longer and not ſo ſquare as the turbet. Its back is covered with ſmall ſcales; and thoſe which are taken in Europe are much leſs than the fletans of Port des Français.

titioners in their attempts to remedy deformities of this part by the uſe of the knife.

“ The general colour of theſe people is olive, a fainter tinge of which is apparent in their nails, which they ſuffer to grow very long; the hue of the ſkin, however, varies in different individuals, and in various parts of the ſame individual, according to their expoſure to the action of the air and ſun.

“ Their hair is, in general, neither ſo coarſe nor black as that of the South Americans. Cheſnut coloured hair is by no means unfrequent among them. Their beard is alſo fuller, and their armpits and parts of ſex better provided with hair.

“ The perfect evenneſs of their teeth led me at firſt to ſuſpect that it was the effect of art; but after an attentive and minute examination, I could perceive no wearing away of the enamel, and I ſaw that this regularity is natural. They tattoo and paint their face and body, and bore their ears and the cartilage of their noſe.

“ Some writers have imagined, that the cuſtom of painting the face and body, ſo generally adopted by the Africans, Americans, and Weſt Indians, is only intended as a preſervative againſt noxious inſects. I think, however, that I am warranted in aſſerting its ſole end to be ornament. I found it to prevail among the inhabitants of Eaſter Iſland and the natives of *Port des Français*, without obſerving among them either venomous inſects or reptiles. Beſides, I remarked that they wore paint only when they paid us a viſit; for they made no uſe of it when in their own houſes.”

M. Perouſe himſelf ſpeaks not ſo favourably of the women as M. Rollin. “ They are (he ſays) the moſt diſguſting of any on the earth, covered with ſtinking ſkins, which are frequently untanned; and yet they failed not to excite deſires in ſome perſons, in fact of no ſmall conſequence: they at firſt ſtarted many difficulties, giving aſſurances by their geſtures that they ran the riſk of their lives; but being overcome by preſents, they had no objection to the ſun being a witneſs, and abſolutely refuſed to retire into the wood.” There can be no doubt that this planet is the god of theſe people, ſince they frequently addreſſed themſelves to it in their prayers; but our voyagers ſaw neither temple nor prieſt, nor the leaſt trace of public worſhip at ſtated times. They burn their dead.

FRE'GATES FRANÇAISE *Baſſe de*, the name given by La Perouſe to a dangerous reef of ſunken rocks which he diſcovered in the Pacific ocean. On the north-weſt extremity of this reef they perceived an iſlet or ſplit rock from 20 to 25 fathoms in height and about 50 toiſes in diameter. From this iſlet the reef extends more than four leagues to the ſouth-eaſt; and upon the extremity of the point in that direction, the frigates had almoſt ſtruck before the breakers were obſerved. This was during a fine clear night and ſmooth ſea. With great propriety, the Commodore returned in the morning to aſcertain the geographical ſituation of this unknown rock; and he eſtimated the iſlet to be in 23° 45′ N. Lat. and 168° 10′ W. Long. from Paris.

FRICTION, in mechanics, is a ſubject of great importance both to the practical engineer and to the ſpeculative philoſopher. It is therefore our duty to correct, in this Supplement, the miſtakes into which we fell when treating of that ſubject in the *Encyclopædia*. What we have there taught of friction (ſee MECHANICS, Sect. II. § 8.) is taken from Ferguſon; but it has been ſhewn by Mr Vince, that the experiments from which his concluſions were drawn were not properly inſtituted. That eminent mathematician and philoſopher therefore entered upon the inveſtigation of the ſubject anew, and endeavoured, by a ſet of experiments, to determine the following queſtions:

1. Whether friction be a uniformly retarding force?
2. The quantity of friction?
3. Whether the friction varies in proportion to the preſſure or weight?
4. Whether the friction be the ſame on whichever of its ſurfaces a body moves?

1. With reſpect to the firſt of theſe queſtions, the author truly obſerves, that if friction be a uniform force, the difference between it and the given force of the moving power employed to overcome it muſt alſo be uniform; and that therefore the moving power, if it be a body deſcending by its own weight, muſt deſcend with a uniformly accelerated velocity, juſt as when there was no friction. The ſpaces deſcribed from the beginning of the motion will indeed be diminiſhed in any given time on account of the friction; but ſtill they muſt be to each other as the ſquares of the times employed. See DYNAMICS in this *Supplement*.

2. A plane was therefore adjuſted parallel to the horizon, at the extremity of which was placed a pulley, which could be elevated or depreſſed, in order to render the ſtring which connected the body and the moving force parallel to the plane. A ſcale accurately divided was placed by the ſide of the pulley perpendicular to the horizon, by the ſide of which the moving force deſcended; upon the ſcale was placed a moveable ſtage, which could be adjuſted to the ſpace through which the moving force deſcended in any given time; which time was meaſured by a well-regulated pendulum clock vibrating ſeconds. Every thing being thus prepared, the following experiments were made to aſcertain the law of friction.

3. *Exp.* 1. A body was placed upon the horizontal plane, and a moving force applied, which, from repeated trials, was found to deſcend 52¼ inches in 4″; for by the beat of the clock, and the ſound of the moving force when it arrived at the ſtage, the ſpace could be very accurately adjuſted to the time: The ſtage was then removed to that point to which the moving force would deſcend in 3″, upon ſuppoſition that the ſpaces deſcribed by the moving power were as the ſquares of the times; and the ſpace was found to agree very accurately with the time: the ſtage was then removed to that point to which the moving force ought to deſcend in 2″, upon the ſame ſuppoſition, and the deſcent was found to agree exactly with the time: laſtly, the ſtage was adjuſted to that point to which the moving force ought to deſcend in 1″, upon the ſame ſuppoſition, and the ſpace was obſerved to agree with the time. Now, in order to find whether a difference in the time of deſcent could be obſerved by removing the ſtage a little above and below the poſitions which correſponded to the above times, the experiment was tried, and the deſcent was always found too ſoon in the former, and too late in the latter caſe; by which the author was aſſured, that the ſpaces firſt mentioned correſponded exactly to the times. And, for the greater certainty, each deſcent was repeated eight or ten times;

and

and every caution uſed in this experiment was alſo made uſe of in all the following.

Exp. 2. A ſecond body was laid upon the horizontal plane, and a moving force applied which deſcended $41\frac{3}{4}$ inches in 3″; the ſtage was then adjuſted to the ſpace correſponding to 2″, upon ſuppoſition that the ſpaces deſcended through were as the ſquares of the times, and it was found to agree accurately with the time; the ſtage was then adjuſted to the ſpace correſponding to 1″, upon the ſame ſuppoſition, and it was found to agree with the time.

Exp. 3. A third body was laid upon the horizontal plane, and a moving force applied, which deſcended $59\frac{5}{8}$ inches in 4″; the ſtage was then adjuſted to the ſpace correſponding to 3″, upon ſuppoſition that the ſpaces deſcended through were as the ſquares of the times, and it was found to agree with the time; the ſtage was then adjuſted to the ſpace correſponding to 2″, upon the ſame ſuppoſition, and it was found to agree with the time; the ſtage was then adjuſted to the ſpace correſponding to 1″, and was found to agree with the time.

Exp. 4. A fourth body was then taken and laid upon the horizontal plane, and a moving force applied, which deſcended 55 inches in 4″; the ſtage was then adjuſted to the ſpace through which it ought to deſcend in 3″, upon ſuppoſition that the ſpaces deſcended through were as the ſquares of the times, and it was found to agree with the time; the ſtage was then adjuſted to the ſpace correſponding to 2″, upon the ſame ſuppoſition, and was found to agree with the time; laſtly, the ſtage was adjuſted to the ſpace correſponding to 1″, and it was found to agree exactly with the time.

Beſides theſe experiments, a great number of others were made with hard bodies, or thoſe whoſe parts ſo firmly cohered as not to be moved *inter ſe* by the friction; and, in each experiment, bodies of very different degrees of friction were choſen, and the reſults all agreed with thoſe related above; we may therefore conclude, that the *friction of hard bodies in motion is a uniformly retarding force.*

But to determine whether the ſame was true for bodies when covered with cloth, woollen, &c. experiments were made in order to aſcertain it; when it was found, in all caſes, that the retarding force increaſed with the velocity; but, upon covering bodies with paper, the conſequences were found to agree with thoſe related above.

4. Having proved that the retarding force of all hard bodies ariſing from friction is uniform, the quantity of friction, conſidered as equivalent to a weight without inertia drawing the body on the horizontal plane backwards, or acting contrary to the moving force, may be immediately deduced from the foregoing experiments. For let M = the moving force expreſſed by its weight; F = the friction; W = the weight of the body upon the horizontal plane; S = the ſpace through which the moving force deſcended in the time t expreſſed in ſeconds; $r = 16\frac{1}{12}$ feet; then the whole accelerative force (the force of gravity being unity) will be $\frac{M-F}{M+W}$; hence, by the laws of uniformly accelerated motions, $\frac{M-F}{M+W} \times r t^2 = S$, conſequently $F = M - \frac{\overline{M \times W} \times S}{r t^2}$. To exemplify this, let us take the caſe of the laſt experiment, where $M = 7$, $W = 25\frac{3}{4}$, $S = 4\frac{7}{12}$ feet, $t = 4''$; hence $F = 7 - \frac{32\frac{3}{4} \times 4\frac{7}{12}}{16\frac{1}{12} \times 16} = 6.417$; conſequently the friction was to the weight of the rubbing body as 6.4167 to 25.75. And the great accuracy of determining the friction by this method is manifeſt from hence, that if an error of one inch had been made in the deſcent (and experiments carefully made may always determine the ſpace to a much greater exactneſs), it would not have affected the concluſion $\frac{1}{800}$dth part of the whole.

5. We come, in the next place, to determine whether friction, *cæteris paribus*, varies in proportion to the weight or preſſure. Now if the whole quantity of the friction of a body, meaſured by a weight without inertia equivalent to the friction drawing the body backwards, increaſes in proportion to its weight, it is manifeſt that the retardation of the velocity of the body ariſing from the friction will not be altered; for the retardation varies as $\frac{\text{Quantity of friction}}{\text{Quantity of matter}}$; hence, if a body be put in motion upon the horizontal plane by any moving force, if both the weight of the body and the moving force be increaſed in the ſame ratio, the acceleration ariſing from that moving force will remain the ſame, becauſe the accelerative force varies as the moving force divided by the whole quantity of matter, and both are increaſed in the ſame ratio; and if the quantity of friction increaſes alſo as the weight, then the retardation ariſing from the friction will, from what has been ſaid, remain the ſame, and therefore the whole acceleration of the body will not be altered; conſequently the body ought, upon this ſuppoſition, ſtill to deſcribe the ſame ſpace in the ſame time. Hence, by obſerving the ſpaces deſcribed in the ſame time, when both the body and the moving force are increaſed in the ſame ratio, we may determine whether the friction increaſes in proportion to the weight. The following experiments were therefore made in order to aſcertain this matter:

Exp. 1. A body weighing 10 oz. by a moving force of 4 oz. deſcribed in 2″ a ſpace of 51 inches; by loading the body with 10 oz. and the moving force with 4 oz. it deſcribed 56 inches in 2″; and by loading the body again with 10 oz. and the moving force with 4 oz. it deſcribed 63 inches in 2″.

Exp. 2. A body, whoſe weight was 16 oz. by a moving force of 5 oz. deſcribed a ſpace of 49 inches in 3″; and by loading the body with 64 oz. and the moving force with 20 oz. the ſpace deſcribed in the ſame time was 64 inches.

Exp. 3. A body weighing 6 oz. by a moving force of $2\frac{1}{2}$ oz. deſcribed 28 inches in 2″; and by loading the body with 24 oz. and the moving force with 10 oz. the ſpace deſcribed in the ſame time was 54 inches.

Exp. 4. A body weighing 8 oz. by a moving force of 4 oz. deſcribed $33\frac{1}{2}$ inches in 2″; and by loading the body with 8 oz. and the moving force with 4 oz. the ſpace deſcribed in the ſame time was 47 inches.

Exp. 5. A body whoſe weight was 9 oz. by a moving force of $4\frac{1}{2}$ oz. deſcribed 48 inches in 2″; and by loading the body with 9 oz. and the moving force with $4\frac{1}{2}$ oz. the ſpace deſcribed in the ſame time was 60 inches.

Exp. 6. A body weighing 10 oz. by a moving force of

3 oz.

3 oz. deſcribed 20 inches in 2″; by loading the body with 10 oz. and the moving force with 3 oz. the ſpace deſcribed in the ſame time was 31 inches; and by loading the body again with 30 oz. and the moving force with 9 oz. the ſpace deſcribed was 34 inches in 2″.

From theſe experiments, and many others which it is not neceſſary here to relate, it appears, that the ſpace deſcribed is always increaſed by increaſing the weight of the body and the accelerative force in the ſame ratio; and as the acceleration ariſing from the moving force continued the ſame, it is manifeſt, that the retardation ariſing from the friction muſt have been diminiſhed, for the whole accelerative force muſt have been increaſed on account of the increaſe of the ſpace deſcribed in the ſame time; and hence (as the retardation from friction varies as $\frac{\text{Quantity of friction}}{\text{Quantity of matter}}$) *the quantity of friction increaſes in a leſs ratio than the quantity of matter or weight of the body.*

6. We come now to the laſt thing which it was propoſed to determine, that is, whether the friction varies by varying the ſurface on which the body moves. Let us call two of the ſurfaces A and *a*, the former being the greater, and the latter the leſs. Now the weight on every given part of *a* is as much greater than the weight on an equal part of A, as A is greater than *a*; if therefore the friction was in proportion to the weight, *cæteris paribus*, it is manifeſt, that the friction on *a* would be equal to the friction on A, the whole friction being, upon ſuch a ſuppoſition, as the weight on any given part of each ſurface multiplied into the number of ſuch parts or into the whole area, which products, from the proportion above, are equal. But from the laſt experiments it has been proved, that the friction on any given ſurface increaſes in a leſs ratio than the weight; conſequently the friction on any given part of *a* has a leſs ratio to the friction on an equal part of A than A has to *a*, and hence the friction on *a* is leſs than the friction on A, that is, the ſmalleſt ſurface has always the leaſt friction.

As this concluſion is contrary to the generally received opinion, Mr Vince thought it proper to confirm it by a ſet of experiments made with different bodies of exactly the ſame degree of roughneſs on their two ſurfaces.

Exp. 1. A body was taken whoſe flat ſurface was to its edge as 22 : 9, and with the ſame moving force the body deſcribed on its flat ſide $33\frac{1}{2}$ inches in 2″, and on its edge 47 inches in the ſame time.

Exp. 2. A ſecond body was taken whoſe flat ſurface was to its edge as 32 : 3, and with the ſame moving force it deſcribed on its flat ſide 32 inches in 2″, and on its edge it deſcribed $37\frac{1}{2}$ inches in the ſame time.

Exp. 3. He took another body and covered one of its ſurfaces, whoſe length was 9 inches, with a fine rough paper, and by applying a moving force, it deſcribed 25 inches in 2″; he then took off ſome paper from the middle, leaving only $\frac{3}{8}$ths of an inch at the two ends, and with the ſame moving force it deſcribed 40 inches in the ſame time.

Exp. 4. Another body was taken which had one of its ſurfaces, whoſe length was 9 inches, covered with a fine rough paper, and by applying a moving force it deſcribed 42 inches in 2″; ſome of the paper was then taken off from the middle, leaving only $1\frac{3}{8}$ inches at the two ends, and with the ſame moving force it deſcribed 54 inches in 2″; he then took off more paper, leaving only $\frac{1}{4}$ of an inch at the two ends, and the body then deſcribed, by the ſame moving force, 60 inches in the ſame time.

In the two laſt experiments the paper which was taken off the ſurface was laid on the body, that its weight might not be altered.

Exp. 5. A body was taken whoſe flat ſurface was to its edge as 30 : 17; the *flat* ſide was laid upon the horizontal plane, a moving force was applied, and the ſtage was fixed in order to ſtop the moving force, in conſequence of which the body would then go on with the velocity acquired until the friction had deſtroyed all its motion; when it appeared from a mean of 12 trials that the body moved, after its acceleration ceaſed, $5\frac{2}{7}$ inches before it ſtopped. The *edge* was then applied, and the moving force deſcended through the ſame ſpace; and it was found, from a mean of the ſame number of trials, that the ſpace deſcribed was $7\frac{1}{7}$ inches before the body loſt all its motion, after it ceaſed to be accelerated.

Exp. 6. Another body was then taken whoſe flat ſurface was to its edge as 60 : 19, and by proceeding as before, on the flat ſurface it deſcribed, at a mean of 12 trials, $5\frac{1}{8}$ inches, and on the edge $6\frac{11}{24}$ inches, before it ſtopped, after the acceleration ceaſed.

Exp. 7. Another body was taken whoſe flat ſurface was to its edge as 26 : 3, and the ſpaces deſcribed on theſe two ſurfaces, after the acceleration ended, were, at a mean of ten trials, $4\frac{3}{7}$ and $7\frac{7}{10}$ inches reſpectively.

From all theſe different experiments it appears, that the ſmalleſt ſurface had always the leaſt friction, which agrees with the conſequence deduced from the conſideration that the friction does not increaſe in ſo great a ratio as the weight; we may therefore conclude, that *the friction of a body does not continue the ſame when it has different ſurfaces applied to the plane on which it moves, but that the ſmalleſt ſurface will have the leaſt friction.*

To the experiments inſtituted by Mr Ferguſon and others, from which concluſions have been drawn ſo different from theſe, our author makes the following objections: It was their object to find what moving force would *juſt* put a body at reſt in motion; and having, as they thought, found it, they thence concluded, that the accelerative force was then equal to the friction. But it is manifeſt, as Mr Vince obſerves, that any force which will put a body in motion muſt be *greater* than the force which oppoſes its motion, otherwiſe it could not overcome it; and hence, if there were no other objection than this, it is evident, that the friction could not be very accurately obtained: but there is another objection which totally deſtroys the experiment ſo far as it tends to ſhew the quantity of friction, which is the ſtrong coheſion of the body to the plane when it lies at reſt; and this is confirmed by the following experiments. *1ſt*, A body of $12\frac{3}{4}$ oz. was laid upon an horizontal plane, and then loaded with a weight of 8 lb. and ſuch a moving force was applied as would, when the body was juſt *put* in motion, continue that motion without any acceleration; in which caſe the friction muſt be juſt equal to the accelerative force. The body was then ſtopped, when it appeared that the ſame moving force which had *kept* the body in motion before,

fore, would not *put* it in motion, and it was found neceſſary to take off 4½ oz. from the body before the ſame moving force *would* put it in motion; it appears therefore, that this body, when laid upon the plane, at reſt, acquired a very ſtrong coheſion to it. 2*dly*, A body whoſe weight was 16 oz. was laid at reſt upon the horizontal plane, and it was found that a moving force of 6 oz. would juſt *put* it in motion; but that a moving force of 4 oz. *would*, when it was juſt put in motion, *continue* that motion without any acceleration, and therefore the accelerative force muſt *then* have been equal to the friction, and not when the moving force of 6 oz. was applied.

From theſe experiments, therefore, it appears how very conſiderable the coheſion was in proportion to the friction when the body was in motion; it being, in the latter caſe, almoſt ⅓d, and in the former it was found to be very nearly equal to the whole friction. All the concluſions therefore deduced from the experiments, which have been inſtituted to determine the friction from the force neceſſary to *put* a body in motion, have manifeſtly been totally falſe; as ſuch experiments only ſhew the reſiſtance which ariſes from the coheſion and friction conjointly.

Our author concludes this part of his ſubject with the following remark upon n° 5: "It appears from all the experiments (ſays he) which I have made, that the proportion of the increaſe of the friction to the increaſe of the weight was different in all the different bodies which were made uſe of; no general rule therefore can be eſtabliſhed to determine this for *all* bodies, and the experiments which I have hitherto made have not been ſufficient to determine it for the *ſame* body."

He then proceeds to eſtabliſh a theory upon the principles which he has deduced from his experiments. That theory is comprehended in five propoſitions, of which the object of the firſt is "to find the time of deſcent, and the number of revolutions made by a cylinder rolling down an inclined plane in conſequence of its friction.

II. "To determine the ſpace through which a body, projected on an horizontal plane with a given velocity, will move before it ſtops, or before its motion becomes uniform.

III. "To find the centre of friction.

IV. "To determine, from the given velocity with which a body begins to revolve about the centre of its baſe, the number of revolutions which that body will make before all its motion be deſtroyed.

V. "To find the nature of the curve deſcribed by any point of a body affected by friction when it deſcends down any inclined plane."

To give the ſolutions of theſe problems, with the corollaries deduced from them, would ſwell this article to very little purpoſe; for they would be unintelligible to the mere mechanic, and the mathematician will either ſolve them for himſelf, or have recourſe to the original memoir, where he will find ſolutions at once elegant and perſpicuous.

FRIGORIFIC Mixtures, are thoſe which experience has taught philoſophers to employ for the purpoſe of producing artificial cold. Some of theſe mixtures are enumerated, under the title Cold (*Encycl.*), and a much more accurate liſt of them is given, together with the principle upon which they produce their effect, in the article Chemistry, n° 282. (*Suppl.*). There is one mixture, however, not mentioned in that liſt, which was employed by Seguin, and ſeems, on many accounts, to be the moſt eligible that has yet been propoſed. Conſidering the muriats (ſee Chemistry-*Index, Suppl.*) as a claſs of ſalts beſt ſuited for the purpoſe, he gave the decided preference to muriat of lime in cryſtals; and his method was to mix the cryſtals, previouſly pulveriſed, with an equal weight of uncompreſſed ſnow.

By means of this mixture Mr W. H. Pepys junior, of the London Philoſophical Society, with the aſſiſtance of ſome friends, froze, on the 8th of February 1799, 56 lbs. averdupoiſe of mercury into a ſolid maſs. The mercury was put into a ſtrong bladder and well ſecured at the mouth, the temperature of the laboratory at the time being + 33°. A mixture conſiſting of muriat of lime 2 lb. at + 33°, and the ſame weight of ſnow at + 32° gave — 42° (a). The mercury was put as gently as poſſible into this mixture (to prevent a rupture of the bladder), by means of a cloth held at the four corners. When the cold mixture had robbed the mercury of ſo much of its heat as to have its own temperature thereby raiſed from — 42° to + 5, another mixture, the ſame in every reſpect as the laſt, was made, which gave, on trial with the thermometer, — 43°. The mercury was now received into the cloth, and put gently into this new mixture, where it was left to be cooled ſtill lower than before.

In the mean time five pounds of muriat of lime, in a large pail made of tinned iron, and japanned inſide and outſide, was placed in a cooling mixture in an earthenware pan. The mixture in the pan, which conſiſted of 4 lb. of muriat of lime and a like quantity of ſnow, of the ſame temperature as the former, in one hour reduced the 5 lb. of muriat in the pail to — 15°. The mixture was then emptied out of the earthen pan, and four large corks, at proper diſtances, placed on its bottom, to ſerve as reſts for the japanned pail which was now put into the pan. The corks anſwered the purpoſe of inſulating the inner veſſel, while the exterior one kept off the ſurrounding atmoſphere, and preſerved the air between the two at a low temperature.

To the 5 lb. of muriat of lime which had been cooled, as already noticed, to — 15°, and which ſtill remained in the metallic veſſel, was now added ſnow, uncompreſſed and free from moiſture, at the uſual temperature of + 32°. In leſs than three minutes the mixture gave a temperature of — 62°: a degree of cold which perhaps was never before produced in this country, being 94° below the freezing point of water.

The mercury, which, by immerſion in the ſecond cooling mixture to which it was expoſed, was by this time reduced to — 30°, was now, by the means employed before, cautiouſly put into the laſt-made mixture of the temperature of — 62°. A hoop with net-work faſtened to its upper edge, and of ſuch a breadth in the rim

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(a) The thermometer made uſe of in this experiment was filled with tinged alcohol, and accurately divided according to Fahrenheit's ſcale.

Frigorific.

rim that the net-work, when loaded with the bladder of mercury, could not reach its lower edge, was at the bottom of the mixture, to prevent the bladder from coming in contact with the veſſel; by which means the mercury was ſuſpended in the middle of the mixture. As ſoon as the bladder was ſafely depoſited on the net-work, the veſſels were carefully covered over with a cloth, to impede the paſſage of heat from the ſurrounding atmoſphere into the freezing materials. The condenſation of moiſture from the atmoſphere by the agency of ſo low a temperature was greater than could have been expected: it floated like ſteam over the veſſels, and, but for the interpoſed covering, would have given the mixture more temperature than was deſirable.

After one hour and forty minutes they found, by means of a ſearcher introduced for the purpoſe, that the mercury was ſolid and fixed. The temperature of the mixture at this time was — 46, that is, 16° higher than when the mercury was put into it.

Our young philoſophers having neglected to fling the hoop and net-work in ſuch a manner as might have enabled them to lift it out of the mixture at once, with the bladder and its contents, were obliged to turn out the whole contents of the pail into a large evaporating capſule made of iron. This was not effected without the mercury ſtriking againſt its bottom and being fractured, though it received a conſiderable increaſe of temperature from the capſule. The fracture was ſimilar to that of zinc, but with parts more cubical. The larger pieces were kept for ſome minutes before fuſion took place, while others were twiſted and bent into various forms, to the no ſmall gratification and ſurpriſe of thoſe who never witneſſed or expected to ſee ſuch an effect produced on ſo fuſible a metal.

In experiments of the kind here deſcribed, all the exterior veſſels ſhould be of earthen-ware or wood, which being bad conductors of heat, prevent the ingredients from receiving heat from the atmoſphere and ſurrounding objects with the ſame facility that they would through metals; and, for a ſimilar reaſon, the interior veſſels are beſt of metal, that they may allow the heat to paſs more readily from the ſubſtance to be cooled into the frigorific mixture employed for that purpoſe.

Muriat of lime is certainly the moſt powerful, and at the ſame time the moſt economical ſubſtance that can be employed for producing artificial cold; for its firſt coſt is a mere trifle, being a reſiduum from many chemical proceſſes, as the diſtillation of pure ammonia, &c. and often thrown away: beſides, it may be repeatedly uſed for ſimilar experiments, nothing being neceſſary for this purpoſe but filtration and evaporation to bring it to its firſt ſtate. The evaporation ſhould be carried on till the ſolution becomes as thick as a ſtrong ſyrup, and upon cooling the whole will be cryſtalliſed: it muſt then be powdered, put up in dry bottles, well corked, and covered with bladder or cement to prevent liquefaction; which otherwiſe would ſoon take place, owing to the great affinity the muriat has for moiſture.

The powerful effects produced by the frigorific mixture of muriat of lime and ſnow, preſent a wide field for experiments to determine the poſſibility of fixing ſome of the gaſes by intenſe cold. And we are happy to be informed by Mr Pepys, that, as ſoon as an opportunity offers, he and his friends mean to make ſome experiments with that view, and to communicate the reſult of them to the editor of the valuable miſcellany * from which we have taken this account of his experiment on mercury.

Frio
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Fuel

* The Philoſophical Magazine.

FRIO, a ſmall iſland on the coaſt of the Brazils, ſituated in 32° 2′ ſouth lat. and 41° 31′ 45″ weſt lon. The land of Frio is high, with a hollow in the middle, which gives it, at a diſtance, the reſemblance of two ſeparate iſlands. The paſſage between the iſland and the continent is about a mile broad, and ſeemed to Sir Eraſmus Gower to be clear from ſhoals.

FROST, as is well known in Scotland, is particularly deſtructive to the bloſſom of fruit trees; and the following method of ſecuring ſuch trees from being damaged by early froſts may be acceptable to many of our readers. A rope is to be interwoven among the branches of the tree, and one end of it brought down ſo as to be immerſed in a bucket of water. The rope, it is ſaid, will act as a conductor, and convey the effects of the froſt from the tree to the water. This idea is not new; for the following paſſage may be found in Colerus: "If you dig a trench around the root of a tree, and fill it with water, or keep the roots moiſt till it has bloomed, it will not be injured by the froſt. Or, in ſpring, ſuſpend a veſſel filled with water from the tree. If you wiſh to preſerve the bloom from being hurt by the froſt, place a veſſel of water below it, and the froſt will fall into it." *Philoſophical Magazine*, n° 11.

FUEL, whatever is proper to burn, or make a fire, either for warming a room or dreſſing victuals. The fuel moſt generally uſed in Great Britain is pit-coal, which is a very expenſive article; and that expence is greatly increaſed by the waſte of coal occaſioned by the injudicious manner in which fires in open chimneys are commonly managed. The enormous waſte of fuel in London, for inſtance, may be eſtimated by the vaſt dark cloud which continually hangs over that great metropolis, and frequently overſhadows the whole country far and wide; for this denſe cloud is certainly compoſed almoſt entirely of unconſumed coal, which has eſcaped by the chimneys, and continues to ſail about in the air, till, having loſt the heat which gave it volatility, it falls in a dry ſhower of extremely fine black duſt to the ground, obſcuring the atmoſphere in its deſcent, and frequently changing the brighteſt day into more than Egyptian darkneſs.

"I never (ſays Court Rumford) view from a diſtance, as I come into town, this black cloud which hangs over London, without wiſhing to be able to compute the immenſe number of chaldrons of coals of which it is compoſed; for could this be aſcertained, I am perſuaded ſo ſtriking a fact would awaken the curioſity, and excite the aſtoniſhment of all ranks of the inhabitants; and perhaps turn their minds to an object of economy to which they have hitherto paid little attention."

The object to which the benevolent author more particularly wiſhes to direct the public attention, is the lighting of a coal fire, in which more wood ſhould be employed than is commonly uſed, and fewer coals; and as ſoon as the fire burns bright, and the coals are well lighted, and not before, more coals ſhould be added to increaſe the fire to its proper ſize.

Kindling balls, compoſed of equal parts of coal,—charcoal,—and clay, the two former reduced to a fine powder,

powder, well mixed and kneaded together, with the clay moiſtened with water, and then formed into balls of the ſize of hens eggs, and thoroughly dried, might be uſed with great advantage inſtead of wood for kindling fires. Theſe kindling balls may be made ſo inflammable as to take fire in an inſtant and with the ſmalleſt ſpark, by dipping them in a ſtrong ſolution of nitre, and then drying them again; and they would neither be expenſive nor liable to be ſpoiled by long keeping. Perhaps a quantity of pure charcoal, reduced to a very fine powder, and mixed with the ſolution of nitre in which they are dipped, would render them ſtill more inflammable.

The Count thinks that the fires which are made in the open chimneys of elegant apartments might be greatly improved by preparing the fuel; for nothing (ſays he) was ever more dirty, inelegant, and diſguſting, than a common coal fire.

Fire balls, of the ſize of gooſe eggs, compoſed of coal and charcoal in powder, mixed up with a due proportion of wet clay, and well dried, would make a much more cleanly, and in all reſpects a pleaſanter fire, than can be made with crude coals; and, he believes, would not be more expenſive fuel. In Flanders, and in ſeveral parts of Germany, and particularly in the duchies of Juliers and Bergen, where coals are uſed as fuel, the coals are always prepared before they are uſed, by pounding them to a powder, and mixing them up with an equal weight of clay, and a ſufficient quantity of water to form the whole into a maſs, which is kneaded together and formed into cakes; which cakes are afterwards well dried and kept in a dry place for uſe. And it has been found, by long experience, that the expence attending this preparation is amply repaid by the improvement of the fuel. The coals, thus mixed with clay, not only burn longer, but give much more heat than when they are burnt in their crude ſtate.

It will doubtleſs appear extraordinary to thoſe who have not conſidered the ſubject with ſome attention, that the quantity of heat produced in the combuſtion of any given quantity of coals ſhould be increaſed by mixing the coals with clay, which is certainly an incombuſtible body; but the phenomenon may be explained in a ſatisfactory manner.

The heat generated in the combuſtion of any ſmall particle of coal exiſting under two diſtinct forms, namely, in that which is combined with the flame and ſmoke which riſe from the fire, and which, if means are not found to ſtop it, goes off immediately by the chimney and is loſt—and the radiant heat which is ſent off from the fire in all directions in right lines:—It is therefore reaſonable to conclude, that the particles of clay, which are ſurrounded on all ſides by the flame, arreſt a part at leaſt of the combined heat, and prevent its eſcape; and this combined heat, ſo arreſted, heating the clay red hot, is retained in it, and being changed by this operation to radiant heat, is afterwards emitted, and may be directed and employed to uſeful purpoſes. In the compoſition of fire-balls, the Count thinks it probable that a certain proportion of chaff, of ſtraw cut very fine, or even of ſaw-duſt, might be employed with great advantage.

FULLING of woollen cloths (ſee the method of performing the operation under the article Fulling, *Encycl.*) depends, like Felting, ſo entirely upon the ſtructure of wool and hair, that the following obſervations, which are not unimportant, will be intelligible to every reader who has peruſed that article in this *Supplement*.

The aſperities with which the ſurface of wool is every where ſurrounded, and the diſpoſition which it has to aſſume a progreſſive motion towards the root, render the ſpinning of wool, and making it into cloth, difficult operations. In order to ſpin wool, and afterwards to weave it, we are obliged to cover its fibres with a coating of oil, which, filling the cavities, renders the aſperities leſs ſenſible; in the ſame way as oil, when rubbed over the ſurface of a very fine file, renders it ſtill leſs rough. When the piece of cloth is finiſhed, it muſt be cleanſed from this oil; which, beſides giving it a diſagreeable ſmell, would cauſe it to ſoil whatever it came in contact with, and would prevent its taking the colour which is intended to be given to it by the dyer. To deprive it of the oil, it is carried to the fulling-mill, where it is beat with hammers in a trough full of water, in which ſome clay has been mixed; the clay combines with the oil, which it ſeparates from the cloth, and both together are waſhed away by the freſh water which is brought to it by the machine; thus, after a certain time, the oil is entirely waſhed out of the cloth.

But the ſcouring of the cloth is not the only object in fulling it; the alternate preſſure given by the mallets to the piece of cloth, occaſions, eſpecially when the ſcouring is pretty far advanced, an effect analogous to that which is produced upon hats by the hands of the hatter; the fibres of wool which compoſe one of the threads, whether of the warp or the woof, aſſume a progreſſive movement, introduce themſelves among thoſe of the threads neareſt to them, then into thoſe which follow; and thus, by degrees, all the threads, both of the warp and the woof, become felted together. The cloth, after having, by the above means, become ſhortened in all its dimenſions, partakes both of the nature of cloth and of that of felt; it may be cut without being ſubject to ravel, and, on that account, we are not obliged to hem the edges of the pieces of which clothes are made. Laſtly, As the threads of the warp and thoſe of the woof are no longer ſo diſtinct and ſeparated from each other, the cloth, which has acquired a greater degree of thickneſs, forms a warmer clothing. Knit worſted alſo is, by fulling, rendered leſs apt to run, in caſe a ſtitch ſhould drop in it.

FULMINATING Gold. } See Chemistry, *Suppl.*
Fulminating Silver. } nos 849 and 850.

Mr Berthollet, the inventor of fulminating ſilver, having contented himſelf with a general and conciſe deſcription of this ſubject, many practical chemiſts have failed in their attempts to prepare it; and others, forming their opinions from the ſpecimens which they had made, have been expoſed to great danger; as will appear from the following relation:

An ounce of fine ſilver was diſſolved in the courſe of eight hours in an ounce of pure nitrous acid, of the London Pharmacopœia, diluted previouſly with three ounces of diſtilled water in a glaſs matraſs. The ſolution being poured off, the reſiduary black powder and the matraſs were waſhed with ſeven or eight ounces of warm diſtilled water, and this was added to the ſolution. The black powder, being gold, was rejected; ſome gold being thus ſeparable from any ſilver of commerce.

To the foregoing diluted ſolution, pure lime-water prepared with diſtilled water was added gradually; for the ſolution ought not to be poured into the lime water. When about thirty pints of lime-water had been expended, and the precipitate had ſubſided, more lime-water was added, by ſucceſſive pints, as long as it cauſed any precipitation. For it was deemed fitter that the precipitation ſhould not be perfected, than that an exceſs of lime-water ſhould be uſed; the earthy pellicle of the exceſſive lime-water being apt to mix with the precipitate. The clear liquor being poured away, the precipitate was poured off, and waſhed into a filter.

When the ſaline liquor had drained from it, two ounces of diſtilled water were poured on the magma; and when this water had paſſed, freſh portions were ſucceſſively added and paſſed, until the whole quantity of water thus expended in waſhing away the nitrous calcareous ſalt amounted to a quart.

The filter being then unfolded, to let the magma of oxide of ſilver ſpread on the flattened paper, it was placed on a chalk-ſtone to accelerate the exſiccation, and was gradually dried in the open air; a cap of paper being placed looſely over it to exclude the duſt.

When the weather ſerved, the cap was removed, to expoſe the oxide to the rays of the ſun; although this was not deemed neceſſary; and exſiccation was promoted by cutting the oxide into thin ſlices. When perfectly dry it weighed 1 oz. 4 dwts. and about one-fifth of it was conſidered as oxygen.

When aqua ammoniæ puræ of any pharmacopœia is uſed with this oxide, either in the ſmall quantity which blackens it completely, or in a greater quantity, the black matter which ſubſides, and which has been repreſented by ſyſtematic writers as the fulminating compound, has no ſuch property, any farther than may be owing to the matter depoſited from the alkaline ſolution during the exſiccation.

The alkaline liquor containing the fulminating ſilver ought to be poured off from the inſoluble powder, and expoſed in a ſhallow veſſel to the air. In conſequence of the exhalation, black ſhining cryſtals form on the ſurface only, and ſoon join to form a pellicle. As this pellicle adheres a little to the ſides of the veſſel, or maintains its figure, the liquor may be poured off by a gentle inclination of the veſſel.

This liquor will yield another pellicle in the ſame way; but the third or fourth pellicle will be paler than the former, and weaker in the exploſion. The firſt pellicles, when ſlowly dried, explode by the touch of a feather, or by their being heated to about 96°.

The quantity of water in the ordinary aqua ammoniæ puræ renders it leſs active in the ſolution of the oxide, and is an impediment to the ſpeedy formation and ſeparation of the fulminating ſilver; and an experimenter who has often uſed twenty grains of the oxide to produce ſucceſſive pellicles of fulminating ſilver, which may be ſeparately exploded with ſafety, and who has perceived that the pellicles never explode whilſt wet, if they be not heated, would, in all probability, reſolve on the following improvement, and expoſe himſelf to the unforeſeen danger of it.

Diſtilled water was impregnated with as much pure ammoniac as it could eaſily retain under the ordinary temperature of the air. A quantity of this ſtrong ammoniacal liquor, equal in bulk to a quarter of an ounce of water, was placed in a ſmall bottle, and 24 grains of the oxide of ſilver, ground to fine powder, were added. The bottle, being almoſt filled, was corked, to prevent the formation of that film which uſually appeared in conſequence of the exhalation of the ammoniac in other experiments.

During the ſolution of the oxide, bubbles of the gaſeous kind aroſe from it, and the ſolution acquired a blue colour. As no film appeared, the bottle was agitated three or four times in the courſe of as many hours, in order to promote the ſolution of a ſmall quantity of blackened oxide which remained at the bottom. The experimenter conſidering this as an ample proviſion for twenty different charges, to be exploded in different circumſtances, in the preſence of the ſociety, intended to pour off the ſolution into as many ſmall veſſels, and to weigh the reſiduary black powder, after allowing two hours more for the ſolution.

On the ſixth hour he took his uſual precaution of wearing ſpectacles; and obſerving that a ſmall quantity of black powder ſtill remained undiſſolved, and that no film was yet formed at the ſurface, he took the bottle by the neck to ſhake it; knowing that it might explode by the heat of his hand, if he were to graſp it, and that the exploſion in this circumſtance might wound him dangerouſly.

In the inſtant of ſhaking, it exploded with a report that ſtunned him. The bottle was blown into fragments ſo ſmall as to appear like glaſs coarſely powdered. The hand which held it was impreſſed as by the blow of a great hammer, and loſt the ſenſe of feeling for ſome ſeconds; and about 52 ſmall grains of glaſs were lodged, many of them deeply, in the ſkin of the palm and fingers. The liquor ſtained his whole dreſs, and every part of the ſkin that it touched. Thus it appeared that fulminating ſilver may be made which will explode even when cold and wet, by the mere diſturbance of the arrangement of its parts, in the aqueous fluid.

In ſubſequent experiments, privately and carefully conducted, it ſeemed that the property of exploding in the cold liquor, by mere commotion, depended on the unuſual quantity or poximity of the exploſive molecules in a given bulk of the liquor. And the flat bottoms, as well as the ſides, of the thick veſſels of glaſs or potters-ware, whether they ſtood on boards or iron plates, were always beaten to ſmall fragments.

This afforded a curious inſtance of the poſſible equilibrium between the powers tending to retain the caloric and thoſe which effect the expulſion of it; and experiments and conſiderations of this kind ſeemed to promiſe a true ſolution of the phenomena of Rupert's drops.

FUNCTION, a term uſed in analytics for an algebraical expreſſion, anyhow compounded of a certain letter or quantity with other quantities or numbers; and the expreſſion is ſaid to be a function of that letter or quantity. Thus $a - 4x$, or $ax + 3x^2$, or $2x - a\sqrt{a^2 - x^2}$, or x^c, or c^x, is each of them a function of the quantity x.

FURD-Y-HUCKEECUT, in Bengal, ſignifies a paper of deſcription.

Furd-y-Sowal, paper of requeſt.

FUST, in architecture, the ſhaft of a column, or the part comprehended between the baſe and the capital, called alſo the naked.

G.

Gaguedi.

GAGUEDI, a tree peculiar to Lamalmon, in Abyſſinia, is thus deſcribed by Mr Bruce. The leaves are long, and broader as they approach the end. The point is obtuſe; they are of a dead green, not unlike the willow, and placed alternately one above the other on the ſtalk. The calyx is compoſed of many broad ſcales lying one above the other, which operates by the preſſure upon one another, and keeps the calyx ſhut before the flower arrives at perfection. The flower is monopetalous, or made of one leaf; it is divided at the top into four ſegments; where theſe end, it is covered with a tuft of down, reſembling hair, and this is the caſe at the top alſo. When the flower is young and unripe, they are laid regularly ſo as to incloſe one another in a circle. As they grow old and expand, they ſeem to loſe their regular form, and become more confuſed, till at laſt, when arrived at its full perfection, they range themſelves parallel to the lips of the calyx, and perpendicular to the ſtamina, in the ſame order as a roſe. The common receptacle of the flower is oblong, and very capacious, of a yellow colour, and covered with ſmall leaves like hair. The ſtile is plain, ſimple, and upright, and covered at the bottom with a tuft of down, and is below the common receptacle of the flower.

Our author ſays that he has obſerved, in the middle of a very hot day, that the flowers unbend themſelves more, the calyx ſeems to expand, and the whole flower to turn itſelf towards the ſun in the ſame manner as does the ſunflower. When the branch is cut, the flower dries as it were inſtantaneouſly, ſo that it ſeems to contain very little humidity.

GALVANISM.

1
Galvaniſm improperly called *animal electricity*.

GALVANISM is the name now commonly given to the influence diſcovered nearly eight years ago by the celebrated Galvani, profeſſor of anatomy at Bologna, and which, by him and ſome other authors, has been called *animal electricity*. We prefer the former name, becauſe we think it by no means proved that the phenomena diſcovered by Galvani depend either upon the electric fluid, or upon any law of animal life. While that is the caſe, it is ſurely better to diſtinguiſh a new branch of ſcience by the name of the inventor, than to give it an appellation which probably may, and in our opinion certainy does, lead to an erroneous theory.

2
Diſcovery of galvaniſm.

M. Galvani was engaged in a ſet of experiments, the object of which was to demonſtrate, if poſſible, the dependence of muſcular motion upon electricity. In the courſe of this inveſtigation, he had met with ſeveral new and ſtriking appearances which were certainly electrical; ſoon after which, a fortunate accident led to the diſcovery of the phenomena which conſtitute the chief ſubject of this article. The ſtrong reſemblance which theſe bore to the electrical facts which he had before obſerved, led almoſt irreſiſtibly to the concluſion that they all depended upon the ſame cauſe. This opinion he immediately adopted; and his ſubſequent experiments and reaſonings were naturally directed to ſupport it. The ſplendor of his diſcovery dazzled the imaginations of thoſe who proſecuted the enquiry; and for ſome time his theory, in ſo far at leaſt as it attributed the whole to the agency of the electric fluid, was ſanctioned by univerſal approbation. Of late, however, this opinion has rather loſt ground; and there are now many philoſophers who conſider the phenomena as totally unconnected with electricity.

3
Object of this article.

We propoſe, in the *firſt* place, to enumerate the chief facts which have been aſcertained on the ſubject; we ſhall then enquire, whether or not the cauſe of the appearances be the electric fluid; and, *thirdly*, we ſhall examine how far it has been proved that this cauſe is neceſſarily connected with animal life.

Whilſt Galvani was one day employed in diſſecting a frog, in a room where ſome of his friends were amuſing themſelves with electrical experiments, one of them having happened to draw a ſpark from the conductor at the ſame time that the profeſſor touched one of the nerves of the animal, its whole body was inſtantly ſhaken by a violent convulſion. Aſtoniſhed at the phenomenon, and at firſt imagining that it might be owing to his having wounded the nerve, he pricked it with the point of his knife, to aſſure himſelf whether or not this was the caſe, but no motion of the frog's body was produced. He now touched the nerve with the inſtrument as at firſt, and directed a ſpark to be taken at the ſame time from the machine, on which the contractions were renewed. Upon a third trial, the animal remained motionleſs; but obſerving that he held his knife by the handle, which was made of ivory, he changed it for a metallic one, and immediately the movements took place, which never was the caſe when he uſed an electric ſubſtance.

After having made a great many ſimilar experiments with the electrical machine, he reſolved to proſecute the ſubject with atmoſpheric electricity. With this view he raiſed a conductor on the roof of his houſe, from which he brought an iron wire into his room. To this he attached metal conductors, connected with the nerves of the animals deſtined to be the ſubjects of his experiments; and to their legs he faſtened wires which reached the floor. Theſe experiments were not confined to frogs alone. Different animals, both of cold and warm blood, were ſubjected to them; and in all of them conſiderable movements were excited whenever it lightned. Theſe preceded thunder, and correſponded with its intenſity and repetition; and even when no lightning appeared, the movements took place when any ſtormy cloud paſſed over the apparatus. That all theſe appearances were produced by the electric fluid was obvious.

Having ſoon after this ſuſpended ſome frogs from the iron paliſades which ſurrounded his garden, by means of metallic hooks fixed in the ſpines of their backs, he obſerved that their muſcles contracted frequently and involuntarily as if from a ſhock of electricity. Not doubting that the contractions depended on the electric fluid, he at firſt ſuſpected that they were connected with changes in the ſtate of the atmoſphere. He ſoon found, however, that this was not the caſe; and having varied, in many different ways, the circumſtances in which the frogs were placed, he at length diſcovered that he could produce the movements at pleaſure by touching the animals with two different metals, which, at the ſame time, touched one another either immediately or by the intervention of ſome other ſubſtance capable of conducting electricity.

All the experiments that have yet been made may be reduced to the following, which will give the otherwiſe uninformed reader a preciſe notion of the ſubject.

Lay bare about an inch of a great nerve, leading to any limb or muſcle. Let that end of the bared part which is fartheſt from the limb be in cloſe contact with a bit of zinc. Touch the zinc with a bit of ſilver, while another part of the ſilver touches, either the naked nerve, if not dry, or, whether it be dry or not, the limb or muſcle to which it leads. Violent contractions are produced in the limb or muſcle, but not in any muſcle on the other ſide of the zinc.

Or, touch the bared nerve with a piece of zinc, and touch, with a piece of ſilver, either the bared nerve, or the limb; no convulſion is obſerved, till the zinc and ſilver are alſo made to touch each other.

4 Has engaged much ſcientific attention.

A fact ſo new, illuſtrated by many experiments and much ingenious reaſoning, which Profeſſor Galvani ſoon publiſhed, could not fail to attract the attention of phyſiologiſts all over Europe; and the reſult of a vaſt number of experiments, equally cruel and ſurpriſing, has been from time to time laid before the public by Valli, Fowler, Monro, Volta, Humboldt, and others.

Frogs, unhappily for themſelves, have been found the moſt convenient ſubjects for theſe experiments, as they retain their muſcular irritability and ſuſceptibility of the galvanic influence very long. Many hours after they have been decapitated, or have had their brain and ſpinal marrow deſtroyed, ſtrong convulſions can be produced in them by the application of the metals. A leg ſeparated from the body will often continue capable of excitement for ſeveral days. Nay, very diſtinct movements have been produced in frogs pretty far advanced in the proceſs of putrefaction. Different kinds of fiſhes, and many other animals both of cold and warm blood, have been ſubjected to ſimilar experiments, and have exhibited the ſame phenomena; but the warm blooded animals loſe their ſuſceptibility of galvaniſm, as of every other ſtimulus, very ſoon after death.

5 The metals.

Almoſt any two metals will produce the movements; but, it is believed, the moſt powerful are the following, in the order in which they are here placed: 1. Zinc; 2. Tin; 3. Lead; in conjunction with, 1. Gold; 2. Silver; 3. Molybdena; 4. Steel; 5. Copper. Upon this point, however, authors are not perfectly agreed.

The proceſs by which theſe ſingular phenomena are produced, conſiſts in effecting, by the uſe of the exciting apparatus, a mutual communication between any two points of contact, more or leſs diſtant from one another, in a ſyſtem of nervous and muſcular organs. The ſphere of this mutual communication may be regarded as a complete circle, divided into two parts.

6 Animal and excitatory arcs.

That part of it which conſiſts of the organs of the animal under the experiment, has been called *the animal arc*; that which is formed by the galvanic inſtruments has been called *the excitatory arc*. The latter uſually conſiſts of more pieces than one; of which ſome are named *ſtays*, *braces*, &c. others *communicators*, from their reſpective uſes.

7 Experiments of the French inſtitute.

A very numerous train of experiments on galvaniſm has been made by a committee of the Phyſical and Mathematical Claſs of the National Inſtitute of France; and as their report comprehends a vaſt number of the moſt important facts which are yet known on the ſubject, we ſhall preſent our readers with the ſubſtance of it (A).

The immenſe maſs of matter which reſulted from the experiments of the committee, is, in their report, preſented, not in the order in which the experiments were made, but in a ſort of claſſification, by means of which a more diſtinct knowledge of the ſubject is obtained at one view. The facts are arranged under theſe ſix heads. *1ſt*, Reſults of the different combinations and diſpoſitions of the parts of the *animal arc*. *2d*, Account of what has been obſerved of the nature and the different diſpoſitions of the *excitatory arc*. *3d*, Circumſtances not entering into the compoſition of the galvanic circle, which, nevertheleſs, by their influence, modify, alter, or entirely prevent the ſucceſs of the experiments. *4th*, Means propoſed for varying, diminiſhing, or reſtoring the ſenſibility to galvaniſm. *5th*, Attempts to compare the phenomena of galvaniſm with thoſe of electricity. *6th*, Additional experiments, performed by M. Humboldt, in the preſence of the members of the committee; which have a reference to ſeveral of the proofs ſtated in the foregoing articles.

8 On the animal arc.

I. To the number of twenty experiments were made on the *animal arc*. The firſt ſeven of theſe were directed to aſcertain the relations between the nerves and thoſe muſcles over which they are diſtributed. In the laſt thirteen, the nerves were cut aſunder, or ſubjected to ligatures; the ſection or ligature being always between the extremities of the arc. Nerves taken from different animals, or from different parts of the ſame animal, and joined in one and the ſame arc, were among the particular ſubjects of theſe experiments; as were alſo the ſolitary nerve, and the ſolitary muſcle, included between the extremities of the *excitatory arc*. There were interpoſed, too, in the courſe of theſe experiments, portions of nerves, and of muſcles, diſtinct from thoſe parts. And, in ſome of the experiments, the animal was without the ſkin and the epidermis.

The following are inferences which have been deduced from theſe experiments:

9 Inferences.

1. The animal arc may conſiſt either of nerves and muſcles together, or of nerves alone, without muſcles (B).

2. Nerves are, therefore, the eſſential part of the animal

(A) The members of the committee were, M. M. Coulomb, Sabbatier, Pelletan, Charles, Fourcroy, Vauquelin, Guyton, *alias* Morveau, and Hallé. M. M. Venturi, De Modene, and M. Humboldt, aſſiſted in the experiment.

(B) We are ſtrongly inclined to doubt the truth of this propoſition. Dr Fowler was at firſt led to think that contractions could be excited in a limb without the metals having any communication with it, except through the medium of the nerve. Recollecting, however, that a very ſmall quantity of moiſture ſerves as a conductor of galvaniſm, he ſuſpected, and our opinion perfectly coincides with his, that in every caſe where contractions are nimal arc; for the muſcles are always more or leſs interſected by the nerves; and are, conſequently, in part, a nervous organ.

3. All the parts of the animal arc muſt be either mutually continuous, or at leaſt contiguous to one another. But even contiguity is ſufficient to enable the galvanic phænomena to take place.

4. The ſection or ligature of a nerve interrupts not the galvanic phenomena, if the parts which are cut aſunder or bound up ſtill remain in cloſe contiguity to one another.

5. No diverſity of the parts forming the animal arc, though theſe be taken from different parts of the ſame animal, or even from different animals, will have power to impair its galvanic ſuſceptibility, provided only that theſe parts be ſtill mutually contiguous.

6. If the *integrity* or galvanic ſuſceptibility of the animal arc be ſuſpended by the ſeparation of any of its parts to ſome diſtance from one another, it may be reſtored by the interpoſition of ſome ſubſtances, not of an animal nature, between the divided parts. Metallic ſubſtances are in particular fit for this uſe. But the mutual contiguity of all the ſubſtances entering into the compoſition of the arc muſt ever be carefully preſerved. Mr Humboldt diſcovered that a bit of freſh morelle (*Helvella mitra Linn.*) will ſupply the place of a part of the nerve.

7. The muſcular organs which indicate, by contraction, the preſence of the galvanic influence, are always thoſe in which the nerves of a complete animal arc have their ultimate termination.

From this it follows, that the muſcles affected by galvaniſm are always thoſe correſponding to that extremity of the arc which is the moſt remote from the origin of the nerves of which it is compoſed.

8. When all the nerves of the animal arc originate towards one of its extremities, then only thoſe muſcles which correſpond with the oppoſite extremity are ſuſceptible of galvanic convulſions.

9. When an animal arc conſiſts of more than one ſyſtem of different nerves, which have all their origin about the middle of the arc, then will the muſcles of theſe ſeveral ſyſtems of nerves be moved alike at both the extremities of the arc.

10. It ſeems likewiſe to appear, from a variety of theſe experiments, that the opinion of thoſe is inadmiſſible, who aſcribe the phænomena of galvaniſm to the concurrence of two different and reciprocally correſponding influences, one belonging to the nerve, the other to the muſcle, and who compare the relations between the nerve and the muſcle, in theſe phænomena, to thoſe between the interior and the exterior coating of the Leyden phial.

11. It appears, laſtly, that the covering of the epidermis, in the entire animal body, acts as an obſtacle to the deciſive diſplay of the effects of galvaniſm; and that,

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are produced in a limb without any apparent communication between the metals and the muſcles, except through the medium of a nerve, the communication is in fact completed by the moiſture upon the ſurface of the nerve. In this caſe, the animal arc may be conſidered as conſiſting of three pieces, diſpoſed in the following order; the nerve, the muſcle, and the water adhering to the ſurface of the nerve. The latter, indeed, ought rather to be conſidered as a part of the excitatory arc. "When a nerve (ſays Dr Fowler), which for ſome time has been detached from ſurrounding parts, is either carefully wiped quite dry with a piece of fine muſlin, or (leſt this ſhould be thought to injure its ſtructure) ſuffered to remain ſuſpended till its moiſture has evaporated, no contractions can be excited in the muſcles, to which it is diſtributed, by touching it alone with any two metals in contact with each other; but if it be again moiſtened with a few drops of water, contractions inſtantly take place. And, in this way, by alternately drying and moiſtening the nerve, contractions may at pleaſure be alternately ſuſpended and renewed for a conſiderable time. It may, indeed, be contended, that the moiſture ſoftened, and thus reſtored elaſticity and free expanſion to the dried cellular membrane ſurrounding the fibres, of which the trunk of a nerve is compoſed; and thus, by removing conſtraint, gave free play to their organization.

"But from obſerving, that in every other inſtance where contractions are produced by the mutual contact of the metals, a conducting ſubſtance is interpoſed between them and the muſcles as well as between them and the nerve; I think it would be unphiloſophical not to allow, that, in the inſtance in queſtion, the moiſture, adhering to the ſurface of the nerve, formed that requiſite communication between the metals and the muſcles." We know of no accurate experiment by which it has ever been ſhewn, that contractions can be produced in a limb without a communication being eſtabliſhed between the metals and nerve, and again between the muſcles and the metals, either directly, or through ſome medium capable of conducting galvaniſm.

To remove the only objection which can be made to Dr Fowler's experiment, and of which we have ſeen that he was himſelf aware, namely, that the nerve while dry is incapable of performing its functions, we repeated it in the following manner: A ſmall, but vigorous and lively, male frog was decapitated, and the ſciatic nerve being laid bare from the knee upwards, was cut through where it paſſes out of the pelvis. Fifteen minutes after the head was cut off, the nerve having been cautiouſly ſeparated from the ſurrounding parts, and coated with tinfoil in the uſual manner, a ſilver probe was applied to it and its coating, without any other communication with the muſcles, and ſtrong contractions took place in the leg. The nerve was now very carefully dried with a piece of fine linen, and the probe was applied as before to the tinfoil and the nerve; no movement whatever took place. Things remaining preciſely in this ſituation, one end of the probe being ſtill in contact with the nerve and its coating, the other end was applied to the muſcles of the thigh, and the leg immediately contracted as ſtrongly as ever. Upon moiſtening the nerve, the contractions were again produced by applying the probe to the nerve and tinfoil alone. We find from this experiment, which we have ſeveral times repeated with the utmoſt care, and with the ſame reſult, that the dry nerve retained its functions completely. This appears to us perfectly deciſive of the queſtion.

that, though from its extreme tenuity, it may not altogether prevent theſe effects, yet it cannot but very materially diminiſh them.

10 Experiments on the excitatory arc. II. The *Excitatory Arc* is uſually formed of three different pieces, made of different metals. Of theſe, one muſt be in contact with the nerve; the other muſt touch the muſcle; and the third muſt form the mean of communication between theſe two. This arrangement, though not indiſpenſably neceſſary, is at leaſt the moſt convenient.

In reſpect to the excitatory arc, the committee examined, 1ſt, The application of metallic ſubſtances to form it: in reſpect to which they endeavoured to aſcertain the number and the diverſity of the pieces of metal of which this arc may be compoſed; the metallic mixtures or alloys which are capable of being employed for this uſe; the particular degree of the friction of one metal upon another, which is favourable to the exhibition of the phenomena; the different ſtates, in reſpect to galvaniſm, of metals differently mineralized. 2dly, The effects of the uſe of carbonic ſubſtances in forming the excitatory arc. 3dly, The effects in the ſame formation, of bodies, which are either non-conductors, or elſe very imperfect conductors of electricity, ſuch as jet, aſphaltus, ſulphur, amber, ſealing-wax, diamond, &c. 4thly, The conſequences of the interpoſition of water, and of ſubſtances moiſtened with water, between the different parts of the excitatory arc. In forming their excitatory arcs, too, they made themſelves the chord of the arc; they introduced into it animal ſubſtances which had loſt their vitality; they rubbed the ſupporters with the dry fingers, ſo as to mark them with nothing but the traces of the perſpiration from the ſkin. They made, likewiſe, ſome experiments for the purpoſe of aſcertaining the relations between, on the one hand, the extent and magnitude of the ſurfaces of the parts compoſing the arc, and, on the other, the effects produced by its energy. From their experiments they have alſo drawn ſome inferences concerning the relative efficiencies of the ſeveral conſtituent parts of the exciting arc. It is impoſſible for us here to relate in detail all this train of experiments. The following corollaries expreſs the ſubſtance of thoſe general truths, which their authors were led to infer from them.

11 Inferences. 1. The excitatory arc poſſeſſes the greateſt power of galvaniſm, when it is compoſed of at leaſt three diſtinct pieces; each of a peculiar nature: the metals, water, and humid ſubſtances, carbonaceous matters, and animal ſubſtances, ſtripped of the epidermis, being the only materials out of which theſe pieces may be formed.

2. Nevertheleſs the excitatory arc appears to be not deſtitute of exciting energy, even when it conſiſts but of one piece or of ſeveral pieces, all of one proper ſubſtance (c). In general it muſt be owned, identity of nature in the conſtituent pieces, and particularly in the ſupports forming the extremities of the arc, diminiſhes, in a very ſenſible manner, its galvanic energy.

3. The ſlighteſt difference of nature induced upon the parts, whether by any feeble alloy, or by friction with extraneous ſubſtances, is at any time ſufficient to communicate to the excitatory arc that full power in which the identity of its compoſition may have made it defective.

4. As the animal arc is ſuſceptible of being in part made up of metallic ſubſtances, or ſuch others as are adapted to enter into the compoſition of the excitatory arc; ſo, on the other hand, the excitatory arc admits of being in part formed of thoſe ſubſtances which are the proper components of the animal arc.

5. The energies of both the excitatory and the animal arcs are alike ſuſpended by the ſeparation of their component parts, or at leaſt by the ſeparation of theſe parts to a certain diſtance.

6. Even the ſmalleſt degree of moiſture is ſufficient to

(c) We do not think it has ever been proved, that one piece of metal, or ſeveral pieces of the ſame metal, are capable of forming the excitatory arc. It is admitted on all hands, that the ſlighteſt alloy communicates galvanic energy to a piece of metal; that is, renders it capable of forming the excitatory arc. It is alſo known, that the metallic oxides are much leſs perfect conductors of galvaniſm than their correſponding reguli, to make uſe of an antiquated expreſſion. It appears to us, that in all caſes where one metal appears to act, more eſpecially where friction with the fingers, or breathing on a piece of metal formerly inert, give it galvanic powers; in all theſe caſes, we think it probable that a ſlight degree of oxidation, produced in ſome part of the ſurface of the metal, gives it activity by deſtroying the homogeneity of its nature. We do not find that this circumſtance has been in general ſufficiently attended to. Dr Wells having diſcovered that charcoal acts powerfully as an exciter when applied along with a metal, found that by friction it alſo can be rendered capable of acting ſingly. What change is thus produced in it we can only conjecture; but that it is ſomething which deſtroys the identity of its ſtructure, rendering it in ſome meaſure a heterogeneous ſubſtance, muſt be admitted.

Candour forces us to acknowledge, that in one of Mr Humboldt's experiments, it ſeems very difficult to point out any want of homogeneity in the exciting arc. He put into a china cup ſome mercury exactly purified; he placed the whole near a warm ſtove, in order that the entire maſs might aſſume an equal temperature: the ſurface was clear without the appearance of oxidation, humidity, or duſt. A thigh of a frog, prepared in ſuch a manner that a crural nerve and a bundle of muſcular fibres of the ſame length hung down ſeparately, was ſuſpended by two ſilken threads above the mercury. When the nerve alone touched the ſurface of the metal, no irritation was manifeſted; but as ſoon as the muſcular bundle and the nerve touched the mercury together, they fell into convulſions ſo briſk, that the ſkin was extended as in an attack of tetanus. This is by far the moſt deciſive experiment which has been tried on the ſame ſide of the queſtion; but as it muſt be admitted, that in moſt caſes two metals are abſolutely neceſſary, and that a ſingle metal often derives activity from circumſtances ſo ſlight, that we could not *a priori* have expected that they were capable of producing any change; we feel ourſelves compelled to conclude, that in M. Humboldt's experiment ſome ſimilar very ſlight circumſtance had eſcaped unobſerved; perhaps ſome gilding, or ornaments with metallic colours, in a ſtate of oxidation.

to join the parts of the excitatory arc, and to determine their effects upon the animal arc.

7. The influence upon the ſtate of the atmoſphere, and of ſurrounding circumſtances, upon the ſucceſs of the experiments of galvaniſm, is, conſequently, very great. In order, therefore, to perform theſe experiments with due accuracy, the ſtate of the hygrometer, and of other meteorological inſtruments, muſt be vigilantly inſpected during their progreſs; and the influence of the perſons making the experiment upon the ſphere within which it is made, muſt likewiſe be carefully attended to.

8. The experiments which were made to aſcertain the nature of the animal arc, together with thoſe made upon the excitatory arc, with a view to the compariſon of the effects of the fleſh of animals, with or without the epidermis, and of the different effects of this epidermis, when it is wet and when it is dry, appear to ſuggeſt to us, that the epidermis is one of thoſe ſubſtances which diminiſh or interrupt the efficacy of the excitatory arc. The epidermis is, as well as the hairs and briſtles of animal bodies, among the number of thoſe ſubſtances which deſerve the appellation of *idio-electrics*.

9. Examine the ſubſtances which are fit for the formation of the excitatory arc, and you will find that the greater part of thoſe which have been ſucceſsfully put to this uſe are ſubſtances capable of acting as conductors of the electrical fluid; but that the ſubſtances which interrupt the operation of galvaniſm are generally ſuch as are well known alſo to reſiſt the tranſmiſſion of electricity.

10. Laſtly, it appears, that the galvanic energy depends, not only upon the nature and arrangement of the component parts of the excitatory arc, but on their extent too, and on the magnitudes of their tranſmitting ſurfaces.

12
Experiments relating to circumſtances different from the arcs.

III. The committee appear to have uſed no leſs care and diſcernment in experiments upon thoſe circumſtances which, though different from the ſtructure of the galvanic circle and its two conſtituent arcs, have, however, *a deciſive influence upon the exhibition of the phænomena of galvaniſm.* Some curious obſervations were made on the differences in the ſtate of the parts expoſed to the galvanic action. It was aſcertained, that frogs freſh from the ditches did by no means exhibit the ſame phænomena as thoſe which had been during ſome days preſerved in the houſe; nor did the limbs of animals, when recently ſtripped of the ſkin, preſent the ſame appearances as after they had been ſubjected to a variety of galvanic experiments; nor were the ſame effects to be produced upon the parts of animal bodies which, after a certain number of trials, had been left for a while at reſt, and then taken up again, as upon thoſe which had been ſubjected to one continued train of experiments. The committee next examined the variations in the ſucceſs of the experiments upon a ſtrong lively frog, which may be produced by varying the mode in which the *communicator* is carried from the one *ſupporter* to the other: when the communicator is brought into contact with the ſupporter, or is withdrawn from actual contact with it; when the *communicator* is brought ſlowly, or when it is brought rapidly, into contact with the *ſupporter;* the effects are nearly the ſame: and a ſmart convulſion is, in all theſe caſes, produced at the moment of the commencement of the mutual contact, or of its ceſſation. But when the frog is fatigued, the effects are different. Theſe ſucceſſive experiments likewiſe affect the reſults of one another, by means even of their ſucceſſion ſolely. And they are alſo naturally ſubject to be influenced by the nature of the media amidſt which they are performed; ſuch as common air, water, an electrical atmoſphere. The following are the inferences which have been deduced from this claſs of theſe experiments.

13
Inferences.

1. In many caſes the galvanic energy is excited by exerciſe, is exhauſted by continued motion, is renovated by reſt.

2. The multiplicity of the cauſes by which the experiments of galvaniſm are liable to be influenced to ſucceſs or failure, is ſo great, that we cannot, as yet, be too cautious in either rejecting or believing theſe accounts which we hear of the ſucceſs of any ſuch experiments; unleſs when we are able accurately to appreciate all the influencing circumſtances.

3. This is remarkably confirmed by a fact, which the committee have related in their paper, and which reſpects the continuation of the galvanic ſpaſm.

The communicator being ſupported by the hand, and reſting, ſeemingly, without change of poſition, ſtill upon the ſame point of contact, there is known to take place a real change in the galvanic contact, although the communicator have remained thus apparently motionleſs.

From this, it may be farther inferred, that the ſmalleſt poſſible change in the relative ſituations of the parts of the galvanic circle and the excitatory arc, is capable of producing an effect upon the ſuſceptible animal, and of occaſioning miſtakes in regard to the ſucceſs of the experiment, if the utmoſt care be not taken to notice and eſtimate every variation that can happen.

4. The truth of the foregoing propoſition is farther confirmed by the experiments upon the manner in which the galvanic movements are affected by the advancing or the withdrawing of the communicator. For theſe experiments fully evince the neceſſity for the moſt vigilant obſervation of every movement in the proceſs of an experiment, not only collectively, but in their ſucceſſion, and at the different periods of the operation.

5. It ſhould ſeem that there are, in the formation of the excitatory arc, independently of its modes of acting in the galvanic operations, certain enervating, and certain exciting diſpoſitions; of which ſome not only augment or diminiſh the energy in the preſent inſtance, but, beſides, diſpoſe the animal to a greater or a ſmaller ſuſceptibility, under ſubſequent experiments.

6. In order to accuracy of experiment, and to the correct aſcertaining of the effects of an experiment. it is of great importance to know the preciſe ſtate of the animal, the manner in which it has been preſerved and ſuſtained to the preſent moment, the ſtate of the atmoſphere, particularly as it is indicated by the hygrometer, by the barometer, the thermometer, and the electrometer.

7. It were to be wiſhed, that in making a ſtatement of experiments of different ſorts, theſe ſhould be arranged in the order of their efficacy, and that there might thus be formed a *galvanic ſcale,* which ſhould help us to determine the preciſe degree of the galvanic

ſuſceptibility of any animal in this or that particular ſtate or poſition, ſhould direct us in ſubjecting every ſuch animal only to experiments ſuitable to its particular ſuſceptibility; ſhould enable us to eſtimate, from the *efficacy* or *inefficacy* of our experiments, the galvanic value of the circumſtances in which we every day find ourſelves, and ſhould enable us to judge when the ſucceſs or miſcarriage of an experiment can afford room for certain concluſions abſolutely negative or affirmative.

14
Experiments on the galvanic ſuſceptibility of animal bodies, &c.

IV. In their experiments upon *the means of varying, diminiſhing, and renewing the ſuſceptibility of animal bodies* to the influence of galvaniſm, the committee examined, 1ſt, the influence of electricity upon that ſuſceptibility; 2d, the effects of the muſcular organs, and of certain liquors, ſuch as alcohol, the oxygenated muriatic acid, the ſolutions of potaſh and opium, upon the galvanic properties; 3d, and at the medical ſchool of Paris they made a number of experiments, in order to aſcertain what new modifications the galvanic energy undergoes in various caſes of ſuffocation or aſphyxia. Theſe laſt-mentioned experiments were made upon hot-blooded animals, of which ſome were reduced into the ſtate of aſphyxia by ſubmerſion, ſome by ſtrangulation, ſome by the action of gaſes, while others were killed *in vacuo* by the diſcharge of the electric ſpark. In that ſuffocation which was produced by ſulphurated hydrogenous gas, by carbonic vapours, and by ſubmerſion, in which the animal was ſuſpended by the hinder feet, the galvanic ſuſceptibility was entirely deſtroyed. The galvanic ſuſceptibility was only ſuſpended by ſuffocation produced by the pure carbonic acid confined under mercury. It was diminiſhed, but not deſtroyed, in thoſe caſes of ſuffocation, which were occaſioned by ſulphurated hydrogenous gas that had loſt a portion of its ſulphur, by gas ammoniac, gas azote, or ſuch gaſes as had been exhauſted of their pure air by reſpiration; and the ſame thing was found to take place in animals which had periſhed by total ſubmerſion. But the galvanic ſuſceptibility ſurvived unaltered in ſuffocations brought on by ſubmerſion in mercury, by pure hydrogenous gas, by carbonated hydrogenous gas, by oxygenated muriatic acid, by ſulphureous acid; as alſo when the ſuffocation was occaſioned by ſtrangulation, by the abſtraction of the air in the air-pump, or by diſcharges from an electrical battery. The reſults of the experiments at the medical ſchool ſuggeſted the following reflections:

15
Reflections.

1. Though it be true that all caſes of ſuffocation reſemble one another in the privation of reſpirable air, and in the ſuſpenſion of the functions of reſpiration, and of the circulation of the blood; yet, in their other circumſtances, they are ſubject to great differences, ariſing from diverſity of nature in the ſubſtances by which they are occaſioned.

2. Of theſe cauſes, ſome appear to act with a more thorough efficacy, penetrating at once all parts of the nervous and muſcular ſyſtems. Others again ſeem to act but ſuperficially, producing only pulmonary aſphyxia, with its immediate effects.

3. One of the moſt remarkable changes not confined to the organs of reſpiration, conſiſts in the alterations produced on the galvanic ſuſceptibility. In that reſpect the various caſes of aſphyxia differ greatly one from another.

4. The ſtate of the irritability of the muſcles, when examined by means of bodies, the mechanical action of which cauſes the muſcles to contract by irritating them, is far from always correſponding to the ſtate of their galvanic ſuſceptibility.

5. Laſtly, the cauſes of ſuffocation or aſphyxia, do not act upon all parts of the muſcular ſyſtem in the ſame manner; but the heart is very often found in a ſtate extremely different from that of the other muſcles.

16
Compariſon of the phenomena of galvaniſm with thoſe of electricity.

V. *The compariſon between the phenomena of galvaniſm and thoſe of electricity* is perhaps one of the moſt intereſting objects of attention in the whole body of animal phyſiology. It is well known that Galvani was accidentally led to his diſcovery by obſerving the motions of ſome frogs, at a certain diſtance from an electrical machine diſcharging ſparks. The committee from the inſtitute made, therefore, ſome attempts to aſcertain the relations between electricity and galvaniſm. Having firſt paid due attention to the ſuſceptibility of animals toward the influence of electricity, they then ſought to diſcover to what preciſe degree animals diveſted of the natural covering of the epidermis were liable to be affected by the variations of the electrical fluid in the atmoſphere around them. Next, comparing the ſuſceptibility of electricity with the ſuſceptibility of galvaniſm, they perceived that quantities of the electrical fluid, ſuch as are ſtill capable of being very accurately meaſured by the electrometer, are, however, often too weak to act upon a frog that retains the moſt perfect ſenſibility to all the energy of galvaniſm. The members of the committee purpoſe to proſecute farther their experiments upon this part of the ſubject.

17
Reſults of ſome experiments by Humboldt.

VI. The following are the general reſults of the experiments made by M. Humboldt in the preſence of the committee:

1. There is no truth in the aſſertion of certain phyſiologiſts, that the experiments of galvaniſm fail when tried upon the heart and thoſe other muſcles of which the contractions depend not upon volition; for theſe organs have been found to be actually ſubject to the influence of galvaniſm (D).

2. The effects of galvaniſm are liable to be interrupted by the conſtriction of a nerve, whenever both the nerve and the conſtricting ligature are enveloped in the fleſh of the animal body (E).

3. The powers of the exciting arc may be renovated or deſtroyed, even though its ſupporters remain the ſame, and although the extremities of the arc be unchanged. Only the relations of the intermediate matters require to be altered.

4. There are atmoſpheres of galvaniſm.

5. There are ſubſtances which, though in an eminent manner conductors of electricity, yet interrupt the motions of galvaniſm.

M. Humboldt had performed alſo other experiments which,

(D) This was demonſtrated ſix years ago by Dr Fowler.

(E) Dr Valli made this obſervation ſoon after the diſcovery of galvaniſm.

which, when he attempted to repeat them before the committee, could not be brought to ſucceed, on account, as was ſuppoſed, of the ſeaſon of the year.

Such are the principal reſults of this valuable train of experiments upon galvaniſm. From them our readers will perceive that this intereſting ſubject is ſtill very imperfectly underſtood, and will form ſome idea of the importance of the diſcoveries which a diligent proſecution of it promiſes to the philoſopher and the phyſician.

18 Effects of galvaniſm upon ſome of the organs of ſenſe.

The effects of galvaniſm upon ſome of the organs of ſenſe are no leſs ſtriking than thoſe which we have ſeen it capable of producing upon the muſcles.

If the upper and under ſurfaces of the tongue be coated with two different metals, and theſe be brought into contact with each other, a peculiar ſenſation, reſembling taſte, is produced in the tongue the moment that the metals touch each other. With the greater number of metals this ſenſation is ſcarcely perceptible; but with zinc and gold, zinc and ſilver, or zinc and molybdena, it is very ſtrong and diſagreeable. Dr Fowler thinks it is ſtrongeſt with zinc and gold; to us it appears a good deal ſtronger with zinc and ſilver. It is ſenſibly ſtronger when the zinc is applied to the upper, and the ſilver to the under ſurface of the tongue, than when this order is inverted. The ſenſation is moſt diſtinct when the tongue is of the ordinary temperature, and the metals of the ſame temperature with the tongue. Any conſiderable increaſe or diminution of heat in either greatly leſſens the effect. Mr Subſir of Berlin, in his *Theorie des Plaiſers*, p. 155, (publiſhed in 1767) takes notice of the diſagreeable taſte produced by ſilver and lead in contact upon the tongue. This is the firſt inſtance of galvaniſm that had been made public.

To enſure complete ſucceſs to the experiment, the metals ought to be allowed to remain ſome time in contact with the tongue before they are made to touch each other, that the taſte of the metals themſelves may not be confounded with the ſenſation produced by their mere contact. Whatever has a tendency to blunt the ſenſibility of the tongue, as opium, alcohol, acids, and the like, diminiſhes the effect of the metals.

It is difficult to deſcribe the ſenſation thus produced accurately. It has been called *ſubacid;* but we think it more nearly reſembles the effect produced by allowing a grain or two of nitre to lie upon the tongue for ſome time, than any other taſte with which we are acquainted. Joined to this, there is evidently a metallic taſte, which varies with the metal employed; but we are inclined to conſider this as the ordinary effect of the metals upon the tongue, which cannot be perfectly diſtinguiſhed from that occaſioned by their mutual contact.

This taſte can alſo be produced by applying one of the metals to the tongue, and the other to any part of the Schneiderian membrane. Profeſſor Robiſon has made many experiments of this kind, the reſult of which is contained in a letter to Dr Fowler. "I find (ſays he), that if a piece of zinc be applied to the tongue, and be in contact with a piece of ſilver which touches any part of the lining of the mouth, noſtrils, ear, urethra, or anus, the ſenſation reſembling taſte is felt on the tongue. If the experiment be inverted, by applying the ſilver to the tongue, the irritation produced by the zinc is not ſenſible, except in the mouth and the urethra, and is very ſlight. I find the irritation by the zinc ſtrongeſt when the contact is very ſlight, and confined to a narrow ſpace, and when the contact of the ſilver is very extenſive, as when the tongue is applied to the cavity of a ſilver ſpoon. When the zinc touches in an extenſive ſurface, the irritation produced by a narrow contact of the ſilver is very diſtinct, eſpecially on the upper ſide of the tongue, and along its margin. This irritation ſeems to be mere pungency, without any reſemblance to taſte, and it leaves a laſting impreſſion like that made by cauſtic alkali.

"When a rod of zinc, and one of ſilver, are applied to the roof of the mouth, as far back as poſſible, the irritations produced by bringing their outer ends into contact are very ſtrong, and that by the zinc reſembles taſte in the ſame manner as when applied to the tongue."

M. Volta found, that when a tin cup, filled with an alkaline liquor, is held in one or both hands previouſly moiſtened with water, if the point of the tongue is dipped in the liquor, an acid taſte is perceived. This is at firſt diſtinct and pretty ſtrong, but gradually yields to the alkaline taſte of the liquor. The acid taſte is ſtill more remarkable, when, inſtead of an alkaline liquor, an inſipid mucilage is made uſe of. The ſame philoſopher found, that when a cup made of tin, or, what is better, of zinc, was filled with water, and placed upon a ſilver ſupport, if the point of the tongue was applied to the water, it was found quite inſipid, till he laid hold of the ſilver ſupport, with the hand well moiſtened, when a very diſtinct and very ſtrong acid taſte was immediately perceived.

If one of the metals be applied to the tongue, and the other to the ball of the eye, a pale luminous flaſh is perceived when they are brought into contact with each other, and the ſenſation reſembling taſte is at the ſame time produced in the tongue. A flaſh is, in like manner, produced when one of the metals is applied to the eye, and the other to any part of the palate, fauces, or inſide of the cheek. This experiment requires a good deal of attention in the performance; care muſt be taken not to preſs the piece of metal againſt the ball of the eye, leſt a flaſh ſhould be produced by the mere mechanical preſſure. It ſhould be cautiouſly introduced between the eye-lids, till it juſt touch any part of the ball; and it ſhould be allowed to remain in that ſituation for ſome time before it is brought into contact with the other piece of metal, that the parts may be ſo far accuſtomed to it as to admit of the ſenſations produced being properly attended to. The experiment ſucceeds very well with tin and ſilver; but the flaſh is more bright when zinc and gold are uſed. The piece of metal which is applied to the ball of the eye muſt be finely poliſhed, otherwiſe the mechanical irritation is ſometimes ſo great as to prevent the flaſh from being perceived. Dr Robiſon has obſerved, that the brightneſs of the flaſh correſponds with the extent of contact of the metal with the tongue, palate, fauces, or cheek.

If a piece of one of the metals be placed as high up as poſſible between the gums and the upper lip, and the other in a ſimilar ſituation with reſpect to the under lip, a very vivid flaſh of light is obſerved at the moment that they are brought into contact, and another at the inſtant of their ſeparation. While they remain in contact, no flaſh is obſerved.

When a rod of ſilver is thruſt as far as poſſible up one of the noſtrils, and then brought into contact with a piece of zinc placed upon the tongue, a very ſtrong flaſh of light is produced in the correſponding eye at the inſtant of contact. We have ſometimes imagined that the flaſh in this experiment was produced before the metals actually touched ; but in this we may have been deceived.

The following curious experiment was firſt made by Profeſſor Robiſon : " Put a plate of zinc into one cheek, and a plate of ſilver (a crown piece) into the other, at a little diſtance from each other. Apply the cheeks to them as extenſively as poſſible. Thruſt in a rod of zinc between the zinc and the cheek, and a rod of ſilver between the ſilver and the other cheek. Bring their outer ends ſlowly into contact, and a ſmart convulſive twitch will be felt in the parts of the gums ſituated between them, accompanied by bright flaſhes in the eyes. And theſe will be diſtinctly perceived before contact, and a ſecond time on ſeparating the ends of the rods, or when they have again attained what may be called *the ſtriking diſtance*. If the rods be alternated, no effect whatever is produced."—The flaſhes produced in this laſt experiment are rather more vivid than any which we have been able to excite by the other methods. The convulſive twitches are very diſtinct, and ſomewhat painful, but quite different from the ſenſation produced by an electric ſhock. If the edges of the tongue be allowed to touch the plates of metal in the cheeks, the ſenſation reſembling taſte is felt very ſtrongly ; but this does not in the leaſt impair the other effects of the experiment.

No method has yet, we believe, been diſcovered of applying the galvanic influence ſo as to affect the ſenſes of ſmelling or hearing. We have tried many experiments with this view, chiefly on the organs of ſmelling, but hitherto without any ſucceſs (F). Neither has the ſenſe of touch been affected by it, unleſs, indeed, the following experiment be conſidered in that view : Let a ſmall portion of the cuticle be removed from any part of the body by a ſharp knife, and carry the inciſion to ſuch a depth that the blood ſhall juſt begin to ooze from the cutis vera. Let a piece of zinc be applied here, and a piece of ſilver to the tongue ; when they are brought into contact, a very ſmart irritation will be felt at the wound.

Some very ſingular facts of this kind have been diſcovered by M. Humboldt, who had the reſolution to make himſelf the ſubject of many well-deviſed experiments. One of the moſt remarkable of theſe is the following : He cauſed two bliſtering plaſters to be applied on the deltoid muſcle of both his own ſhoulders. When the left bliſter was opened, a liquor flowed out, which left no other appearance on the ſkin than a ſlight varniſh, which diſappeared by waſhing. The wound was afterwards left to dry up : this precaution was neceſſary, in order that the acrid humour which the galvanic irritation would produce, might not be attributed to the idioſyncriſis of the veſſels. This painful operation was ſcarcely commenced on the wound, by the application of zinc and ſilver, before the ſerous humour was diſcharged in abundance ; its colour became viſibly dark in a few ſeconds, and left on the parts of the ſkin where it paſſed traces of a brown inflamed red. This humour having deſcended towards the pit of the ſtomach, and ſtopped there, cauſed a redneſs of more than an inch in ſurface. The humour, when traced along the epidermis, left ſtains, which, after having been waſhed, appeared of a bluiſh red. The inflamed places having been imprudently waſhed with cold water, increaſed ſo much in colour and extent, that M. Humboldt, as well as his phyſician Dr Schalleru, who aſſiſted at theſe experiments, entertained ſome apprehenſion for the conſequences.

Having now taken notice of the principal facts that are hitherto known in galvaniſm, we proceed to conſider ſome of the leading opinions on the ſubject.

19
Phenomena of galvaniſm ſuppoſed to reſult from electricity;

The firſt writers upon the diſcovery of Galvani ſeem almoſt univerſally to have taken it for granted, that the phenomena depend on the electric fluid ; and leaving this very important queſtion behind them, proceeded to explain how this fluid produces ſuch effects. The celebrated diſcoverer of this influence himſelf conſiders a muſcle as the perfect prototype of a Leyden phial. When a muſcle contracts upon a connection being formed, by means of one or more metals between its external ſurface and the nerve which penetrates it, M. Galvani contends, that, previouſly to this effect, the inner and outer parts of the muſcle contain different quantities of the electric fluid ; that the nerve is conſequently in the ſame ſtate, with reſpect to that fluid, as the internal ſubſtance of the muſcle ; and that, upon the application of one or more metals between its outer ſurface and the nerve, an electrical diſcharge takes place, which is the cauſe of the contraction of the muſcle. Thus the nerve is ſuppoſed to perform the office of the wire connected with the internal ſurface of the phial ; and the excitatory arc is conſidered merely as a conductor.

This theory appears to us juſt as incapable of explaining the phenomena of galvaniſm as it is inconſiſtent with the known laws which regulate the motions of the electric fluid. We ſhall not conſider it minutely ; for we hope it will ſoon appear highly probable, if not certain, that the electric fluid has no ſhare in the production of the phenomena in queſtion. If this be the caſe, all the different modifications of that theory muſt of courſe fall to the ground. At preſent we ſhall content ourſelves with aſking the following queſtions :

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This ſuppoſition ill founded.

1. How is it poſſible for the electric fluid to be condenſed in a muſcle, which is wholly ſurrounded by ſubſtances capable of conducting that fluid ?

2. If we ſuppoſe there is ſome non-deſcript non-conducting ſubſtance placed between the external and internal

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(F) Profeſſor Robiſon has long ago obſerved, that the flavour of a pinch of ſnuff taken from a box made of tin-plate, which has been long in uſe, ſo that the tin coating is removed in many places, is extremely different from that of ſnuff when taken from a new box, or a box lined with tin-foil. The ſame difference is obſerved when we rub a piece of pure tin, or of pure iron and a half worn tinned plate, with the finger. Alſo, if we rub a caſt ſteel razor, and a common table knife conſiſting of iron and ſteel welded together. This is ſurely owing to a cauſe of the ſame kind.

ternal parts of a muſcle, which may admit of the one being poſitively, and the other negatively electrified at the ſame time—how comes it to paſs that a diſcharge does not take place, and a conſequent contraction enſue, when any ſubſtance whatever, capable of conducting the electric fluid, is interpoſed between the nerve and the external ſurface of the muſcle? For example, when the nerve and muſcle are laid bare, and the animal thrown into water; or when the nerve is cut through, and the end applied to the external ſurface of the muſcles.

3. How does it happen, when one diſcharge actually takes place, in conſequence of the application of the excitatory arc, that the balance is not inſtantly reſtored? That this does not happen, appears by the ſame muſcle and nerve being capable of producing many hundreds of ſimilar, and equally ſtrong diſcharges, without any apparent means of the equilibrium being again diſturbed.

We have never ſeen any anſwers to theſe queſtions which appeared to us at all ſatisfactory; and till we have ſeen them anſwered, we muſt be excuſed for diſbelieving M. Galvani's theory.

One of the earlieſt writers, and one of the moſt aſſiduous inveſtigators of the phenomena of galvaniſm, is Dr Valli. He differs in opinion from Galvani upon ſeveral points; but agrees with him in thinking electricity and galvaniſm the ſame. Let us conſider the proofs by which he ſupports this doctrine.

" I have aſſerted (ſays he), that the nervous fluid is the ſame with electricity, and with good reaſon; for

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" Subſtances which conduct electricity are conductors likewiſe of the nervous fluid.

" Subſtances which are not conductors of electricity do not conduct the nervous fluid.

" Non-conducting bodies, which acquire by heat the property of conducting electricity, preſerve it likewiſe for the nervous fluid.

" Cold, at a certain degree, renders water a non-conductor of electricity as well as of the nervous fluid.

" The velocity of the nervous fluid is, as far as we can calculate, the ſame with that of electricity.

" The obſtacles which the nerves, under certain circumſtances, oppoſe to electricity, they preſent likewiſe to the nervous fluid.

" Attraction is a property of the electric fluid, and this attraction has been diſcovered in the nervous fluid.

" We here ſee the greateſt analogy between theſe fluids; nay, I may even add, the characters of their identity."

That there is a conſiderable analogy between ſome of the effects of the electric fluid and ſome of the phenomena of galvaniſm, we readily admit; but that " the characters of their identity" are anywhere to be found, we abſolutely deny. In the above paſſage, Dr Valli conſiders it as certain that the nervous fluid is the cauſe of the phenomena diſcovered by Galvani. But it has never been demonſtrated irrefragably, that any ſuch thing as a nervous fluid exiſts, and ſtill leſs that this is the ſame with the influence diſcovered by Galvani.

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That bodies are, in general, conductors or non-conductors of galvaniſm, according as they are conductors or non-conductors of electricity, we believe to be true; but this rule is by no means without exception, as it certainly would be, if galvaniſm and electricity were the ſame. There is an experiment of Dr Fowler's, which ſeems to ſhew that water is a more powerful conductor of galvaniſm than mercury; though the reverſe is generally allowed as to electricity.

If the abdomen of a frog be filled with water, and a ſilver probe paſſed through it ſo as to touch the ſciatic nerves, no contractions are produced; neither do they appear when the probe is touched above the ſurface of the water with a piece of zinc. But if the zinc be applied to the probe at the ſurface of the water, contractions are produced as vigorous as if both the metals touched the nerve. Here the water ſerves as a conducting medium between the nerves and the point where the metals touch each other: but if the abdomen be filled with mercury inſtead of water, no contractions are produced by applying the ſilver probe to the nerves, and touching the probe with the zinc at the ſurface of the mercury. We do not ſee how this experiment can be accounted for, except by allowing that water is a more powerful conductor of galvaniſm than mercury.

If this experiment ſhould be thought inconcluſive, we have the authority of M. Humboldt, and of the committee of the National Inſtitute of France, for ſaying that there are ſubſtances which, though in an eminent manner conductors of electricity, yet interrupt the motions of galvaniſm. This is certainly ſufficient to take away all weight from Dr Valli's two firſt reaſons for conſidering theſe two fluids as the ſame, viz. that all conductors of electricity are likewiſe conductors of galvaniſm; and that all bodies which do not conduct the former are alſo non-conductors of the latter. Theſe two are by far the moſt important of his reaſons; and if they were true in their full extent, they would certainly ſhew a very ſtriking analogy, though they would by no means deſerve the appellation of " characters of identity."

As to the Doctor's two next propoſitions, which regard the effects of heat and cold in rendering bodies conductors or non-conductors, they are, in fact, only branches of the two firſt; and as we have ſeen that theſe are not univerſally true, we might admit that they are correct in this particular, without weakening our argument. For this reaſon we ſhall not conſider them minutely; but we may obſerve that Dr Fowler's experiments ſhew that boiling water, and water cooled down to the freezing point, both conduct this influence as well as water at the ordinary temperature of the atmoſphere. If any change in the conducting power takes place beyond theſe points, it may with greater probability be aſcribed to the changes of form which the water undergoes, than to the increaſe or diminution of its temperature.

We confeſs ourſelves perfectly ignorant of any data upon which Dr Valli could found a calculation, the reſult of which could ſhew that the velocity of the nervous fluid is the ſame with that of electricity. Suppoſe we ſhould take it into our heads to aſſert that the velocity of galvaniſm is the ſame with that of light, we apprehend our author could not eaſily demonſtrate the contrary. Neither, in all probability, would he conſider this aſſertion of ours as a ſufficient proof that galvaniſm and light are the ſame.

With regard to the next propoſition, that " the obſtacles which the nerves, under certain circumſtances, oppoſe to electricity, they preſent likewiſe to the nervous fluid;" we may remark, that any obſtacle which deſtroys the functions of a nerve completely, will prevent the muſcles which are ſupplied by that nerve from contracting upon the application of any ſtimulus whatever (G). It does not, however, by any means follow, that the paſſage of either the galvanic or the electric fluid is prevented. The nerves may ſtill be very good conductors of both, though the muſcle is deprived of all power of contracting. That there are obſtacles, however, which the nerves, under certain circumſtances, preſent to the paſſage of electricity, but which they do not under the ſame circumſtances preſent to galvaniſm, we think abundantly demonſtrated by Dr Valli's own experiments.

23 Inconſiſtent with his own experiments,

"I have frequently obſerved (ſays he) that the legs, of which the nerves had been tied at a certain diſtance from the muſcles, did not feel the action of a certain quantity of artificial electricity, although they were violently convulſed by exciting that which was inherent and peculiar to them." What then was the cauſe of the difference obſerved in theſe caſes between the effects of galvaniſm and electricity? Was it, that the quantity or degree of the former exceeded that of the latter? Be it ſo.

Dr Valli informs us, that in his experiments, an electric charge which could flaſh through a thickneſs of air equal to .035 of an inch, produced no movement in the leg of a frog of which the crural nerve was tied, while the other leg, of which the nerve was left free, underwent conſiderable movements.

That the influence diſcovered by Galvani can paſs through an exceeding thin plate of air, is certain, as it is tranſmitted from link to link of a chain, where no conſiderable force is uſed to bring the links into contact. Dr Robiſon's experiment, too, in which the flaſhes of light are diſtinctly obſerved before the rods of ſilver and zinc touch each other, is another proof of the ſame fact; and, if we be not deceived, the ſame thing takes place when a rod of ſilver thruſt up the noſtril is applied to a piece of zinc in contact with the tongue. But that it will only paſs through an exceeding thin plate of air, any man may convince himſelf by an experiment firſt tried by Dr Fowler, which is eaſily repeated. If a ſtick of ſealing-wax be coated with tinfoil, it will be found a very good conductor; but if, with a ſharp pen-knife, an almoſt imperceptible diviſion be made acroſs the tinfoil, even this interruption of continuity in the conductor will be found ſufficient effectually to bar the paſſage of galvaniſm.

We find, then, that a quantity of the electric fluid which can paſs through a plate of air of the thickneſs of .035 of an inch, is obſtructed by a ligature upon a nerve, while the galvanic influence paſſes readily along a nerve included in a ligature, but is obſtructed completely by making an almoſt imperceptible diviſion in a good conductor. The plate of air in this caſe ſurely is not near .035 of an inch in thickneſs. It reſults inconteſtibly, from a compariſon of theſe two experiments, that there is, between theſe two agents, ſome other difference beſides the mere degree of intenſity.

We come now to the laſt reaſon which our author aſſigns for his belief that galvaniſm, or, as he chooſes to call it, the *nervous fluid*, is the ſame with electricity. It will be found a very important one. That property by which bodies charged with the electric fluid attract or repel other bodies, according as they are in the ſame or the oppoſite ſtate of electricity from themſelves, is ſo ſtriking, and at the ſame time ſo univerſal, that it has been very properly adopted as the meaſure of this fluid. If it were true, then, that the galvanic influence poſſeſſed the ſame properties of attraction and repulſion as the electric fluid, this circumſtance would certainly increaſe the analogy between them very much. As we have already ſeen, however, that they differ in other eſſential points, even if it were true that they agreed in this, it could conſtitute no proof of their identity. But if, on the other hand, we ſhould find that this aſſertion of our author is founded on error, and that the galvanic influence poſſeſſes in no degree whatever thoſe properties of attraction and repulſion which have always been juſtly conſidered as eſſential characteriſtics of the electric fluid, we ſhall then be fully juſtified in aſſerting, that theſe two agents, however much they may reſemble each other in ſome leſs important particulars, are in their nature totally diſtinct and unconnected.

24 And with the knowledge of electricity.

Let us examine the proofs by which Dr Valli's aſſertion is ſupported. He tells us, that he obſerved the hairs of a mouſe, attached to the nerves of frogs, by the tinfoil with which he ſurrounded them, alternately attracted and repelled by each other, whenever another metal was ſo applied as to excite contractions in the frogs. We are very far from meaning to inſinuate that Dr Valli did not ſee, or think he ſaw, what he thus deſcribes; but that the motion of the hairs muſt have ariſen from ſome cauſe, different from that to which he aſcribed it, cannot admit of a doubt; for hairs, in ſuch a ſtate of electricity as he ſuppoſes, never attract, but always repel each other.

Dr Fowler, who has paid particular attention to this part of his ſubject, has many times repeated this experiment, both in the manner deſcribed by Dr Valli and with every variation in the diſpoſition of the hairs which he could deviſe: but whether they were placed on the metals, the nerves, or the muſcles, or upon all at the ſame time, he has never in any inſtance been able to obſerve them agitated in the ſlighteſt degree. He has made ſimilar experiments upon a dog, and upon a large and lively ſkate, by diſpoſing, in the ſame way that Valli did the hairs of a mouſe, flakes of the fineſt flax, ſwan-down, and gold leaf: but although the contractions produced in the ſkate, by the contact of the metals, were ſo ſtrong as to make the animal bound from the table, not the leaſt appearance of electricity was indicated. He next ſuſpended from a ſtick of glaſs, fixed in the ceiling of a cloſe room, ſome threads, five feet in length, of the flax uſed in the former experiment; and brought ſome frogs recently killed, and inſulated upon glaſs, as near to them as poſſible without touching: but the threads were in nowiſe affected by the contractions produced in the frogs.

In a very ingenious paper upon galvaniſm by Dr Wells,

(G) We do not here mean that contraction which muſcles are ſuſceptible of long after death, upon having their fibres mechanically irritated, which is produced by what phyſiologiſts have called the *vis inſita*, and which is perfectly known to our cooks, as it was to their predeceſſors in the Roman kitchens, as the foundation of the art of crimping. We at preſent confine ourſelves to contraction produced through the medium of the nerves.

25 eaſoning 'Dr Wells n the me ſub- ct,

Wells, which is publiſhed in the London Philoſophical Tranſactions for 1795, that gentleman maintains the opinion, that the influence diſcovered by Galvani is electrical. He admits, that it is not attended with thoſe appearances of attraction and repulſion which are held to be the teſts of the preſence of electricity; but he contends, that "neither ought ſigns of attraction and repulſion to be in this caſe preſented on the ſuppoſition that the influence is electrical; ſince it is neceſſary, for the exhibition of ſuch appearances, that bodies, after becoming electrical, ſhould remain ſo during ſome ſenſible portion of time; it being well known, for example, that the paſſage of the charge of a Leyden phial, from one of its ſurfaces to the other, does not affect the moſt delicate electrometer, ſuſpended from a wire, or other ſubſtance, which forms the communication between them."

26 nconclu- ve like- iſe.

That the charge of a Leyden phial does not, in paſſing along a wire, affect an electrometer, is certain; and it is equally true, that we have no means of applying an electrometer to a quantity of galvaniſm in a ſtate of reſt in a body. If this influence ever exiſts in ſuch a ſtate, we have no teſt by which we can diſcover its preſence; and it is only from the effects which it produces *in tranſitu* that we know of its exiſtence. But the electric fluid, in paſſing from link to link of a chain, ſenſibly affects an electrometer; and in Dr Fowler's experiment with the ſkate, for example, as more than one piece of metal is employed as an exciter, the fluid, in paſſing from one piece to another, ſhould have affected the light ſubſtances which were placed upon them. This appears to us a ſufficient anſwer to the objection ſtarted by Dr Wells: but the ſame objection having been lately made to us by a gentleman from whom we ſhall always receive every ſuggeſtion with uncommon deference, we thought it worth while to try the following experiment:

Three hours after a frog had been decapitated, it ſhewed ſtrong ſigns of galvanic ſuſceptibility. One of the ſciatic nerves being coated with tinfoil in the uſual manner, the leg was laid upon a plate of zinc. A gentleman was deſired to lay hold of the nerve and its coating with the fingers of one hand, which had been previouſly dipped in water, while with the other hand, alſo wet, he held the end of a ſmall braſs chain about two inches in length. Another gentleman now took hold of the other end of the chain, and, with a ſilver probe, held in his other hand, touched the plate of zinc. The influence being thus made to paſs through the chain, the leg contracted vigorouſly; but a very ſenſible electrometer, held ſo near to the chain as almoſt to touch it, was neither attracted nor repelled. In performing this experiment, it was neceſſary to have the hands wet, as the dry cuticle tends much to obſtruct the paſſage of galvaniſm; but the utmoſt care was taken that the chain ſhould be perfectly dry, otherwiſe the influence might have been tranſmitted by the moiſture upon its ſurface without paſſing through the chain itſelf.

To avoid the poſſibility of this happening, the experiment was varied in the following manner: The frog's leg was laid upon a plate of zinc, and the nerve upon a plate of ſilver. A gentleman now took a ſilver probe, and one end of the braſs chain in contact with it, in one hand; and in the other hand he held the other end of the chain in contact with a rod of zinc. He now touched the ſilver plate with the rod of ſilver, and the zinc plate with the rod of zinc. As the influence was not now to be made to paſs through his body, there was no neceſſity for his hands being wet; the whole excitatory arc was therefore made completely dry. In this way very ſtrong contractions were excited in the leg, and ſtill the electrometer was not affected in the ſmalleſt degree when brought near the chain.

It is proper to obſerve, that Dr Valli, in his aſſertion that attraction is a property of galvaniſm, does not reſt entirely upon his own obſervation: a committee of the Academy of Sciences at Paris performed the following experiment along with him: "They placed a prepared frog in a veſſel which contained the electrometer of M. Coulomb, charged negatively and poſitively by turns. In both caſes, in exciting the animal in the common way, the ball of the electrometer was attracted." It appears to us that Dr Valli and the committee have been deceived by the friction produced by the motion of the animals under their experiments having excited ſo much electricity as to affect the electrometer. The firſt time we tried the experiment abovementioned with the braſs chain, we were almoſt miſled by a ſimilar circumſtance. Inſtead of an artificial electrometer, which we happened not to have at hand, we made uſe of a very long and ſlender human hair; and we found that it was ſtrongly attracted by the chain. Upon an attentive examination, however, we found that this did not ariſe from the action of the influence paſſing thro' the chain, but from the ſtate of the hair itſelf, which was ſo highly electrical as to be ſtrongly attracted by every conducting ſubſtance which it approached. Upon ſubſtituting another hair, which ſhewed no mark of being either poſitively or negatively electrified, it was neither attracted nor repelled by the chain. From the above, or ſome ſimilar circumſtance, it is probable that Dr Valli's miſtake has originated; but we are confident, that whoever will repeat the experiment with ſufficient attention, will find the reſult preciſely as we have deſcribed it.

Perhaps it may ſtill be ſaid, that although we have never been able to diſcover attraction and repulſion as properties of galvaniſm, this may ariſe from our not being able to accumulate this influence in ſufficient quantity. To this reaſoning, if reaſoning it can be called, we oppoſe the following conſiderations, which ſtate a diſſimilarity in the phenomena of electricity and galvaniſm, that ſeems abſolutely irreconcileable with the identity of the cauſe.

27 Demonſtration, that the phenomena of galvaniſm and of electricity reſult not from the ſame cauſe.

Nothing is more completely eſtabliſhed in the ſcience of electricity than this, that all thoſe appearances which we call *attractions*, *repulſions*, *abſtractions*, *and accumulation of electric fluid*, are preciſely ſimilar to what would be the appearances, if electricity were a fluid, whoſe particles repel each other, and attract the particles of other matter, according to a certain law (See Electricity, *Suppl.*). Of all thoſe phenomena, the moſt remarkable is the accumulation of electric energy (to give it no more definite name), by means of thin idioelectrics, coated with non-electrics; ſuch, namely, as are exhibited by the Leyden phial, the condenſer, the doubler, &c.

If the phenomena of galvaniſm are produced by the paſſage of electric fluid from one extremity of the excitatory arc to the other, this paſſage will be regulated by the known laws of electricity. It may therefore be accumulated

accumulated *(in tranſitu)* by means of an apparatus ſimilar to the coated pane, or to the condenſer. Profeſſor Robiſon, with this view, made the following experiments :

1. He made a part of the conductor to his condenſer, or collector of atmoſpheric electricity, conſiſt of a long glaſs rod, on one ſide of which was faſtened (with varniſh) a very narrow ſlip of tinfoil; there was a fine point at one end of this rod, and a gold leaf electrometer at the other. This apparatus was inſulated at one end of a room 19 feet long, having a window in the middle of each ſide. A ſmall electric machine was placed at the other end. On a dry day, with a gentle breeze in a direction acroſs the room, both windows were opened a little way, ſo that there was a continual ſtream of air acroſs the room. The machine was worked; and after a ſhort time had elapſed, the electrometer began to diverge, gradually opened, and at laſt ſtruck the conducting ſlips on each ſide, and then collapſed, and again began to diverge. The windows were ſhut; and immediately, without working the machine, the electrometer diverged rapidly, and touched the ſides of the phial every minute and half. This continued ſo long, that there ſeemed to be no end to it. The Profeſſor now made a cut acroſs the tinfoil with a very ſharp knife; the electrometer now diverged very feebly, and 7½ minutes elapſed before it touched the ſides. He paſſed the knife a ſecond time through the cut. This widened it (though ſcarcely ſenſible to the eye), becauſe the knife had been blunted by the glaſs in the firſt operation. All divergency of the electrometer was now at an end; and although the machine was worked till the electric ſmell was ſenſible at the door to a perſon who happened to come in at this time, no tendency to divergence was obſerved. (*N. B.* the top of the electrometer had no conducting ſubſtance about it, except the ſlip of tinfoil).

The cut, being examined with a microſcope furniſhed with a micrometer, was $\frac{31}{1000}$th of an inch. It was now filled up, by binding over it another ſlip of tinfoil. A plate of talc, whoſe thickneſs did not exceed the 900th of an inch, was coated on one ſide in a circle of 1½ inch diameter. The electrometer was removed, and the coated ſide of the talc was put into cloſe contact with the ſlip of tinfoil on the glaſs rod. A ſtand of tin, whoſe top was a plate of 1½ inch diameter, ſmeared over with mercury, was placed in contact with the other ſide of the talc, and they were preſſed into very cloſe and continuous contact.

The machine being now worked, the coated talc received a charge in about 5 minutes ſufficient to give a very ſmart ſhock: and this was repeated with great regularity every five or ſix minutes. The windows were now thrown open, and the room cleared of its former contents of air, till none of thoſe preſent could perceive any electric ſmell. The machine was now worked again. But after half an hour, only a very faint twitch was felt; but enough to ſhew that an accumulation was taking place. The windows were now half ſhut. After working the machine about five minutes, a faint twitch was obtained; after a quarter of an hour more, there was a moderate ſhock.

In this ſtate of things, the apparatus was examined as a condenſer, by firſt taking out the ſharp point by an inſulating handle, and then removing the tin ſtand. Examined in this way, it appeared plainly that, even when all the windows were open, the accumulation began almoſt as ſoon as the machine was worked. Nay, it was found, on another day equally favourable, that a plate of talc $\frac{47}{1000}$ or $\frac{50}{1000}$ of an inch thick, took a charge, although a cut of $\frac{31}{1000}$ wide did not allow the electricity to fly acroſs it. This is perfectly ſimilar to all our experiments on coated glaſs. The thickneſs which admits an accumulation is almoſt incomparably greater than the diſtance to which a ſpark will fly, or a concuſſion is producible, in the ſame intenſity of electricity.

2. The above deſcribed apparatus was inſulated, and a wire connected with each end. To one wire was joined a thin plate of lac, coated on the ſide next the wire; and to the other a piece of moiſt leather covered with tin-foil. Theſe plates were rubbed together by means of inſulating handles. The plate of coated talc quickly took a charge.

The ſame plate of talc, and afterwards another plate not more than half as thick, was now made part of the excitatory arc, and ſometimes part of the animal arc. Sometimes plates of varniſh, incomparably thinner than either of theſe, were employed. But all Profeſſor Robiſon's attempts to produce an accumulation of galvanic energy in this way were fruitleſs. The ſecond form of the electrical experiment was adopted, as having a ſomewhat greater reſemblance to the ſuppoſed procedure of galvaniſm; but the well-informed electrician will eaſily perceive, that the firſt form is far more delicate and deciſive.

The internal procedure in the electric and galvanic convulſions is therefore ſo different, nay, oppoſite, that we cannot bring ourſelves to think that the appearances are operations of the ſame agent (H).

We have now gone over all the points of reſemblance which, in Dr Valli's opinion, conſtitute the characters of the identity of galvaniſm and electricity. We think that, without going farther, we might ſafely reſt our aſſertion, that theſe two agents are perfectly diſtinct and unconnected with each other. But there are ſeveral other circumſtances which merit attention.

28
Farther conſiderations on electricity and galvaniſm.

No electrical phenomenon can take place between two bodies, unleſs theſe bodies be in oppoſite ſtates of electricity with regard to each other. Now, how are we to account for the accumulation of electricity in any body, or part of a body, ſurrounded on all hands by conducting ſubſtances? The experiments of Galvani ſucceed equally well, whether the ſubjects of them be inſulated or ſurrounded by conductors; whether performed in the drieſt air or under water (I); whether, by

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(H) What if it were called *metallorgaſm*, which tranſlates exactly metallic irritation, or metallegerſiſm, from μεταλλον, and εγερσις *excitatio*.

(I) Dr Fowler mentions an exception to this. "When the ſeparated leg of a frog was held under water, and formed part of the circuit through which this influence had to paſs in order to excite another leg, it never contracted; although it did, and ſtrongly, when held above the ſurface." In this caſe it is plain, that the frog's leg by means of an electrical machine, we charge the animal and the metals till every part of them ſtrongly affect the electrometer, or whether we reverſe the experiment and electrify them negatively, ſtill no change is produced in the force or frequency of the actions excited by the application of the metals. Is there any electrical experiment which could continue to give the ſame reſult in ſuch oppoſite circumſtances? or is there any poſſibility of accounting for it conſiſtently with the known laws of the electric fluid?

The writers on this ſubject who adopt the electric theory, inſtead of attempting to explain how the electric fluid can be condenſed in a body ſurrounded by conducting ſubſtances, have recourſe to the analogy of the gymnotus, torpedo, and other fiſhes of the ſame kind. Here, ſay they, we have in fact the electric fluid accumulated in ſuch a ſituation, and there is no reaſoning againſt facts. We anſwer, that theſe animals are all furniſhed with organs of a very peculiar ſtructure, which may poſſibly be fitted for the purpoſe of ſuch a condenſation. Beſides, we apprehend it has never been inconteſtibly proved that theſe ſingular animals derive their powers from the electric fluid. Without wiſhing to enter into this queſtion, which is foreign to our preſent ſubject, we may remark that Mr Walſh diſcovered, that the ſhock of the torpedo would not paſs through a ſmall braſs chain; a circumſtance in which it differs remarkably both from electricity and from the influence diſcovered by Galvani.

It were worth while to try Profeſſor Robiſon's methods of accumulation in the examination of the convulſions occaſioned by the torpedo. The Profeſſor ſuſpects that the popular horror at the lamprey, and the accounts of cramps and pains produced by it, have their ſource in ſome ſimilar powers of that animal.

Dr Valli's reaſoning on this part of the ſubject is very curious. He takes it for granted that the gymnotus owes its influence to the electric fluid. Then, though the gymnotus gives ſhocks and emits ſparks, while the torpedo only gives ſhocks without emitting ſparks, he ſays it would be abſurd to aſſert that the torpedo derives its influence from a cauſe different from the gymnotus. Again, though the influence diſcovered by Galvani neither gives ſhocks nor emits ſparks, it would ſtill be abſurd to maintain that it is not the ſame as the electric fluid, and as the influence of the gymnotus and torpedo. To diſſent from any part of this very logical deduction, he declares would be contrary to the laws of philoſophiſing! *Riſum teneatis?*

Afraid, probably, that his readers might be tempted to offend againſt theſe new laws, he proceeds to ſtrengthen them by the analogy of animals and vegetables retaining an uniform temperature *in media*, warmer or colder than their own bodies; from which he argues that they may alſo have a power of accumulating electricity, and retaining it in a particular part, though their whole bodies are conductors. But the caſes are in no reſpect ſimilar. Neither animals nor vegetables accumulate caloric in any particular part of their bodies in preference to any other part. They have no power of *retaining* caloric in their bodies more ſtrongly than any other bodies do; for if they are placed in a medium colder than themſelves, they are continually imparting caloric to that medium. Neither is there the ſmalleſt proof, from any experiments yet publiſhed, that when placed in a medium warmer than themſelves, they do not continually abſorb caloric from it. The exiſtence of a frigorific power in animals appears to us exceedingly problematical; but if it were proved to exiſt, it would by no means demonſtrate that animals or vegetables have a faculty of declining to abſorb caloric from bodies warmer than themſelves. It is readily admitted, that animals and vegetables have a power, within certain limits, of preſerving their temperature higher than that of the ſurrounding medium; nor is there any thing ſurpriſing in this, as the caloric, which they are continually receiving by the decompoſition of oxygenous gas, is diſſipated ſlowly. But if we ſhould allow that animals have a ſimilar faculty of generating the electric fluid; from the nature of that fluid it muſt be continually communicated, not only to every part of the bodies of the animals themſelves, the whole of which are conductors, but to every conducting ſubſtance contiguous to them: and this muſt take place, not ſlowly, like the diſſipation of caloric, but inſtantaneouſly, ſo as to render any ſenſible accumulation impoſſible.

29
Difference in their mode of excitement,

Galvaniſm differs from electricity in nothing more remarkably than in the mode of its excitement and diſcharge. To produce the phenomena diſcovered by Galvani, no operation at all ſimilar to the friction of an electric upon a conducting ſubſtance is neceſſary (K). The nerves and muſcles have only to be laid bare, and a communication formed between them by means of the excitatory arc, when the contractions immediately enſue. In the caſe of electricity, a ſingle diſcharge having reſtored the equilibrium, no farther effects can be produced till this has been again deſtroyed by ſome means capable of producing a condenſation in one quarter and a comparative rarefaction in another. The fact is very different with regard to galvaniſm; for with it the number of ſhocks which may be given appears to be infinite. Nay, they frequently become ſtronger in proportion as they have been longer continued: this influence differing extremely in this particular, too, from the electric fluid, which, beſides being itſelf exhauſted, never fails in a remarkable manner to exhauſt the contractile power of the muſcles.

30
And in the duration of their effects.

The permanence of the effects of galvaniſm is ſtill more ſtriking in the experiments upon the organ of taſte. When the metals are applied to the tongue, the ſenſation

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leg had in fact formed no part of the circuit through which the influence paſſed; the influence had been tranſmitted by the water in which the leg was held.

(K) It is true, as we have noticed above, that galvanic energy is ſometimes communicated to a conducting ſubſtance by rubbing it upon ſome other ſubſtance; but this has no reſemblance to the excitement of electricity by friction. The galvanic energy is communicated in this caſe to a *conducting* ſubſtance, and it ſucceeds as readily when both the bodies are of this claſs as when one of them is an idio-electric. But no electric phenomenon has ever been produced by the friction of two conducting bodies upon each other; one of them muſt be an idio-electric, and it is in this one that the excitement takes place.

ſenſation produced is not ſudden and tranſient ; but ſo long as the metals are in contact with the tongue and with each other, ſo long does the taſte continue ; and, after ſome time, it becomes inſufferably diſagreeable. M. Volta, who adopts the electric theory with various modifications, ſenſible of the permanence of the effect, in his curious experiments abovementioned ſuppoſes, that a ſtream of electricity paſſes from the tin cup to the liquor, from this to the tongue of the perſon making the experiment, then through his body, and returns through the water upon his hands to the cup ; and thus he ſuppoſes the fluid to move perpetually in a circle. It is ſurely unneceſſary for us to obſerve, that the ſuppoſition of a ſtream of electricity continually moving in a circle in this manner, is wholly inconſiſtent with the laws which appear in every caſe to regulate the motions of that fluid. The ſame obſervation applies to the manner in which he explains moſt of the other phenomena of galvaniſm.

The electric fluid cannot be put in motion but by deſtroying the equilibrium to which it perpetually tends ; but whenever this is deſtroyed, all that is required to produce a diſcharge is, that a ſingle conducting ſubſtance be placed between the two points in which it is unequally diſtributed. Here again there is a very wide diſtinction between this fluid and the influence diſcovered by Galvani. M. Volta divides all conductors of galvaniſm into two claſſes ; 1ſt, Dry conductors, comprehending metals, pyrites, ſome other minerals, and charcoal ; and, 2d, Moiſt conductors. He aſſerts, that it is abſolutely neceſſary, in order to the production of the phenomena, that two conductors of the firſt claſs touch each other immediately on one hand, while at their other extremities they touch conductors of the ſecond claſs. Whether this be admitted or not, we have already ſtated our opinion that the action of two different ſubſtances is abſolutely neceſſary in order to excite contractions : and although it is contended by ſome writers that a ſingle piece of metal has ſometimes been found ſufficient, yet even they muſt allow that, in by far the greater number of caſes, it has been found neceſſary to make uſe of two metals, and that the effect is even heighened in general by employing three. In the whole ſcience of electricity, we do not know a ſingle fact which bears the ſlighteſt analogy to this. Never in a ſingle inſtance has it been found, that the effects of a Leyden phial have been increaſed by uſing a conductor formed of two or more metals in procuring the diſcharge.

31
Some m
non-con
ductors
galvaniſ

Before leaving the ſubject of conductors, we may take notice of a very curious and important fact mentioned by Dr Valli. "Amongſt men," ſays he, "there are ſome individuals who are good conductors, others who are leſs ſo ; and ſome again who appear to be almoſt non-conductors. I was one day carrying on, with three of my friends, ſome experiments upon frogs. A frog was put in water, and we each by turn eſſayed its power. Two of us excited ſtrong convulſions, the third only feeble ones, and the fourth none at all. This experiment was repeated frequently with the ſame reſult. This is not the only example I could adduce of the reality of this fact, but I do not think it neceſſary to dwell any longer upon it." We have met with one individual who is not ſenſible of any peculiar ſenſation when the metals are applied to his tongue. This ſeems in ſome meaſure to corroborate Dr Valli's obſervation. It is apprehended, however, that all men are equally good conductors of electricity.

There is ſtill another very marked diſtinction between the effects of galvaniſm and electricity. No ſhock at all reſembling that produced by the electric fluid has ever been felt by any perſon whoſe body was made a part of the chain conducting the galvanic influence, while a very ſmall quantity of the electric fluid is immediately felt (L). In Dr Robiſon's experiment with the plates of zinc and ſilver in the cheeks, there is no doubt a convulſive twitch diſtinctly felt in the gums ; but, as we have already obſerved, the ſenſation thus produced is quite different from that which is felt from an electric ſhock (M)

There is an experiment related by Dr Valli, which ſeems to ſhew that nothing like an electric ſhock is felt, even when this influence is tranſmitted through a nerve, ſo as to excite convulſions. Having laid bare the nerves of a fowl's wing, without cutting them, and without killing the fowl, upon applying the metals very ſmart movements were produced, but the animal remained perfectly tranquil. Nor was this owing to the fowl

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(L) There is an exception to this rule which ought to be taken notice of. M. Cotugno informs us, that when he was one day employed in diſſecting a live mouſe, he received a ſenſible ſhock from the animal. But as neither he nor any other perſon has ever been ſimilarly affected in any other inſtance, it ſeems pretty certain that he was deceived into the belief of a ſhock from the ſenſation produced by the ſtruggles of the animal he diſſected.

(M) "No one (ſays M. Humboldt) can ſpeak more decidedly on this ſubject than myſelf, having made ſeveral experiments on my own perſon, the ſeat of which, in ſome inſtances, was the ſocket of a tooth which I had cauſed to be extracted ; in others, certain wounds which I made in my hand ; and in others, the excoriations produced by four bliſtering plaſters." The following is the reſult of theſe painful experiments. The galvanic irritation is always painful, and the more ſo in proportion as the irritated part is more injured and the time of irritation more prolonged. The firſt ſtrokes are felt but ſlightly ; the five or ſix following are much more ſenſible, and even ſcarcely to be endured, until the irritated nerve becomes inſenſible from continued ſtimulus. The ſenſation does not at all reſemble that which is cauſed by the electric commotion and the electric bath ; it is a peculiar kind of pain, which is neither ſharp, pungent, penetrating, nor by intermiſſions, like that which is cauſed by the electric fluid. We may diſtinguiſh a violent ſtroke, a regular preſſure, accompanied by an unintermitting glow, which is incomparably more active when the wound is covered with a plate of ſilver and irritated by a rod of zinc, than when the plate of zinc is placed on the wound, and the ſilver pincers are uſed to eſtabliſh the communication.

fowl being in a ſtate of inſenſibility; for when the nerves were pricked or irritated it ſcreamed violently. But all animals ſhew ſigns of great uneaſineſs from an electric ſhock.

In general, it muſt be confeſſed, that animals under experiments of this kind ſeem reſtleſs and uneaſy. The great diſtinction of which we ſpeak at preſent, conſiſts in this, that the electric fluid produces a ſhock and uneaſy ſenſation when any part of the body is introduced into the conducting chain; while the influence diſcovered by Galvani, on the contary, when merely tranſmitted through the body in this manner, gives no ſhock, nor any ſenſation whatever, inſomuch that we are not ſenſible of its paſſage. If this influence be made to act directly on a nerve, there is, no doubt, ſome kind of irritation produced, as appears from the effect of the metals upon the tongue, the eye, and other nervous parts; but ſtill this action bears no analogy to that of the electric fluid. As the application of the metals to the organs of ſenſe, produces in each organ the peculiar ſenſation for which it is conſtructed, as taſte in the tongue, light in the eye, &c. ſo when nerves intended merely for muſcular motion are ſubjected to the action of galvaniſm, the effect produced is motion in the muſcles on which they are diſtributed.

If this view of the matter be juſt, it will explain why no ſhock is felt when the human body is made a part of the conducting chain. In that caſe the influence does not, in all probability, act directly upon any nerve; and we ſee that this influence poſſeſſes no power, like the electric fluid, of producing a convulſive ſhock, when merely paſſed through any part of the body; but it has this peculiar property, when paſſed directly through a nerve, it excites that nerve to perform the function for which it was intended by nature. To this it will no doubt be objected, that contractions may be excited in different parts of a frog without any diviſion being made in its ſkin; and here it may be ſuppoſed that the influence is not made to paſs directly through a nerve. But it ought to be recollected that the ſkin of theſe animals is abundantly ſupplied with nerves, whoſe trunks communicate at different places with thoſe which ſupply the muſcles; and that the contractions are always ſtrong and eaſily excited, in proportion as they are applied near to the courſe of any of the nerves which go to the muſcles. But though we had no doubt thac the influence might be tranſmitted through the bodies of theſe animals, as well as through the human body, without any contractions being produced, we have thought it worth while to aſcertain the fact by the following experiment.

A frog was prepared in the uſual manner by coating its ſciatic nerve with tinfoil, and laying the leg upon a plate of zinc. Another frog, in a very vigorous ſtate, had its fore legs and cheſt attached to a rod of ſilver, and its poſterior extremities to a rod of zinc. The ſilver rod was applied to the tinfoil and nerve of the prepared frog, and the zinc rod to the plate of zinc upon which the leg was laid. Immediately very ſtrong contractions took place in the leg; but no motion, nor the ſlighteſt mark of uneaſineſs, appeared in the other frog through the body of which the influence muſt have paſſed. It is neceſſary in this experiment to dry the body of the frog which is to ſerve as a conductor very carefully, otherwiſe the influence might be tranſmitted by the water upon its ſurface without paſſing through its body.

There is an experiment mentioned by Dr Fowler, which ſhews a ſtriking difference between electricity and galvaniſm. It was inſtituted with a view to aſcertain the effects of the latter upon the blood-veſſels. The Doctor relates it as follows: "Having laid bare and ſeparated from ſurrounding parts and from each other, the crural artery and nerve in the thigh of a full grown frog, I cut out the whole of the nerve between the pelvis and the knee: I then inſinuated beneath the artery a thin plate of ſealing wax, ſpread upon paper, and broad enough to keep a large portion of the artery completely apart from the reſt of the thigh. The blood ſtill continued to flow through the whole courſe of the artery in an undiminiſhed ſtream. The artery, thus partially inſulated, was touched with ſilver and zinc, which were then brought into contact with each other; but no contraction whatever was produced in any muſcle of the limb. This experiment was frequently repeated upon ſeveral different frogs, both in whom the nerve was, and in whom it was not divided. The reſult was uniformly the ſame. But vivid contractions were produced in the whole limb when an electric ſpark, or even a full ſtream of the aura was paſſed into the artery."

Before taking leave of this branch of our ſubject, it may be proper to take notice of one fact, which may be thought to militate againſt the doctrine we have endeavoured to eſtabliſh. It is ſaid that a frog, exhauſted and brought near to a charged electrophorus, has been found to reſume its ſuſceptibility. We think this fact may be accounted for without admitting any connection between galvaniſm and electricity, merely by ſuppoſing that the irritability of the muſcles, which had been exhauſted, was reſtored by the application of a moderate ſtimulus, (the electric fluid), of a kind different from thoſe by which it had been exhauſted. Such of our readers as are acquainted with the writings of modern phyſiologiſts on the ſubject of muſcular irritability, will know that facts of this kind are very common. Thus it has been found by M. Humboldt, that the oxygenated muriatic acid has often reſtored irritability. To this explanation it will no doubt be objected, that the application of other ſtimuli, as alcohol and a ſolution of potaſh, inſtead of reſtoring, totally deſtroy the ſuſceptibility of galvaniſm. Suſpecting, that although theſe ſubſtances in a concentrated ſtate deſtroy the ſuſceptibility, yet that when ſufficiently diluted, they might be found to have the oppoſite effect, we tried the following experiment, which confirmed our conjecture.

A frog, 57 hours after it had been decapitated, had ceaſed for above an hour to be capable of excitement by the application of the metals in any way that could be deviſed. A few drops of alcohol being diluted with about a tea-ſpoonful of water, the nerve and the muſcles which had been laid bare, as well as the whole ſkin of the animal, were wet with it. Upon the application of an excitatory arc, compoſed of four pieces, gold, zinc, ſilver, and tinfoil, a few very ſlight contractions of the toes were diſtinctly obſerved. After this, no means that we could think of produced the ſmalleſt excitement. Alcohol was now applied in a more concentrated ſtate, but without any effect. The ſame

four

four pieces of metal which produced the contractions of the toes, had been uſed before the diluted alcohol was applied, but without effect. We have not tried the application of potaſh much diluted.

From what has been ſaid, we think we are fully warranted in ſaying, that although ſome of the phenomena diſcovered by Galvani bear a ſtriking reſemblance to ſome of thoſe produced by the electric fluid ; yet there are others, and theſe not the leaſt important, which differ ſo widely from any effects which have ever been ſeen to ariſe from that fluid, that they muſt derive their origin from ſome other cauſe. Our readers may probably think that we have dedicated too much time to this queſtion ; but as we conceive it to be the moſt important point which can be diſcuſſed on this ſubject, we thought it worth while to conſider it at ſome length; and we were the more convinced of the neceſſity of doing ſo, from this conſideration, that there are ſtill ſome writers of high authority who maintain the hypotheſis, that galvaniſm and electricity are the ſame.

32 The galvanic influence probably foreign from animals.

The next queſtion that occurs to us with regard to the nature of galvaniſm is, whether or not it depends upon any law of animal life ? To us it appears rather more probable, that the influence which incites the muſcles of animals to contract in the experiments of Galvani, is ſomething quite foreign to the animals themſelves; as much ſo as the electric fluid of the Leyden phial is to the animal which receives a ſhock from it, in both caſes the body of the animal acting as a mere conductor. Upon this queſtion, however, we confeſs that we have neither facts nor arguments to adduce ſufficient to warrant our drawing any certain concluſion. It will doubtleſs be aſked, if this influence be ſomething foreign to the bodies of animals, why do we never find it acting anywhere but in their bodies ? why is it not, like the electric fluid, capable of being made evident to the ſenſes by its effects upon inanimate matter ? The only anſwer which we are in a condition to give to this queſtion is, that it may very poſſibly be capable of producing important effects upon inanimate matter, nay, theſe effects may be the ſubject of our daily obſervation ; but for want of our being ſufficiently acquainted with galvaniſm to point out the relation between theſe effects and their cauſe, the effects themſelves are either not explained at all, or aſcribed perhaps to ſome other power, with which they have no connection. In like manner, the electric fluid has doubtleſs been producing moſt important effects from the beginning of time ; but, prior to the diſcovery of that fluid, theſe were either not explained at all, or conſidered as originating from ſome cauſe which, in fact, had no ſhare in their production.

The great difficulty is to obtain ſome teſt by which we may detect the galvanic influence when actually preſent in inanimate matter. Hitherto we have no ſuch teſt ; nor ſhould we know that ſuch an influence exiſts, but for the effects which it produces upon the bodies of animals through the medium of their nerves. If we had any means of aſcertaining its exiſtence, either in a ſeparate ſtate, or conjoined with inanimate matter, the ſcience would make a rapid progreſs, as it would be eaſy to diverſify experiments ſo as to diſcover its nature and effects. To detect it in a ſeparate ſtate is, in all probability, impoſſible ; but that the zeal and ingenuity of philoſophers will one day be able to diſcover ſome teſt of its preſence in inanimate matter, there ſeems no reaſon to doubt.

We have made many experiments with a view to diſcover ſuch a teſt, but hitherto without the ſmalleſt ſucceſs. In the trials we have already made, our views have been chiefly confined to the diſcovery of ſome chemical effects of this influence upon inanimate matter. M. Volta and other writers, having conſidered the ſenſation produced by it upon the tongue as ſimilar to that occaſioned by acids, we were not without hopes that it would be found to reſemble that claſs of ſubſtances in ſome of its other properties. We have therefore tranſmitted it through liquids tinged with the moſt delicate vegetable colours ; but no change in theſe colours has been effected by the tranſmiſſion of many galvanic ſhocks. We have alſo tried, in the ſame way, alkaline liquors, without any effect. We next diſſolved in water different neutral ſalts, and other compound bodies, of which the parts are held together by the weakeſt affinities ; but no change has been obſerved to be produced in them by the tranſmiſſion of this influence. Our want of ſucceſs, however, ſhall not deter us from continuing our efforts ; we ſhall vary the nature of our experiments in every way that ſhall occur to us as likely to be attended with advantage ; and if we ſhould ultimately fail, we truſt that others will be more fortunate. Every new fact which is diſcovered upon the ſubject tends to facilitate this inveſtigation, by furniſhing us with new guides to direct the courſe of our experiments.

33 Dr Fowler heſitates on this point.

Dr Fowler is of opinion, that this influence, whatever it may be, is not derived from the metals alone, but that the animals at leaſt contribute to its production, as well as indicate its preſence ; and he ſeems to have been led to adopt this theory chiefly from two conſiderations, neither of which appears to us to have much weight. They are the following : The neceſſity of a communication between the metals and the muſcles, as well as between the metals and the nerves ; and the obſervation, that animals have a more complete controul over its effects than one would expect them to have over an influence wholly external to them. But the communication between the metals and the muſcles may be neceſſary to the contraction of the latter, tho' not to the production of galvaniſm ; which, however, for want of any obvious effect, is not obſerved. That animals have ſome controul over the effects of galvaniſm upon themſelves, may be very true ; but this circumſtance does not appear to us capable of proving any thing, as they have a controul over the effects of other ſtimuli in the ſame way. Thus, an animal of any reſolution can bear, without betraying any uneaſy ſenſation, a blow which, inflicted unexpectedly, would have produced a convulſive ſtart. The will does not in any degree controul the effects produced by galvaniſm upon our ſenſes of taſte, ſeeing &c.; that is, the ſenſations are produced, though we may have reſolution not to betray them. But, ſays Dr Fowler, the will is not able to controul the effects of electricity, when the electricity is otherwiſe ſufficiently ſtrong to excite muſcles to contraction. This argument may tend to ſhew, that galvaniſm differs from electricity ; but as it muſt be admitted, that we can reſiſt the contractions naturally produced by the application of other foreign ſtimuli, it by no means proves that animals have any power of preventing

preventing the excitement or tranſmiſſion of galvaniſm. Beſides, though we cannot prevent an involuntary contraction of our muſcles from taking place when an electric ſhock of conſiderable ſtrength is paſſed through them, yet any man may with his hand draw ſparks from the prime conductor of an electric machine without ſhrinking, though even theſe ſparks would, if he were off his guard, produce a convulſive ſtart.

34
We think without reaſon.

If the galvanic influence exiſted ready formed in the muſcles or nerves of animals, the only thing requiſite to the production of the contractions would be to make a communication between the nerves and muſcles, by means of any ſingle ſubſtance capable of conducting this influence; as water, for example: but the reverſe is known to be true. It may be ſaid, however, that, although there is no proof that any influence naturally reſides in the nerves or muſcles capable of producing the effects mentioned by M. Galvani, theſe ſubſtances may ſtill, by ſome power, independent of the properties they poſſeſs in common with dead matter, *contribute* to the excitement of the influence, which is ſo well known to exiſt in them after a certain application of metals. Upon this part of the ſubject, the obſervations of Dr Wells will be found to merit conſiderable attention.

" It is known (ſays that gentleman), that if a muſcle and its nerve be covered with two pieces of the ſame metal, no motion will take place upon connecting thoſe pieces by means of one or more different metals. After making this experiment one day, I accidentally applied the metal I had uſed as the connector, and which I ſtill held in one hand, to the coating of the muſcle only, while with the other hand I touched the ſimilar coating of the nerve, and was ſurpriſed to find that the muſcle was immediately thrown into contraction. Having produced motions in this way ſufficiently often to place the fact beyond doubt, I next began to conſider its relations to other facts formerly known. I very ſoon perceived, that the immediate exciting cauſe of theſe motions could not be derived from the action of the metals upon the muſcle and nerve to which they were applied; otherwiſe it muſt have been admitted, that my body and a metal formed together a better conductor of the exciting influence than a metal alone; the contrary of which I had known, from many experiments, to be the caſe. The only ſource, therefore, to which it could poſſibly be referred, was the action of the metals upon my own body. It then occurred to me, that a proper opportunity now offered itſelf of determining whether animals contribute to the production of this influence by means of any other property than their moiſture. With this view I employed various moiſt ſubſtances, in which there could be no ſuſpicion of life to conſtitute, with one or more metals, different from that of the coatings of the muſcle and nerve, a connecting medium between theſe coatings, and found that they produced the ſame effect as my body. A ſingle drop of water was even ſufficient for this purpoſe; though, in general, the greater the quantity of the moiſture which was uſed, the more readily and powerfully were contractions of the muſcle excited. But if the mutual operation of metals and moiſture be fully adequate to the excitement of an influence capable of occaſioning muſcles to contract, it follows, as an immediate conſequence, that animals act by their moiſture alone in giving origin to the ſame influence in M. Galvani's experiments, unleſs we are to admit more cauſes of an effect than what are ſufficient for its production." We do not quote the above reaſoning as perfectly concluſive, for it by no means appears to us to be ſo; but it certainly gives ſome probability to the opinion, that galvaniſm is, as M. Volta ſuppoſes, the reſult of the action of two dry conductors, which touch each other immediately on one hand, while at their other extremities they touch conductors of what he calls the ſecond claſs, (that is, moiſture, for all the conductors of the ſecond claſs contain water), and that the bodies of animals act merely as moiſture.

One of M. Humboldt's experiments related above, appears to us to ſtrengthen the concluſion, that the influence diſcovered by Galvani is ſomething perfectly foreign to the bodies of animals. Can it be ſuppoſed that any ſubſtance which naturally reſides in our bodies, ſhould, in a few ſeconds after it is put in motion, convert the ſimple ſerous diſcharge of a bliſter into a dark coloured fluid, of a nature ſo acrid as to irritate and violently inflame the ſkin wherever it touches it? We do not ſay that this is impoſſible, for we are too little acquainted with the laws of ſecretion to ſay with certainty what may, or what may not, produce ſuch a change; but we know no ſimilar alteration produced, *in a few ſeconds*, by a mere change of action in the veſſels themſelves.

35
The cauſe which produces the galvanic effects unknown.

We ſhall not undertake to determine the nature of the cauſe which produces ſuch aſtoniſhing effects. We think it is certainly not the electric fluid, and probably ſomething which reſides or is formed in the excitatory arc; but we conſider our knowledge of galvaniſm as ſtill in its infancy, and our ſtock of facts as infinitely too ſmall to admit of our forming a juſt theory on the ſubject. Fortunately, however, the diſcovery of Galvani has attracted ſo much the attention of philoſophers in every part of Europe, that new facts may be expected to come to light every day; and we hope the time is not very diſtant, when theſe may be ſo claſſed, as to entitle the ſubject to be ranked among the ſciences. See Torpedo in this *Suppl.*

While this article was in the preſs, we were favoured by a friend with an account of ſome German diſſertations on the ſubject, which we are obliged to inſert in this irregular manner.

Mr Creve, ſurgeon in Wurtzburg, had an opportunity of obſerving the galvanic irritation on the leg of a boy, which had been amputated far above the knee in the hoſpital of that city. Immediately after the amputation, Mr Creve laid bare the crural nerve (kniekehlnerven), and ſurrounded it with a ſlip of tinfoil. He touched at once the tinfoil and the nerve with a French crownpiece. In that inſtant the moſt violent convulſions took place in the leg both above and below the knee. The remainder of the thighbone bent with force toward the calf; the foot was more bent than extended. All theſe motions were made with much force and rapidity. None were produced when the tinfoil was taken away, or when a ſteel pincer was uſed in place of a piece of ſilver, or when the tin or ſilver was covered with blood: but they were renewed when theſe obſtacles were removed. Theſe phenomena continued till 38 minutes after the amputation, when the limb became cold.

Dr Chriſtopher Heinrich Pfaff (*in Diſſertatione de Electricitate Animali*, Stutgardt, 1793: ſee alſo Gren's *Journal der Phyſik*, T. viii. p. 196, &c.) has claſſed the phenomena in a very orderly and perſpicuous manner; and the reſult of the numerous experiments made by himſelf and others, correſponds very nearly with our inferences in the preceding pages.

I. *Phenomena of muſcular contraction.*

The general form of his experiments is the ſame with that which we have placed at the beginning of this article; but the following varieties were obſerved:

The nerve being coated with tinfoil, it was always obſerved that the contractions were ſtronger when the ſilver firſt touched the muſcle, and then the coating. If it touched the coating firſt, the effects were always, and very ſenſibly, weaker.

They were ſtill ſtronger when the ſilver did not touch the muſcle at all, but only the nerve and its coating.

When the contractions were weaker at the beginning, they alſo ceaſed ſooner.

No contraction enſued from touching the coating only, or the nerve only, or the muſcle only, with the ſilver.

Continuing the contact did not occaſion any repetition of the contractions, except in ſome caſes, where the ſilver was drawn along different parts of the coating, while its other end remained in contact with the nerve.

The contractions took place only in the muſcles to which the nerve led.

Their ſtrength and duration were greater when the ſurfaces of contact were greater, and when the two metals touched each other in points or ſharp edges.

A ligature, with a ſilk thread below the coating (that is, between the coating and the muſcle, or part of the nerve touched by the ſilver), prevented all contraction; but not if the ligature was between the coating and the brain. If the nerve was cut through below the coating, and the parts ſeparated a quarter of an inch, no contraction followed by touching the coating and the nerve or muſcle: but it took place, if the parts were brought into contact; or even if a piece of any other nerve was put between the parts.

If a conſiderable part of a bared nerve was inſulated and coated, partly with tinfoil and partly with ſilver, contractions were produced in the muſcle to which it led whenever the two metals were brought into contact.

If one crural nerve be coated with tin, and the other with ſilver, contractions are produced in both legs by bringing the metals into contact.

If the nerve be dry under the coating, or when the ſilver touches it, or in both places, we have no contractions; but they begin as ſoon as we moiſten the nerve.

Dr Pfaff infers from theſe phenomena, that the nerve alone is ſubject to the irritation produced by the two metals.

If the prepared frog be immerſed in water, ſo that the coating touches the water, contractions are produced by touching the coating above water with the ſilver, while another part of the ſilver touches the nerve, or the muſcle, or even dips pretty deep in the water.

No ſuch thing happens in oil; or, at beſt, the contractions are very ſlight.

Dr Pfaff could not produce contractions without employing two metals, or a metal and charcoal.

A very thin covering of muſcular fleſh on the nerve did not altogether prevent the contractions, and in many caſes did not ſenſibly diminiſh them.

If a piece of ſilver be laid on the muſcles of the breaſt or belly, and be brought into contact with the tin-coating on the lumbal region, only the muſcles of the breaſt or belly are affected, but not thoſe of the legs.

Dr Pfaff ſays, that the involuntary muſcles are not affected by galvaniſm; and refers for convincing proofs to a diſſertation by Dr Ludwig, ſhewing that the heart is not furniſhed with nerves, (*Scriptor. neurolog. minor. ſelect.* vol. 2.).

II. *Irritation of the Organs of Senſe.*

Here Dr Pfaff's diſſertation contains nothing remarkable.

III. *Conjectures as to the Cauſe.*

Dr Pfaff uſes the ſame arguments that we have employed to refute the opinion of a ſimilarity between the animal organs and the Leyden phial, and the opinion that electricity is the agent. He mentions the opinion of thoſe who maintain that the agent is a fluid put into motion by means of its relation to the metals only, in their action on each other, and who conſider the animal as merely ſerving as a conductor; and alſo ſerving, by its irritability, to give us the information of the preſence of ſuch a fluid, in the ſame manner as another kind of irritation, ſomewhat analogous to it, indicates the preſence and agency of the electric fluid. It may therefore be called the METALLIC IRRITATION; a term which will ſufficiently diſtinguiſh it.

But Dr Pfaff ſeems rather to think that the agent reſides in the animal, and that the metals are the conductors (See a diſſertation, entitled, *Farther Contributions to the Knowledge of Animal Electricity*, in *Gren's Journal der Phyſik*, T. viii. p. 377.). This fluid he conceives to be intimately blended with the *principle of life*; nay, perhaps, to be the ſame. He mentions a thought of Profeſſor Kielmayer, "that it may reſemble the magnetic fluid in its manner of acting, giving connection to the diſtant particles of a nerve, as we obſerve a magnet give an inſtantaneous connection to each of a parcel of iron filings; all of which it would arrange in a certain preciſe manner, if they were ſufficiently moveable, by giving momentary polarity to each." This ſomewhat reſembles Newton's hypothetical whim read to the Royal Society, deſcribing what may be done by means of an æther (See *Birche's Hiſtory of the Royal Society*).

But all this is vague conjecture, and merits little attention. This will be better beſtowed on an obſervation of M. Humboldt of Jena, "that a bit of freſh morelle (the *Helvella mitra* of Linnæus) may be ſubſtituted for a bit of nerve in the animal arc in theſe experiments." This is the only vegetable ſubſtance yet diſcovered to have this property. If the nerve be laid on the morelle, we have only to touch the morelle with the zinc, and the muſcular contractions immediately follow.

GARDECAUT, or GUARD DU CORD, in a watch, is that which ſtops the fuſee when wound up, and for that end is driven up by the ſpring. Some call it Guard-cock; others Guard du Gut.

GARDEN (Francis), better known to the public by the title of *Lord Gardenſtone*, was born at Edinburgh June 24th, in the year 1721. His father was Alexander Garden of Troup; an opulent landholder in Aberdeenſhire; his mother was Jane, daughter of Sir Francis Grant of Cullen, S.C.I.

After paſſing through the uſual courſe of liberal education at the ſchool and the univerſity, he betook himſelf to the ſtudy of law for his profeſſion. In the year 1744 he was admitted a member of the Faculty of Advocates, and called to the Scottiſh bar.

In his practice as an advocate he ſoon began to be diſtinguiſhed, by a ſtrong, native rectitude of underſtanding; by that vivacity of apprehenſion and imagination which is commonly denominated *Genius*; by manly candour in argument, often more perſuaſive than ſubtlety and ſophiſtical artifice; by powers which, with diligence, might eaſily attain to the higheſt eminence of the profeſſion. But the ſame ſtrength, openneſs, and ardour of mind, which diſtinguiſhed him ſo advantageouſly among the pleaders at the bar, tended to give him a fondneſs for the gay enjoyments of convivial intercourſe, which was unfavourable to his progreſs in juridical erudition. Shining in the ſocial and convivial circle, he became leſs ſolicitouſly ambitious than he might otherwiſe have been, of the character of an eloquent advocate, or of a profound and learned lawyer. The vivacity of his genius was averſe from auſtere and plodding ſtudy, while it was captivated by the faſcinations of polite learning and of the fine arts. Nor did he always eſcape thoſe exceſſes in the purſuit of pleaſure into which the temptations of opening life are apt occaſionally to ſeduce the moſt liberal and ingenuous youth. But his cheerful conviviality, his wit, humour, taſte, good-nature, and benevolence of heart, rendered him the delight of all his acquaintance. He became his Majeſty's Solicitor July 3d, 1764.

At length the worth of his character, and his abilities as a lawyer, recommended him to the office of a Judge in the Courts of Seſſion and Juſticiary, the ſupreme judicature, civil and criminal, for Scotland. His place in the Court of Seſſion he continued to occupy till his death; but had, ſome years before, reſigned the office of a Commiſſioner of Juſticiary, and in recompence got a penſion of 200l. per annum. Clear diſcernment, ſtrong good ſenſe, conſcientious honeſty, and amiable benevolence, remarkably diſtinguiſhed all his opinions and conduct as a judge.

We not unfrequently ſee the gay young men of the preſent age, to turn, as they advance towards middle life, from the headlong purſuit of pleaſure to a ſordid and contracted ſelfiſhneſs, which excludes even thoſe few good qualities that ſeemed to accompany their firſt thoughtleſs days. Their life is divided between ſenſuality and that anxious *inhumane* avarice and ambition whoſe ultimate object is, to provide gratifications to ſenſuality and pride. The kindling light of rectitude, and the firſt ſparks of generous humanity, are extinguiſhed in their breaſts as ſoon as thoſe ebullitions of youthful paſſion and inexperience are over, by which the uſeful efficiency of their early good qualities was prevented. Hardly have they become tolerably well acquainted with mankind, when the milk of human kindneſs is turned into gall and venom in their hearts.

It was far otherwiſe with Lord Gardenſtone. As he advanced in years, humanity, taſte, public ſpirit, became ſtill more and more eminently the predominant principles in his mind.—He pitied the condition of the peaſantry, depreſſed rather by their ignorance of the moſt ſkilful modes of labour, and by their remoteneſs from the ſphere of improvement, than by any tyranny or extortion of their landlords. He admired, protected, and cultivated the polite arts He was the ardent votary of political liberty, and friendly to every thing that promiſed a feaſible amelioration of public economy, and the principles of government.

In the year 1762 he purchaſed the eſtate of Johnſton, in the county of Kincardine. Within a few years after he began to attempt a plan of the moſt liberal improvement of the value of this eſtate, by an extenſion of the village of Laurencekirk, adjoining. He offered leaſes of ſmall farms, and of ground for building upon, which were to laſt for the term of one hundred years; and of which the conditions were extremely inviting to the labourers and tradeſmen of the ſurrounding country. Theſe offers were eagerly liſtened to. More deſirous to make the attempt beneficial to the country than to derive profit from it to himſelf, he was induced, within a few years, to reduce his ground-rents to one-half of the original rate.—Weavers, joiners, ſhoemakers, and other artiſans in a conſiderable number, reſorted to ſettle in the riſing village. His Lordſhip's earneſtneſs for the ſucceſs of his project, and to promote the proſperity of the good people whom he had received under his protection, led him to engage in ſeveral undertakings; by the failure of which he incurred conſiderable loſſes. Projects of a printfield, and of manufactures of linen and of ſtockings, attempted with ſanguine hopes in the new village, and chiefly at his Lordſhip's riſk and expence, miſgave in ſuch a manner as might well have finally diſguſted a man of leſs ſteady and ardent philanthropy with every ſuch engagement. But the village ſtill continued to advance. It grew up under his Lordſhip's eye, and was the favourite object of his care. In the year 1779 he procured it to be erected into a burgh of barony; having a magiſtracy, an annual fair, and a weekly market. He provived in it a good inn for the reception of travellers; and with an uncommon attention to the entertainment of the gueſts who might reſort to it, furniſhed this inn with a library of books for their amuſement. He invited an artiſt for drawing, from the continent, to ſettle at Laurencekirk. He had the pleaſure of ſeeing a conſiderable linen manufacture at length fixed in it. A bleachfield was alſo eſtabliſhed as a natural counterpart to the linen manufacture. Before his Lordſhip's death, he ſaw his plan of improving the condition of the labourers, by the formation of a new village at Laurencekirk, crowned with ſucceſs beyond his moſt ſanguine hopes. He has acknowledged, with an amiable frankneſs, in a memoir concerning this village, "That he had tried, in ſome meaſure, a variety of the pleaſures which mankind purſue; but never reliſhed any ſo much as the pleaſure ariſing from the progreſs of his village."

In the year 1785, upon the death of his elder brother,

ther, Alexander Garden of Troup, M. P. for Aberdeenſhire, Lord Gardenſtone ſucceeded to the poſſeſſion of the family eſtates, which were very conſiderable. Until this time his Lordſhip's income had never been more than adequate to the liberal expence into which his rank, and the generoſity of his nature, unavoidably led him. But the addition of a fortune of about three thouſand pounds a-year to his former revenue, gave him the power of performing many acts of beneficence with which he could not before gratify his good heart. It was happy, likewiſe, that his ſucceſſion to this ample income, at a period when the vigour of his conſtitution was rapidly yielding to the infirmities of old age, enabled him to ſeek relief, by a partial ceſſation from buſineſs, by travel, and by other means, which could not have been eaſily compatible with the previous ſtate of his fortune.

In the month of Sept. 1786, he ſet out from London for Dover, and paſſed over into France. After viſiting Paris, he proceeded to Provence, and ſpent the winter months in the genial climate of Hieres. In the ſpring of 1787 he returned northwards, viſiting Geneva, Switzerland, the Netherlands, and the Dutch provinces, and paſſing through Germany into Italy. With a fond curioſity, attentive alike to the wonders of nature, to the noble monuments of the arts, and to the awful remains of ancient grandeur, with which Italy abounds, he viſited all its great cities, and ſurveyed almoſt every remarkable and famous ſcene that it exhibits.

His firſt object, in theſe travels, was to obtain the reſtoration of his declining health by the influence of a milder climate, by gentle, continued, and varied exerciſe; by that pleaſing exhilaration of the temper and ſpirits, which is the beſt medicine to health, and is moſt ſucceſsfully produced by frequent change of place, and of the objects of attention. But the curioſities of nature and art, in thoſe countries through which he travelled, could not fail to attract, in a powerful manner, the curioſity of a mind cultivated and ingenious as his. He, whoſe breaſt glowed with the moſt ardent philanthropy, could not view the varied works and manners of a diverſity of nations of his fellow men, without being deely intereſted by all thoſe circumſtances which might appear to mark their fortunes as happy or wretched. He eagerly collected ſpecimens of the ſpars, the ſhells, the ſtrata of rocks, and the veins of metals, in the ſeveral countries through which he paſſed. He amaſſed alſo cameos, medals, and paintings. He enquired into ſcience, literature, and local inſtitutions. He wrote down his obſervations, from time to time; not indeed with the minute care of a pedant, or the oſtentatious labour of a man travelling with a deſign to publiſh an account of his travels, but ſimply to aid memory and imagination in the future remembrance of objects uſeful or agreeable.

After an abſence of about three years he returned to his native country. The laſt years were ſpent in the diſcharge of the duties of his office as a judge; in ſocial intercourſe with his friends, among whom was the venerable Lord Monboddo, and others of the moſt reſpectable characters that our country has to boaſt of; in the performance of a thouſand generous offices of benevolence and humanity; in cheriſhing thoſe fine arts, of which he was an eminent admirer and judge; and above all, in promoting the comfort, and encouraging the induſtry of his dependants, and in lending his aid to every rational attempt at the improvement of public economy and public virtue.

St Bernard's Well, in the neighbourhood of Edinburgh, had been, long ſince, diſtinguiſhed for the medicinal virtues of its waters. But various circumſtances had alſo concurred of late to throw it into neglect. Yet its waters being ſtrongly mineralized by a ſulphurated hydrogenous gas, were, by this means, unqueſtionably qualified to operate, with highly beneficial effects, in the cure of various diſeaſes. The qualities of this mineral water falling under Lord Gardenſtone's notice, he was induced to purchaſe the property of the well, to direct it to be cleared from ſurrounding obſtacles, which contaminated the virtues of the water, or made it inacceſſible; to erect a beautiful and commodious edifice over it; and to appoint proper perſons to diſtribute the water, for a very trivial compenſation, to the public. The well lies at a diſtance from Edinbugh, which is very convenient for a ſummer morning's walk. Within the few years which have paſſed ſince Lord Gardenſtone's benevolent care brought it into notice, it has attracted many of the inhabitants of that city to viſit in the mornings of ſpring and ſummer. And, undoubtedly, the agreeable exerciſe to which they have thus been allured, and the ſalutary effects of the water, have contributed, in no mean degree, to diſpel diſeaſe, and to confirm, or re-eſtabliſh health. Such monuments are worthy to preſerve the memory of a patriotic and a good man!

As an amuſement for the laſt two or three years of his life, when his increaſing infirmities precluded him from more active exerciſe, and from mingling ſo frequently in the ſociety of his friends as was agreeable to his ſocial and convivial temper, he bethought himſelf of reviſing ſome of the *jeux d'eſprit*, and light fugitive pieces, in which he had indulged the gaiety of his fancy in his earlier days; and a ſmall volume of poems was publiſhed, in which the beſt pieces are, upon good authority, aſcribed to Lord Gardenſtone. He reviſed alſo the memorandums which he had made upon his travels, and permitted them to be ſent to preſs. The two former volumes were publiſhed one after another while his Lordſhip was yet alive; the third after his death. They met with a very favourable reception in the world, and were honoured with the high approbation of the moſt reſpectable writers of periodical criticiſm. They convey much agreeable information, and beſpeak an elegant, enlightened, and amiable mind. The laſt volume is filled chiefly with memorandums of his Lordſhip's travels in Italy; and contains many intereſting criticiſms upon ſome of the nobleſt productions of the fine arts of painting and ſculpture.

His Lordſhip's health had long been declining; and he died a bachelor on the 22d of July 1793, lamented by his relations and friends, by his tenants and humble dependants, and by all true patriots and good men to whom his merits and virtues were known.

Such is the account of Lord Gardenſtone's life, which was prefixed to the third volume of his travelling memorandums; and though it was no doubt an effuſion of fond friendſhip, we believe that the praiſe which it beſtows on his Lordſhip is not much exaggerated. In the latter years of his life, it muſt indeed be confeſſed, that he contracted intimacies with men unworthy

worthy of his regard; and that his attachment to liberty made him form expectations from the French revolution, which even the events which he ſaw ought to have repreſſed. But his mind was by that time weakened by diſeaſe; and it would be very unjuſt to balance the imprudencies of one or two years againſt the meritorious actions of a whole life. Beſides his travelling memorandums and his poems, his Lordſhip publiſhed *A Letter to the Inhabitants of Laurencekirk*, the moſt valuable, in our opinion, of all his publications; for it contains perhaps the moſt ſalutary advices which were ever offered to the inhabitants of a manufacturing town, for the regulation of their conduct towards each other. That the people of Laurencekirk have followed theſe advices, it would give us pleaſure to learn on good authority.

GAS. See that article, *Encycl.* and CHEMISTRY-*Index* in this *Supplement.* We have introduced the word here, to notice ſome experiments made by Profeſſor Jacquin of Vienna, at the deſire of Dr Chladni, on the different gaſes as the vehicle of ſounds. A glaſs bell was furniſhed with a metallic ſtopper cemented to a neck at the top; and in the bore of this cock, within the glaſs, a ſmall flute or pewter (etain) about ſix inches in length was fixed. The glaſs being then placed on the ſhelf of the pneumatic veſſel, and filled with any particular kind of gas, a bladder alſo filled with the ſame gas, and provided with a cock, was adapted to the external aperture of the cock belonging to the bell-glaſs. In this diſpoſition of the apparatus, the flute was made to ſound by gently preſſing the bladder. Comparative experiments were made with atmoſpheric air, oxygen, hydrogen, carbonic acid, and nitrous gas. The intenſity of the ſound did not vary; but when compared with that produced by atmoſpheric air, the oxygen gas gave a ſound half a tone lower; azotic gas, prepared by different methods, conſtantly gave a ſound half a tone lower; hydrogen gas gave nine or eleven tones higher; carbonic acid gas gave one-third lower, and nitrous gas alſo very nearly a third lower. A mixture of oxygen gas and azot, in the proportions of the atmoſpheric air, afforded the tone of this laſt; that is to ſay, it was half a tone higher than each of the component parts alone. When the two gaſes were not uniformly mixed, the ſound was abominably harſh. Chladni intends to give a fuller account of theſe intereſting experiments.—*Journal de Phyſique*, Vol. IV. N. S. p. 57.

GAZONS, in fortification, turfs, or pieces of freſh earth covered with graſs, cut in form of a wedge, about a foot long, and half a foot thick, to line or face the outſide of works made of earth, to keep them up, and prevent their mouldering.

GEOCENTRIC PLACE OF A PLANET, is the place where it appears to us from the earth; or it is a point in the ecliptic, to which a planet, ſeen from the earth, is referred.

GEOCENTRIC Latitude of a Planet, is its latitude as ſeen from the earth, or the inclination of a line connecting the planet and the earth to the plane of the earth's (or true) ecliptic: Or it is the angle which the ſaid line (connecting the planet and the earth) makes with a line drawn to meet a perpendicular let fall from the planet to the plane of the ecliptic.

GEOCENTRIC Longitude of a Planet, is the diſtance meaſured on the ecliptic, in the order of the ſigns, between the geocentric place and the firſt point of Aries.

GEOMETRICAL METHOD OF THE ANCIENTS. The ancients eſtabliſhed the higher parts of their geometry on the ſame principles as the elements of that ſcience, by demonſtrations of the ſame kind: and they were careful not to ſuppoſe any thing done, till by a previous problem they had ſhewn that it could be done by actually performing it. Much leſs did they ſuppoſe any thing to be done that cannot be conceived; ſuch as a line or ſeries to be actually continued to infinity, or a magnitude diminiſhed till it become infinitely leſs than what it is. The elements into which they reſolved magnitudes were finite, and ſuch as might be conceived to be real. Unbounded liberties have of late been introduced; by which geometry, which ought to be perfectly clear, is filled with myſteries.

GEOMETRICAL Solution of a problem, is when the problem is directly reſolved according to the ſtrict rules and principles of geometry, and by lines that are truly geometrical. This expreſſion is uſed in contradiſtinction to an arithmetical, or a mechanical, or inſtrumental ſolution, the problem being reſolved only by a ruler and compaſſes.

The ſame term is likewiſe uſed in oppoſition to all indirect and inadequate kinds of ſolutions, as by approximation, infinite ſeries, &c. So we have no geometrical way of finding the quadrature of the circle, the duplicature of the cube, or two mean proportionals, though there are mechanical ways, and others, by infinite ſeries, &c.

GEORGIUM SIDUS (ſee ASTRONOMY-*Index*, *Encycl.*) has no fewer than ſix ſatellites revolving round it, all diſcovered by Dr Herſchel. Of the two which he firſt diſcovered, one was found to revolve in 8 days 17 h. 1 m. 17 ſec. at the diſtance of 33″ from its primary; and the other in 13 d. 11 h. 5 m. 1,5 ſec. at the diſtance of 44″,23. The planes of their orbits form ſuch large angles with that of the planet itſelf, and conſequently of the ecliptic, as to be almoſt perpendicular to it. To this remarkable departure from the analogy of the old planets, another ſtill more ſingular has been lately announced. They move in a retrograde direction! The new ſatellites revolve as follows, the periodical times being inferred from their greateſt elongations: The interior ſatellite in 5 d. 21 h. 25 m. at the diſtance of 25′,5. A ſatellite intermediate between the two old ones in 10 d. 23 h. 4 m. at the diſtance of 38″,57. The neareſt exterior ſatellite at about double the diſtance of the fartheſt old one, and conſequently its periodical time 38 d. 1 h. 49 m. And the moſt diſtant ſatellite full four times as far from its primary as the old ſecond ſatellite. Whence it will take at leaſt 107 d. 16 h. 40 m. to complete its revolution. Whether the motions of theſe four be direct or retrograde, is, we ſuppoſe, not yet determined.

From ſome obſervations of the Doctor, with an excellent ſeven-feet teleſcope, certain appearances, reſembling that of two rings ſurrounding the planet, and croſſing each other at right angles, were ſeen on ſeveral different days. They were not altered in poſition by turning the ſpeculum in its cell; but (ſays Mr Nicholſon) there is little doubt that they were optical deceptions, becauſe they kept their poſition with reſpect to the tube, after the relative poſition of the parallel had been

been much changed by the earth's rotation, and becauſe they did not appear with larger teleſcopes applied during the courſe of ten years. The diſk of the Georgium Sidus is flattened. It therefore revolves with conſiderable rapidity on its axis. From the very faint light of the ſatellites, they are obſerved to diſappear in thoſe parts of their orbits which bring them apparently neareſt the planet. This does not ariſe from an atmoſphere; for the effect is the ſame, whether the ſatellite be within or beyond the planet.

GERARD (Alexander, D. D.), was the eldeſt ſon of the reverend Gilbert Gerard miniſter of Chapel-Garioch, in the county of Aberdeen. He was born on the 22d of February 1728, and received the firſt rudiments of his education at the pariſh ſchool of Foveran in the ſame county.

It may perhaps be proper to inform our Engliſh readers, that in every pariſh in Scotland there is a ſchool where, for very ſmall fees, the youth of the pariſh are not only taught to read the Engliſh language, to write, and to perform the elementary operations of arithmetic, but are alſo inſtructed in the Greek and Latin languages. Of theſe ſchools, many of the maſters were, about ſixty years ago, eminent for claſſical learning; and it ſeems that Mr Forbes, the maſter of the ſchool of Foveran, poſſeſſed ſuch fame as a teacher, that Mr Gerard judged it more expedient to commit his ſon to his care than to have him educated at the ſchool of his own pariſh, and under his own immediate inſpection. The attainments which that ſon afterwards made in literature, evince that his judgment was correct, and that the ſchoolmaſter of Foveran deſerved the fame which he enjoyed.

Young Gerard, however, did not remain long at Foveran. His father died when he was but ten years old; and his mother removing ſoon afterwards with her family to Aberdeen, he was of courſe put to the grammar ſchool in that city: but ſo ſolid was the foundation which had been already laid, that in two years time he was deemed fit for the univerſity, and was accordingly entered a ſtudent in Mariſchal college. Such rapid progreſs ſupplies the place of that teſtimony which we have not been able to procure, reſpecting his early attachment to literature.

After completing the uſual academical courſe of four years in the ſtudy of Greek, Latin, mathematics, and philoſophy, he was admitted to the degree of maſter of arts; and immediately afterwards commenced the ſtudy of theology, which he proſecuted in the univerſities of Aberdeen and Edinburgh. In 1748, when he had little more than completed his 20th year, he was licenſed to preach in the church of Scotland, and two years afterwards was choſen aſſiſtant to Mr David Fordyce profeſſor of philoſophy in the Mariſchal college and univerſity of Aberdeen. In this capacity he performed the duties of the abſent profeſſor till the 7th of July 1752, when he was appointed ſucceſſor to Mr Fordyce, who had been drowned on the coaſt of Holland, as has been already related in the Encyclopædia.

At that period it was the practice in the Mariſchal college, as it continued to be in the King's, for the ſame profeſſor to carry forward a claſs of ſtudents for three ſucceſſive years through all the different branches of philoſophy which were taught in the college. Theſe were, LOGIC, ONTOLOGY, PNEUMATICS, MORALS, POLITICS, and NATURAL PHILOSOPHY; and Mr Gerard carried one claſs through this extenſive courſe. MATHEMATICS and the GREEK language were taught by ſeparate profeſſors.

About the year 1754, a very material alteration was made in the *order* of teaching philoſophy in the univerſity of Aberdeen; and in the Mariſchal college each profeſſor was reſtricted to one department of ſcience. The principal and profeſſors in that college, juſtly obſerving that the public is intereſted in every thing which relates to education, thought it incumbent upon them to lay before that public the reaſons which had determined them to deviate from the arrangement which they had hitherto obſerved; and they employed Profeſſor Gerard to draw up theſe reaſons. This taſk he performed in a ſmall pamphlet, which, being printed by the appointment of the college, appears to have given very general ſatisfaction.

This, indeed, it could hardly fail to do; for the judicious author points out very clearly the inconveniences of the old, and the advantages of the new plan of academical ſtudy. Having obſerved that the philoſophy which had ſo long kept poſſeſſion of the ſchools, conſiſted, in a great meaſure, of verbal ſubtleties and theories ill-grounded, though ingeniouſly deviſed, he proceeds to contraſt it with the philoſophy of Bacon and Locke, and to ſhow of how little value the former is when compared with the latter. He then enters on a brief examination of the ſcholaſtic logic, and proves, to the conviction of every impartial judge, that the art of ſyllogiſing, though a proper enough introduction to a philoſophy which was built on general principles, either taken for granted, or founded on very narrow and inadequate obſervation, is by no means fitted to aſſiſt the mind in the cultivation of that ſcience which is deduced by induction from particular facts. "The only baſis of philoſophy (ſays he) is now acknowledged to be an accurate and extenſive hiſtory of nature, exhibiting an exact view of the various phenomena, for which philoſophy is to account, and on which it is to found its reaſonings. This being the reformed ſtate of philoſophy, great inconveniences muſt be found in proſecuting the ſcholaſtic order of the ſciences. The ſtudent muſt make a tranſition at once from words and languages to philoſophy, without being previouſly introduced to the knowledge of facts, the ſole foundation of, and preparation for it; he muſt be hurried at the firſt into the moſt abſtruſe, difficult, and ſubtle parts of it; he muſt be put upon examining the nature, foundation, and different kinds of evidence and reaſoning, before he is acquainted with any ſpecimens of theſe kinds by which they may be illuſtrated. And in proportion as philoſophy is more improved, and more thoroughly reformed, theſe inconveniences muſt become more ſenſible.

"The view of theſe (continues he) induced the maſters of the Mariſchal college to think of altering the hitherto received order; and after the moſt mature deliberation, made them at laſt reſolve, that their ſtudents ſhould, after being inſtructed in languages and claſſical learning, be made acquainted with the elements of hiſtory, natural and civil, of geography and chronology, accompanied with the elements of mathematics; that they ſhould then proceed to natural philoſophy; and, laſt of all, to morals, politics, logic, and metaphyſics."

In vindicating this arrangement, he labours with great

great earneſtneſs, and we think with complete ſucceſs, to ſhew the propriety of making logic the laſt branch of academical ſtudy. "All ſciences (ſays he), all departments of knowledge whatever, muſt be premiſed as a ground-work to genuine logic. Hiſtory has one kind of evidence, mathematics another, natural philoſophy one ſtill different, the philoſophy of human nature another diſtinct from all theſe; the ſubordinate branches of theſe ſeveral parts have ſtill minuter peculiarities in the evidence appropriated to them. An unprejudiced mind will in each of theſe be convinced by that ſpecies of argument which is peculiar to it, though it does not reflect *how* it comes to be convinced. By being converſant in *them*, one is prepared for the ſtudy of *logic*; for *they* ſupply him with a fund of materials; in *them* the different kinds of evidence and argument are exemplified; from *them* only thoſe illuſtrations can be taken, without which *its* rules and precepts muſt be unintelligible.

"All juſt concluſions concerning the works of nature muſt be founded on an induction of particulars. And as in *natural philoſophy* theſe particulars are ſupplied by obſervations and experiments on *natural bodies*; ſo in *logic*, the particulars, of which an induction muſt be made, are to be learned only from the body of *arts and ſciences*. Theſe are the ſubjects on which obſervations muſt be made, in order to lay down rules for inveſtigating and proving the truths of which they are made; juſt as the genuine performances of any art are what muſt be conſidered and obſerved in laying down the rules of that art. No ſolid precept can be formed in logic, except by examining arts and ſciences, and attending to the method of reaſoning uſed in them, and to the evidence that accompanies it. In proportion as they are cultivated, and no farther, logic may be improved. And what is true of the invention of logic, is true likewiſe of the ſtudy of it. It can be underſtood no farther, than the ſeveral ſciences which it reviews and criticiſes are previouſly underſtood. Accordingly we find, that all the ſyſtems of logic which have not been compiled from a careful review and examination of the ſeveral ſciences, conſiſt more of ingenious ſubtleties than of uſeful precepts aſſiſting to the mind in the various parts of knowledge. And when logic has been learned before the other ſciences, the ſubſtantial parts of it have been ſcarce attended to, or made any uſe of, in the proſecution of them; nor ſo much as underſtood, but in as far as the mind was gradually opened, and brought to recollect them in its progreſs through the ſciences.

"Logic is preciſely the ſame to *philoſophy* that works of criticiſm are to *poetry*. The rules of criticiſm are formed by an accurate ſcrutiny and examination of the beſt works of poetry. To one who had never read a poem, theſe rules would be obſcure and uſeleſs; he could not comprehend them, far leſs would he be able to form a judgment of their juſtneſs, and of the reaſons on which they are founded. If one peruſes the beſt poetical performances, he will acquire ſome degree of taſte, though he has never profeſſedly ſtudied the rules of criticiſm; and he will, at the ſame time, lay in materials, and obtain a ſtock of examples, which may render theſe rules intelligible to him, and enable him to judge whether they are juſt or not. And by afterwards ſtudying theſe rules, he improves, refines, and corrects his taſte, perceives the principles on which he has founded all his judgments, though he did not in the mean time think of them, and gains additional ſecurity againſt his judging wrong. This may illuſtrate what has been ſaid of the place which logic ought to hold among the ſciences. The obſervations made in it, both concerning the methods of invention and of probation, are founded on, and deduced from, the ſeveral ſciences in which theſe methods are uſed. Neither the obſervations themſelves, nor the reaſons on which they are built, can be fully comprehended by one abſolutely ignorant of theſe ſciences. In ſtudying the particular ſciences, reaſon will ſpontaneouſly exert itſelf: if the proper and natural method of reaſoning is uſed, the mind will, by the native force of its faculties, perceive the evidence, and be convinced by it, though it does not reflect *how* this comes to paſs, nor explicitly conſider according to what general rules the underſtanding is exerted. By afterwards ſtudying theſe rules, one will be farther fitted for proſecuting the ſeveral ſciences; the knowledge of the grounds and laws of evidence will give him the ſecurity of *reflection*, againſt employing wrong methods of proof and improper kinds of evidence, additional to that of *inſtinct* and *natural genius*. And thus logic will greatly contribute to improvement in knowledge; and more ſo, when it is uſed as a *review* of the method taken in the proſecution of ſcience, of the foundations gone upon, and of the general rules that have been obſerved, than when it is applied as an *introduction* to the elements of ſcience; for in the former caſe, its rules can be perfectly underſtood, ſufficiently illuſtrated, and put in practice as they are learned, which in the latter is quite impoſſible."

Having thus vindicated the new arrangement with reſpect to the place which it aſſigns to the ſtudy of logic, he proceeds to inquire in what order the other ſciences ſhould ſucceed each other. "Ethics (ſays he) or moral philoſophy is founded as well as logic on pneumatics, and muſt therefore come after it. The conſtitution of man, and his ſeveral active powers, muſt be explained, before his buſineſs, his duty, and his happineſs, can be diſcovered. Juriſprudence and politics, taking a more complex view of man than morals, by conſidering his various ſtates, as well as his nature and powers, cannot, with any propriety, be introduced till morals have firſt been ſtudied.

"It only remains then to determine whether natural philoſophy or pneumatology ought, in the order of teaching, to have the preference. And many conſiderations ſeem to require that the former ſhould be ſtudied firſt. If it were not, pneumatology would be too far disjoined from the practical ſciences founded on it; one of which, logic, ought, as we have ſeen, to be taught laſt of all. Beſides, we ought always to begin with the eaſieſt and moſt obvious ſubjects, and to proceed gradually to the moſt difficult; and in order to this, we ought to comply as much as poſſible with the natural openings and progreſs of the human mind. Now it is evident, that the mind receives firſt of all impreſſions and ideas of thoſe ſenſible things with which it is ſurrounded. It is not till after it has exerciſed its faculties about them that it reflects on its own operations, or acquires perceptions of them. We are from our earlieſt infancy accuſtomed to obſerve external things, though often tranſiently and inattentively; they lie always in our view, they force themſelves upon us, and we cannot avoid regarding them more or leſs. But we ſeldom attend to the operations of our minds in our earlier years; it is late before we acquire diſtinct notions of them, or can eaſily and readily make them the objects of our contemplation. Farther, external ſenſation, by which bodies are perceived, is a more palpable kind of evidence than internal, from which all our knowledge of ſpirits is derived; it ſtrikes and affects us more. The philoſophy of ſpirits, as well as that of bodies, is founded ſolely on experiments and obſervations; but in the latter it is much eaſier to make theſe than in the former: we can put *bodies* in any ſituation that we pleaſe, and obſerve at leiſure their effects on one another: but the phenomena of the *mind* are of a leſs conſtant nature; we muſt catch them in an inſtant, and be content to glean them up, by obſerving their effects as they accidentally diſcover themſelves in the ſeveral circumſtances of life. The reaſonings alſo by which concluſions are deduced concerning mind are of a more abſtruſe and difficult nature than thoſe employed in the ſcience of bodies; the ideas about which they are converſant are apter to be confounded with one another, and are with greater difficulty kept diſtinct. On all theſe accounts, natural philoſophy muſt be to young minds eaſier than pneumatology, and conſequently ſhould be taught firſt."

For this long digreſſion, if ſuch it ſhall be deemed, we are perſuaded that thoſe who retain any attachment to the place where their minds were firſt imbued with the principles of ſcience, will think no apology requiſite, when they are informed, that the plan of education, which is here ſo ably defended, was about the ſame period adopted by both colleges in the univerſity of Aberdeen; that the writer of this article had his own education in the King's college; and that in the proſperity of that college he ſtill feels himſelf deeply intereſted. Let it be remembered, too, that the publication from which this extract has been made, furniſhes a proof of profeſſor Gerard's abilities, and of the eſtimation in which he was held by his colleagues at a very early period of life; and then ſurely the digreſſion will not be thought impertinent.

He was now profeſſor of moral philoſophy and logic, and of theſe ſciences alone: but though his *plan of education in the Mariſchal College* ſhews the order in which his lectures were arranged, we have not been able to learn on what foundation he built his ſyſtem of ethics. As Hutcheſon's Moral Philoſophy was then much read and admired, it will not detract from Mr Gerard's merits to ſuppoſe, that, with his predeceſſor Mr Fordyce, he was an advocate for the *moral ſenſe* of that author; for there are but three or four foundations on which a ſyſtem of ethics can be raiſed; and it may be doubted whether there be one of them which is not as old as the age of Plato. ' It would indeed be ridiculous in any modern (A) to aim at giving a *new* foundation to moral virtue; for virtue muſt have been practiſed upon ſome ſteady principle from the earlieſt period of human ſociety; and the moſt eminent profeſſor will find ſufficient room for the diſplay of all his learning and ingenuity in illuſtrating the principle which his own judgment has led him to adopt.

Of this profeſſor Gerard was fully ſenſible; and whilſt he was conſcientiouſly diſcharging his duty to his pupils, he neglected no opportunity of improving himſelf. He was member of a literary ſociety at Aberdeen, of which the reſpectability will not be queſtioned, when it is known that it conſiſted of ſuch men as the late Doctors Blackwel, Gregory, Reid, and Campbell, with Dr Beattie, and many others of perhaps equal talents, though not known to the world as authors (B). This ſociety met regularly during the winter, we believe once every fortnight; the members communicated their ſentiments with the utmoſt freedom; every novel opinion was ſure to be canvaſſed on all ſides with impartiality; the underſtandings of the members were thus mutually whetted; and hence originated Reid's *Inquiry into the Human Mind*, Gregory's *Comparative View*, Gerard's *Eſſay on Genius*, Beattie's *Eſſay on Truth*, and Campbell's *Philoſophy of Rhetoric.*

On the 5th of September 1759, Mr Gerard was ordained a miniſter of the Church of Scotland; on the 11th of June 1760, he was appointed profeſſor of divinity in the Mariſchal College, and miniſter of the Grayfriars church in Aberdeen; and at the ſame time, as we ſuppoſe, created doctor in divinity.

On the 18th of June 1771 he reſigned his profeſſorſhip in Mariſchal College, together with his church-living, and was preferred to the theological chair in the univerſity of King's College, then become vacant by the death of profeſſor Lumiſden. In that ſtation he continued, proſecuting his ſtudies, beloved by his colleagues, and revered by his pupils, till his birth-day 1795; when, having juſt completed his 67th year, he died without a groan. His death was occaſioned by a ſchirrous tumor, which began to appear on his face in the year 1794, but without confining him to the houſe, or, except for a very few weeks, interrupting his uſual purſuits. It impaired, however, his health, and gradually undermined his conſtitution. Of this he was very ſoon ſenſible; but he ſaw his diſſolution approaching with the utmoſt compoſure and reſignation, and preſerved to all about him ſo much of that equanimity and placidneſs of temper which had marked the whole courſe of his life, that of him may truly be ſaid,

Multis illi multos annos precantibus
Diri carcinomatis veneno contabuit,
Nexibuſque vitæ paulatim reſolutis,
E terris, meliora ſperans, emigravit.

Were we to hazard an opinion of Dr Gerard's intellectual powers, from having attentively peruſed his works,

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(A) The friends of Mr Godwin, who affect to call his Political Juſtice the *new* philoſophy, will, of courſe, think this a raſh aſſertion; but were it worth while, it would be no very difficult taſk to produce, from the atheiſtical writers of antient Greece, ſomething ſimilar even to his wildeſt paradoxes. Dr Gerard was too well acquainted with the ſubject, and too warm a friend to genuine virtue, to pretend to *novelty* in moral ſcience.

(B) Such as Profeſſor Thomas Gordon, who read lectures in the King's College for 63 or 64 years, and whoſe learning was equalled only by his virtues.

works, we would ſay that he poſſeſſed great rectitude of judgment, rather than any remarkable vigour of mind; that he was capable, by intenſe ſtudy, of becoming maſter of almoſt any ſubject, though perhaps he had not the imagination requiſite for making diſcoveries in ſcience; and that his attainments were ſolid rather than brilliant. What he knew, he knew thoroughly; but to us his knowledge ſeems to have been the reward of labour.

By one, to whom he was well known, and who himſelf ſtands high in the republic of letters *, we are aſſured that he had improved his memory to ſuch a degree, that, in little more than an hour, he could get by heart any ſermon of ordinary length; though far from availing himſelf of this talent, as many would have done, he compoſed with care all the ſermons that he preached. In early life he made it a rule not to ſtudy after ſupper; and from that rule he never deviated, but amuſed himſelf after that time, either with the converſation of his family, or with any light reading that came in his way; and he was generally in bed by half paſt eleven. He ſeems not to have approved of early more than of late ſtudy; for though, for a few years, when as profeſſor of philoſophy he had various ſciences to teach, he roſe regularly, during winter, at five in the morning, he diſcontinued that practice as ſoon as he had it in his power, and did not enter upon ſerious ſtudy till after breakfaſt, generally about ten o'clock. He was indeed very laborious through the day, and could with difficulty be perſuaded to take any bodily exerciſe; but being remarkably temperate in eating and drinking, he enjoyed very good health, which was only occaſionally interrupted by thoſe ſtomach complaints, to which men of ſedentary lives are often ſubject.

The fruits of this inceſſant ſtudy were, beſides the lectures which he read to his different claſſes, 1ſt, *An Eſſay on Taſte*, to which, in 1756, was adjudged the gold medal by the Philoſophical Society of Edinburgh (See SOCIETIES, *Encycl.*), which had propoſed taſte as the ſubject for a prize. Of this eſſay there has been a ſecond, and a third edition; of which the laſt, which was publiſhed in 1780, is conſiderably enlarged and improved. 2d, *Diſſertations on the Genius and Evidences of Chriſtianity*, publiſhed in 1766. 3d, *An Eſſay on Genius*, publiſhed in 1774. 4th, Two volumes of *Sermons*; of which the firſt was publiſhed in 1780, and the ſecond in 1782. 5th, A part of his theological courſe, entitled *The Paſtoral Care*, which was publiſhed in 1799 by his ſon Dr Gilbert Gerard, who ſucceeded him as profeſſor of divinity in the King's college and univerſity of Aberdeen. Beſides theſe works Dr Gerard publiſhed many ſingle ſermons, which were preached on occaſional ſubjects.

Of this amiable and reſpectable inſtructor of youth, we have been favoured with the following character, drawn by a man of talents and virtue †, who was firſt his pupil and afterwards his friend; and though it made part of a funeral ſermon, we believe that, by thoſe who were moſt intimately acquainted with Dr Gerard, the panegyric which it contains will not be deemed extravagant.

" In domeſtic life, his conduct was amiable and exemplary. He poſſeſſed, in a high degree, that kindneſs of heart and affability of manner which intereſted him at all times in the happineſs of his dependants, preſerved good humour in his houſe, and endeared him to his family. He knew how to check improprieties without harſhneſs, and when and how to indulge without impairing his authority. His natural good ſenſe, ſteadineſs, and prudence, prevented him from being thrown into confuſion by the adverſe incidents of life; and enabled him, in preſſing emergencies, to adopt wiſe meaſures, and to adminiſter ſalutary counſel. His tender ſympathy ſoothed the troubled hour of ſorrow; his rational and friendly advice guided his family thro' the perplexities of life, and he feelingly rejoiced in all their innocent enjoyments. His attachments were not confined to his family or his relatives; he was ſuſceptible of warm friendſhip. In ſelecting the objects of it he was cautious, always preferring thoſe whoſe merits entitled them to confidence and regard. His attachment, ſlowly formed, was not to be ſhaken by every oblique inſinuation, or by every idle report to the prejudice of his friend. Steady in his profeſſions of regard, he was capable of conſiderable and diſintereſted exertions to ſerve thoſe whom he really eſteemed. To his judicious advice they had ready acceſs; and his beſt efforts to promote their good they could always command. As a member of ſociety, his houſe was ever the ſeat of hoſpitality, and his door was always open to the ſtranger. In entertaining his friends, he equally avoided the extravagance and oſtentation which did not become his character or ſuit his fortune, and the rigid economy which marks the conduct of thoſe who give with a reluctant and ſparing hand. He neither anxiouſly courted, nor affectedly ſhunned learned converſation. While he never obtruded upon company ſubjects which, by the diſplay of ſuperior knowledge or abilities, were calculated to gratify his own vanity at the expence of hurting others, he always ſtudied, as far as propriety would admit, to adapt his converſation to the temper and inclinations of his aſſociates. To pleaſe the young, and to promote their harmleſs feſtivity, was ever his delight; with cheerfulneſs he deſcended to their trivial amuſements, and in his preſence they felt no reſtraints but thoſe which virtue and decency impoſe. Though he often left for a little ſtudies in which he was keenly engaged, to enjoy the converſation of a friend, he never ſuffered his love of ſociety, one of his ſtrongeſt paſſions, to induce him to ſacrifice any important literary purſuit, or to neglect any neceſſary buſineſs.

" As a clergyman, the office which he held for ſeveral years in Mariſchal college rendered it his duty to be a daily preacher, and gave him a ſeat in the eccleſiaſtical courts. But the unavoidable labour of preparing prelections for his theological pupils, did not prevent his unremitting attention to his public exhibitions in the pulpit. Theſe were marked by that diſtinctneſs of arrangement, that juſtneſs of reaſoning, and that accuracy of compoſition, which effectually ſecured the approbation of the ableſt judges; while by their plainneſs and ſimplicity, they failed not of promoting the edification of the meaneſt capacities. To the low arts of acquiring popularity he never ſtooped: But his prudence, his good ſenſe, his exemplary conduct, and his miniſterial diligence, eſtabliſhed his reſpectability and uſefulneſs, and procured him the full confidence and eſteem of his colleagues. Poſſeſſing more than ordinary

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dinary excellence, envy never led him to depreciate the merits of other preachers. Though one of the beſt of judges, he was always one of the moſt candid hearers. When by his tranſlation to the univerſity of King's college he was releaſed from the labour of conſtant preaching, far from ſhewing any averſion to diſcharge the moſt public miniſterial duties, he was always obedient to preſbyterial appointments; and while health and ſtrength remained, willing to oblige his clerical friends by appearing in their pulpits. Nor in private life did he ever loſe ſight of the character of a clergyman. Having in a publication ably defended its reſpectability, in oppoſition to the ſcoffs and ſneers and ſophiſms of modern ſceptics; he conſidered it as his honour, in his life and converſation, to diſplay its dignity and importance; and to ſhew that the gravity of a Chriſtian paſtor is perfectly conſiſtent with the good breeding of a gentleman, and with the cheerfulneſs, affability, and eaſe of an agreeable companion.

"As a man of letters, his attainments were far above thoſe at which the generality of ſtudents arrive. In his literary purſuits, he had all the advantages of a judgment uncommonly clear and diſtinct; aided, from his earlieſt years, by the moſt indefatigable and perſevering ſtudy. The well-earned reputation with which, before he was promoted to the theological chair, he taught in Mariſchal college different ſciences, inconteſtibly proves that his powers, not confined to one ſubject, juſtly entitled him to eminence in ſeveral branches of literature. His publications, ſeveral of which have been tranſlated into other languages, promiſe fair to extend his fame, and to hand it down to generations yet unborn; and his unremitting labours promiſed ſtill a farther contribution to the general ſtock of learning.

"As a profeſſor of divinity, he will be long and gratefully remembered by his numerous pupils. This was his peculiar department, and in this he ſhone. Poſſeſſing large ſtores of theological knowledge, he was judicious in ſelecting his ſubjects, happy and ſucceſsful in his manner of communicating inſtruction. He had the merit of introducing a new, and in many reſpects a better plan of theological education, than thoſe on which it had been formerly conducted. Liberal, but not looſe, in his ſentiments, his great aim was, not to impoſe by his authority upon his pupils any favourite ſyſtem of opinions; but to impreſs them with a ſenſe of the importance of the miniſterial office, to teach them the proper manner of diſcharging all its duties, and to enable them, by the knowledge of Scripture, to form a juſt and impartial judgment on controverted ſubjects. Solicitous for their improvement, he was ever ready to encourage riſing merit by his warmeſt approbation; and reluctant to damp even unſucceſsful efforts of genius by deſerved cenſure. Having a conſtant eye to what is practically uſeful, rather than to unedifying ſpeculation, he enjoined no duty which he was unwilling to exemplify in his own conduct. Hence that ſtrict regard to the miniſterial character which he uniformly diſplayed, and hence his uncommon punctuality in attending the public ordinances of religion."

GERMINATION, among botaniſts, is a very intereſting ſubject, on which the late diſcoveries in chemiſtry have thrown much light ſince the article GERMINATION was publiſhed in the *Encyclopædia*. In the year 1793, Mr Humboldt diſcovered that ſimple metallic ſubſtances are unfavourable to the germination of plants, and that metallic oxides favour it in proportion to their degree of oxidation. This diſcovery induced him to ſearch for a ſubſtance with which oxygen might be ſo weakly combined as to be eaſily ſeparated, and he made choice of oxigenated muriatic acid gas mixed with water. Creſſes (*lepidium ſativum*) in the oxygenated muriatic acid ſhewed germs at the end of ſix hours, and in common water at the end of 32 hours. The action of the firſt fluid on the vegetable fibres is announced by an enormous quantity of air bubbles which cover the ſeeds, a phenomenon not exhibited by water till at the end of from 30 to 45 minutes. Theſe experiments, announced in Humboldt's *Flora Subterranea Fribergenſis*, and in his Aphoriſms on the chemical phyſiology of Plants, have been repeated by others (A). They were made at a temperature of from 12 to 15 Reaumur. In the ſummer of 1796, Humboldt began a new ſeries of experiments, and found that by joining the ſtimulus of caloric to that of oxygen he was enabled ſtill more to accelerate the progreſs of vegetation. He took the ſeeds of garden creſſes (*lepidium ſativum*), peas (*piſum ſativum*), French beans (*phaſeolis vulgaris*), garden lettuce (*lactuca ſativa*), mignonette (*reſeda odorata*); equal quantities of which were thrown into pure water and the oxygenated muriatic acid at a temperature of 88° F. Creſſes exhibited germs in three hours in the oxigenated muriatic acid, while none were ſeen in water till the end of 26 hours. In the muriatic, nitric (B), or ſulphuric acid, pure or mixed with water, there was no germ at all: the oxygen ſeemed there to be too intimately united with baſes of azot or ſulphur, to be diſengaged by the affinities preſented by the fibres of the vegetable. The author announces, that his diſcoveries may one day be of great benefit in the cultivation of plants. His experiments have been repeated with great induſtry and zeal by ſeveral diſtinguiſhed philoſophers. Profeſſor Pohl at Dreſden cauſed to germinate in oxygenated muriatic acid the ſeed of a new kind of *euphorbia* taken from Bocconi's collection of dried plants, 110 or 120 years old. Jacquin and Vander Schott at Vienna threw into oxygenated muriatic acid all the old ſeeds which had been kept 20 or 30 years at the botanical garden, every attempt to produce vegetation in which had

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(A) See Uſlar's Fragments of Phytology, Plenck's Phyſiology, Villdenow's Dendrology, and *Dictionnaire de Phyſique* par Gehler.

(B) The nitric acid, however, diluted with a great deal of water, accelerates germination alſo, according to the experiments of Candolle, a young naturaliſt, who has applied with great ſucceſs to vegetable phyſiology. This phenomena is the more intereſting, as chemiſtry affords other analogies of the oxygenated muriatic acid and the nitric acid. Profeſſor Pfaſs at Kiel, by purſuing Humboldt's experiments, has found that frogs ſuffocated in oxygenated muriatic acid gas increaſe in irritability, while thoſe which periſh in carbonic acid gas are leſs ſenſible of galvaniſm.

had been fruitleſs, and the greater part of them were ſtimulated with ſucceſs. Even the hardeſt ſeeds yielded to this agent. Among thoſe which germinated were the yellow bonduc or nickar tree (*guilandina bonduc*), the pigeon cytiſus or pigeon pea (*cytiſus cajan*), the *dodonea anguſtifolia*, the climbing mimoſa (*mimoſa ſcandens*), and new kinds of the *homea*.—There are now ſhewn at Vienna very valuable plants which are entirely owing to the oxygenated muriatic acid, and which are at preſent from five to eight inches in height. Humboldt cauſed to germinate the *cluſia roſea*, the ſeeds of which had been brought from the Bahama iſlands by Booſe, and which before had reſiſted every effort to make them vegetate. For this purpoſe he employed a new proceſs, which ſeems likely to be much eaſier for gardeners who have not an opportunity of procuring oxigenated muriatic acid: He formed a paſte by mixing the ſeeds with the black oxide of manganeſe, and then poured over it the muriatic acid diluted with water. Three cubic inches of water were mixed with half a cubic inch of the muriatic acid. The veſſel which contains this mixture muſt be covered, but not cloſely ſhut; elſe it might readily burſt. At the temperature of 95° the muriatic acid becomes ſtrongly oxidated; the oxigenated muriatic gas which is diſengaged paſſes through the ſeeds; and it is during this paſſage that irritation of the vegetable fibres takes place.—*Philoſophical Magazine.*

GESCHE EL AUBE, or GIR GIR, a ſpecies of graſs growing plentifully near *Ras el Feel* on the borders of Abyſſinia. It begins, ſays Mr Bruce, to ſhoot in the end of April, when it firſt feels the humidity of the air. It advances then ſpeedily to its full height, which is about 3 feet 4 inches. It is ripe in the beginning of May, and decays, if not deſtroyed by fire, very ſoon afterwards.

The leaf is long, pointed, narrow, and of a feeble texture. The ſtock from which it ſhoots produces leaves in great abundance, which ſoon turn yellow and fall to the ground. The goats, the only cattle theſe miſerable people have, are very fond of it, and for it abandon all other food while it is within their reach. On the leaves of ſome plants our author ſaw a very ſmall glutinous juice, like to what we ſee upon the leaves of the lime or the plane, but in much leſs quantity; this is of the taſte of ſugar.

From the root of the branch ariſes a number of ſtalks, ſometimes two, but never, as far as he had ſeen, more than three. The flower and ſeed are defended by a wonderful perfection and quantity of ſmall parts. The head, when in its maturity, is of a purpliſh brown.

This ſpecies of graſs was one of the acquiſitions of our author's travels. It was not before known in Europe, nor when he publiſhed his book had the ſeed produced a plant any where but in the garden of the French king.

GHEYSSIQUAS, a nation of Hottentots which inhabits a diſtrict of South Africa bordering on the country of Caffraria. M. Vaillant viſited a horde of this people at no great diſtance from Orange river, as he was returning from his laſt African excurſion to the Cape, and was ſhewn by them a chain of mountains to the eaſt, which extending to a diſtance was loſt in the north, and which, inhabited by their principal tribes, ſeparated them from the Caffies, or at leaſt from the Briquas and Bremas, whom they conſider as tribes of Caffres.

With reſpect to ſuch characteriſtics as are not original and derived from nature, as the form of their dreſs, weapons, inſtruments of muſic, fondneſs for hunting and dancing, and the like, the Gheyſſiquas do not differ from the ſurrounding nations, except in having adopted a particular colour for their ornaments. All the ornaments of the Gheyſſiquas are white, and compoſed of the bones of a ſheep's leg or foot, to which they give a dazzling whiteneſs by proceſſes peculiar to themſelves. Thus, as they fabricate their own necklaces and other articles of luxury, and have no occaſion to purchaſe the materials, they have no dependence on the colonies with reſpect to trade, except for a few neceſſary articles, which they want in common with other ſavages. Accordingly this nation is leſs known and leſs viſited than any other.

The women are well made, lively, and always ready to laugh or dance: yet, with all the gaiety of their diſpoſition, they have the reſervedneſs of manners to which poliſhed nations give the names of modeſty and decorum, and which, in ſo warm a climate, and with ſuch ardent conſtitutions, appears to be a virtue of no eaſy attainment.

Our author ſays that he no where met with a nation ſo truly generous. Though he had nothing to give in exchange, yet during two days that he ſtaid with them, he had bowls of milk brought to him as preſents, night and morning, from every hut. The chief even obliged him to accept a lamb; and though our traveller's attendants were not deſtitute of proviſions, he would give them alſo ſeveral ſheep with which to regale themſelves; a degree of generoſity of which a proper eſtimate can be formed only by thoſe who know ſomething of ſavage manners and ſavage penury.

The practice of ſemi-caſtration prevails among the Gheyſſiquas, and among them only of all the Hottentot tribes; and it prevails in all their hordes without exception. Our author convinced himſelf of this fact by his own eyes; for the men were ſo complaiſant, that, if he had choſen, he might have inſpected the whole horde. Many travellers have written upon the ſubject of this whimſical operation; but they do not agree either as to its origin, the motives that lead to its invention, or the nations by whom it is practiſed. Kolben, who ſays that it commonly conſiſts in the extraction of the left teſticle, repreſents it as a religious ceremony, a general and ſacred law, with all the Hottentots indiſcriminately; but this is unqueſtionably falſe. (See HOTTENTOTS, *Encycl.*) Others attribute it to the deſire of the Gheyſſiquas to render themſelves more fleet in running, an effect which it ſurely is not calculated to produce; and ſome have ſaid that its intention is to prevent the too abundant propagation of the ſpecies. Yet Kolben, though he ſeems inclined to this laſt opinion, affirms that twins are not the leſs common on account of the operation. According to thoſe whom M. Vaillant queſtioned on the ſubject, it is merely a mark of diſtinction, which their anceſtors, being at war with the neighbouring nations, invented for the purpoſe of knowing one another; but, as he himſelf admits, this is a very improbable account of the matter, as they would ſurely have adopted, like the Loangoes, Pomboes, and Cormantins, marks of diſtinction more eaſily diſcerned. Be this as it may, the operation among the Gheyſſiquas is performed by the father, commonly at the birth of the child, though ſometimes not till he has completed his third year.

GHIRGONG, the capital of *Aſam* in Hindoſtan, is, according to Mr Pennant, ſituated in latitude 26° 30′ north. He does not ſtate its longitude. It has four gates, and the city is encompaſſed with a bound hedge of bamboos. The Rajah's palace is ſurrounded by a cauſey, planted on each ſide with a cloſe hedge of bamboos, which ſerves inſtead of a wall. On the outſide there is a ditch, which is always full of water. The Rajah's ſeat is adorned with lattice work and carving. Within and without have been placed plates of braſs, ſo well poliſhed, that when the rays of the ſun ſtrike upon them they ſhine like mirrors. It is an aſcertained fact, that 3000 carpenters and 12,000 labourers were conſtantly employed in this work during two years before it was finiſhed.

Pennant's View of Hindoſtan.

The Aſiatic Reſearches ſpeak much of the wealth of Aſam, and of the plenty and excellency of its natural productions, and that it abounds in all metals but tin. Gold is found in every part of the country by waſhing the ſand of the rivers, and is one of the ſources of revenue ; 12,000, ſome ſay 20,000 people, are employed in that work, each of whom has from the Rajah certain wages. Its gum lac is excellent, and it is very productive of ſilk.

Among the fruits which this country produces are mangoes, plantains, jacks, oranges, citrons, limes, pine apples, and puniala, a ſpecies of tamarind, which has ſuch an excellent flavour, that every perſon who taſtes it prefers it to the plum. There are alſo cocoa nut trees, pepper vines, and areca trees. The ſugar cane excels in ſoftneſs and ſweetneſs, and is of three colours, red, black, and white. There is ginger free from fibres, and betel vines. The ſtrength of vegetation and fertility of the ſoil are ſuch, that whatever ſeed is ſown or ſlips planted they always thrive. The environs of Ghirgong furniſh ſmall apricots, yams, and pomegranates ; but as theſe articles are wild, and not aſſiſted by cultivation and engraftment, they are very indifferent. The principal crop in this country conſiſts in rice and lentiles. Wheat and barley are never ſown ; lignum aloes is alſo a production of this country. The ſilks are excellent, and reſemble thoſe of China, but they manufacture very few more than are required for uſe. They are ſucceſsful in embroidering with flowers and in weaving velvet.—One of their great foreſts is inhabited by abundance of elephants : 6 or 700 may be taken in a year, but they are neglected by the natives, who have neither horſes, camels, nor aſſes, ſuch as are brought from other countries.

According to our author, " the people of Aſam are a baſe unprincipled nation, and have no fixed religion. They follow no rule but that of their own inclination, and make their own vicious minds the teſt of the propriety of their actions. They do not adopt any mode of worſhip practiſed either by heathens or Mahomedans, nor do they concur with any of the known ſects which prevail among mankind ; unlike the pagans of Hindoſtan, they do not reject victuals which have been dreſſed by Moſlems, and they abſtain from no fleſh except human. They even eat animals that have died a natural death."

On this paſſage, one of the ableſt of our literary journaliſts obſerves, that in juſtice to the people of Aſam, we muſt remark, that the above account, extracted from the memoirs of Mir Jumla's expedition into that country, was compoſed by a rigid Mahomedan, at the court of that fanatical tyrant Aurengzebe. The author and his maſter ſaw, in the Aſameſe, only idolaters ; and, in idolaters, the meaneſt of mankind. Their diet, though leſs reſtricted than that of the Hindoos of Bengal, is by no means promiſcuous ; and their religion does not in any way differ from that of Hindoſtan,—as might eaſily be proved by their coins, inſcribed with the names of Hindoo deities.

GIBBON (Edward, Eſq.), the celebrated hiſtorian of the Decline and Fall of the Roman Empire, was born at Putney in the county of Surrey on the 27th of April 1737. He was the firſt child of the marriage of Edward Gibbon, Eſq; and Judith Porten, the youngeſt daughter of a merchant of London.

The family of Gibbon appears to be ancient and honourable ; and our author delights to trace his pedigree from John Gibbon architect to King Edward III. who poſſeſſed lands in the hundred and pariſh of Rolvenden, in the diſtrict which is now called the *Weald* of Kent. In that diſtrict the elder branch of the family ſtill adheres to its native ſoil, without much increaſe or diminution of property ; but the fortunes of the younger branch, from which ſprung the ſubject of this memoir, were fluctuating. It is not, however, with his family, but with himſelf, that we are concerned.

So feeble was his conſtitution, and ſo precarious his life during his childiſh years, that at the baptiſm of each of his brothers (and they were five in number) his father's prudence ſucceſſively repeated the name of Edward, that, in caſe of the death of the eldeſt ſon, this patronymick appellation might ſtill be perpetuated in the family. His brothers and a ſiſter were all ſnatched away in their infancy; and, in terms of affectionate gratitude, he attributes his own preſervation to the more than maternal care of a maiden aunt, his mother's eldeſt ſiſter. " Many anxious and ſolitary days (ſays he) did that dear and excellent woman conſume in the patient trial of every mode of relief and amuſement. Many wakeful nights did ſhe ſit by my bed-ſide in trembling expectation that each hour would be my laſt. Suffice it to ſay, that while every practitioner from Sloane and Ward to the Chevalier Taylor was ſucceſſively ſummoned to torture or relieve me, the care of my mind was too frequently neglected for that of my health. Compaſſion always ſuggeſted an excuſe for the indulgence of the maſter, or the idleneſs of the pupil ; and the chain of my education was broken as often as I was called from the ſchool of learning to the bed of ſickneſs."

His education ſeems indeed to have been far from ſyſtematical. At the age of ſeven he was delivered into the hands of Mr John Kirby, who exerciſed about eighteen months the office of his domeſtic tutor, and of whom he writes in terms of reſpect. This man had been an indigent curate in Cumberland, and when forced by diſtreſs to leave his native country, he was introduced by his learning and his virtue to the family of Mr Gibbon, from whom he might have found at leaſt a temporary ſhelter, had not an act of indiſcretion again driven him into the world. One day reading prayers in the pariſh church, he moſt unluckily forgot the name of of King George; and his patron, a loyal ſubject, diſmiſſed him with ſome reluctance and a decent reward. As our author deſcribes his anceſtors as hereditary Tories, and ſome of them as Jacobites, we think it not improbable that Mr Kirby may have been accuſtomed to omit the name of the King when reading prayers in the family; for otherwiſe he would have pronounced it mechanically in the church.

Be this as it may, our author, upon the diſmiſſion of his tutor, was ſent to Kingſton upon Thames, to a ſchool of ſeventy boys kept by Dr Wooddeſon and his aſſiſtants. He does not repreſent himſelf either as happy or as having made great progreſs at that ſchool. The want of ſtrength and activity diſqualified him for the ſports of the field; his companions reviled him for the ſins of his Tory anceſtors; and his ſtudies were frequently interrupted by ſickneſs. After a real or nominal reſidence of near two years at Kingſton, he was finally recalled (Dec. 1747) by the death of his mother. By this time he was well acquainted with Pope's Homer, the Arabian Nights Entertainments, Dryden's Virgil, and a tranſlation of Ovid's Metamorphoſes; and the entertainment which he received from theſe books gave him a taſte for deſultory reading.

After living a year with his maternal aunt, during which period he read many books on religious ſubjects too deep for the comprehenſion of a boy, he was in January 1749 entered in Weſtminſter ſchool, of which Dr John Nicholl was at that time head maſter. "There (ſays he) in the ſpace of two years, interrupted by danger and debility, I painfully climbed into the third form; and my riper age was left to acquire the beauties of the Latin and the rudiments of the Greek tongue. Inſtead of audaciouſly mingling in the ſports, the quarrels, and the connections of our little world, I was ſtill cheriſhed at home under the maternal wing of my aunt, who now lived in College-ſtreet; and my removal from Weſtminſter long preceded the approach of manhood."

He was firſt carried to Bath for the recovery of his health; then to Wincheſter, where he lived in the houſe of a phyſician; then to Bath again, where he read with a clergyman ſome odes of Horace and ſome epiſodes of Virgil; after which an unſucceſsful trial was made to renew his attendance at Weſtminſter ſchool. "It might now be apprehended (ſays he) that I ſhould continue for life an illiterate cripple; but as I approached my ſixteenth year, Nature diſplayed in my favour her myſterious energies: my conſtitution was fortified and fixed; and my diſorders inſtead of growing with my growth, and ſtrengthening with my ſtrength, moſt wonderfully vaniſhed." In conſequence of this he was carried to Oxford; and before he had accompliſhed his fifteenth year, was, on April 3. 1752, matriculated a gentleman commoner of Magdalen college.

For the honour of that celebrated univerſity, we would fain hope that the account which Mr Gibbon gives of Magdalen college is greatly exaggerated. He repreſents his tutors as totally regardleſs of his morals or his ſtudies. Speaking of the firſt and beſt of them, for he had two, he ſays, "No plan of ſtudy was recommended for my uſe; no exerciſes were preſcribed for his inſpection; and, at the moſt precious ſeaſon of youth, whole days and weeks were ſuffered to elapſe without labour or amuſement, without advice or account." We ſhall make no other remark on this paſſage, than that from gentlemen, who muſt have been contemporary with Mr Gibbon at Magdalen, we have received different accounts of the college; and it is ſurely a very ſingular circumſtance, that at this period of idleneſs, our author ſhould have become enamoured of Sir John Marſham's *Canon Chronicus*, and have conceived the idea of writing an *Eſſay on the age of Seſoſtris*. Such, however, was the caſe. Not only was the eſſay planned, but part of it was written; and though he never finiſhed it, he declares, that his ſolution of ſome difficulties in chronology was not devoid of ingenuity; but he goes on to vilify Oxford. "It might at leaſt be expected (ſays he), that an eccleſiaſtical ſchool ſhould inculcate the orthodox principles of religion. But our venerable mother had contrived to unite the oppoſite extremes of bigotry and indifference: an heretic, or unbeliever, was a monſter in her eyes; but ſhe was *always*, or *often*, or *ſometimes* (A), remiſs in the ſpiritual education of her own children. Without a ſingle lecture, either public or private, either Chriſtian or Proteſtant, without any academical ſubſcription, without any Epiſcopal confirmation, I was led by the dim light of my catechiſm to grope my way to the chapel and communion table, where I was admitted without a queſtion, how far, or by what means, I might be qualified to receive the ſacrament. Such almoſt incredible neglect was productive of the worſt miſchiefs. From my childhood I had been fond of religious diſputation; nor had the elaſtic ſpring been totally broken by the weight of the atmoſphere of Oxford. The blind activity of idleneſs urged me to advance without armour into the dangerous mazes of controverſy; and, at the age of ſixteen, I bewildered myſelf in the errors of the church of Rome."

Thus anxious is our author to account for his reconciliation to the Romiſh church by the negligence of the tutors of his college. This event took place on the 8th of June 1753, when, at the feet of a prieſt in London, he ſolemnly, though privately, abjured the errors of hereſy. An elaborate controverſial epiſtle, approved by his director, and addreſſed to his father, announced and juſtified the ſtep he had taken; and the old gentleman, in the firſt ſally of paſſion, divulging the ſecret, the gates of Magdalen college were ſhut againſt the convert. It was neceſſary therefore to form a new plan of education; and our young Catholic, by the advice of Mr Eliot (afterwards Lord Eliot), was ſettled, on the 30th of June, under the roof and tuition of Mr Pavilliard, a Calviniſt miniſter at Lauſanne in Switzerland.

He repreſents his ſituation there as at firſt extremely uncomfortable. He could not avoid contraſting a ſmall chamber, ill contrived and ill-furniſhed, with his elegant apartment in Magdalen college; and M. Pavilliard being entruſted with the management of his expences, he felt himſelf degraded from the rank of gentleman commoner to that of a ſchool-boy. He began, however, gradually to be reconciled to his fate; and his love of reading returned, which, he ſays, had been chilled by the air of Oxford. He rapidly acquired the French language; and of his tutor he ſays, "My obligations to

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(A) Surely *always* and *ſometimes* are words of very different import: why are they uſed then, in this ſentence, as ſynonymous?

to the leſſons of Mr Pavilliard gratitude will not ſuffer me to forget. He was endued with a clear head and a warm heart; his innate benevolence had aſſuaged the ſpirit of the church; he was rational, becauſe he was moderate: in the courſe of his ſtudies, he had acquired a juſt, though ſuperficial knowledge of moſt branches of literature; by long practice he was ſkilled in the arts of teaching; and he laboured with aſſiduous patience to know the character, gain the affection, and open the mind of his Engliſh pupil."

Under the tuition of this amiable preceptor he deſcribes his progreſs in the French and Latin claſſics, in hiſtory, geography, logic, and metaphyſics, as uncommonly rapid; and he allows to the ſame man a handſome ſhare of the honour of reclaiming him from the errors of popery. The various diſcriminating articles of the Romiſh creed diſappeared like a dream; and, after a full conviction, on Chriſtmas-day 1754, he received the ſacrament in the church of Lauſanne. Thus had our author communicated with three different ſocieties of Chriſtians before the completion of his eighteenth year; and as ſuch changes from church to church are always dangerous, we need not wonder that, in a mind ſo ill-furniſhed as Mr Gibbon's then was for theological inveſtigations, they paved the way for his laſt change to Deiſm. At preſent, however, he ſuſpended his religious inquiries, acquieſcing (as he ſays) with implicit belief in the tenets and myſteries which are adopted by the general conſent of Catholics and Proteſtants.

He continued to proſecute his ſtudies with ardour. Under Mr Pavilliard he learned the Greek alphabet, the grammar, and the pronunciation of the language according to the French accent, and ſoon made himſelf maſter of the works of Homer, Herodotus, and Xenophon. During two winters he attended the private lectures of M. de Traytorrens, who explained the elements of algebra and geometry as far as the conic ſections of the Marquis de l'Hôpital; but in mathematics he was content (he ſays) to receive the paſſive impreſſion of his profeſſor's lectures, without any active exerciſe of his own powers. In the writings of Grotius and Puffendorf he ſtudied the duties of a man, the rights of a citizen, the theory of juſtice, and the laws of peace and war, which have had ſome influence on the practice of modern Europe. "Locke's treatiſe on government (ſays he) inſtructed me in whig principles, which are founded rather in reaſon than experience; but my delight was in the frequent peruſal of Monteſquieu, whoſe energy of ſtyle and boldneſs of hypotheſis were powerful to awaken and ſtimulate the genius of the age"

We have been thus minute in our account of Mr Gibbon's ſtudies, becauſe it furniſhes perhaps the moſt uſeful leſſon which can be drawn from the whole hiſtory of his life. His education had been rendered irregular, and had been often interrupted by ill-health and a feeble conſtitution; but as ſoon as he was able, and had an opportunity, he applied with ardour to the cultivation of letters, and his works bear witneſs that his labour was crowned with ſucceſs. "This part of his ſtory therefore (to uſe the words of Johnſon) well deſerves to be remembered. It may afford uſeful admonition and powerful encouragement to men whoſe abilities have been made, for a time, uſeleſs, and who, having loſt one part of life in idleneſs, are tempted to throw away the remainder in deſpair."

In the year 1757 Voltaire arrived at Lauſanne, and our young ſtudent's deſire to ſee the man who was at once a poet, an hiſtorian, and, as he deemed himſelf, the prince of philoſophers, was ardent, and eaſily gratified. He was received by the vain and arrogant Frenchman with civility as an Engliſh youth, but could not boaſt of any peculiar notice or diſtinction. "The higheſt gratification (ſays he) which I received from Voltaire's reſidence at Lauſanne, was the uncommon circumſtance of hearing a great poet declaim his own productions on the ſtage. His declamation was faſhioned to the pomp and cadence of the old ſtage; and he expreſſed the enthuſiaſm of poetry rather than the feelings of Nature."

About this time Mr Gibbon became enamoured of Mademoiſelle Suſan Curchod, the daughter of the miniſter of Craſſe, in the mountains which ſeparate the Pays de Vaud from the county of Burgundy. In terms of rapture he deſcribes this lady as poſſeſſed of every accompliſhment which could adorn her ſex. She liſtened to the voice of truth and paſſion; her parents honourably encouraged the connection; and our author indulged in the dream of felicity: but on his return to England, he diſcovered that his father would not hear of this ſtrange connection, and that without his conſent he was deſtitute and helpleſs. "After a painful ſtruggle (ſays he) I yielded to my fate. I ſighed as a lover, I obeyed as a ſon, and my wound was inſenſibly healed by time, abſence, and the habits of a new life." The lady conſoled herſelf by giving her hand to M. Neckar, then a rich banker of Paris, afterwards the miniſter, and at laſt one of the deſtroyers of the French monarchy.

In the ſpring of the year 1758 our author was recalled to England. On his arrival in London he haſtened to the houſe of his aunt, Mrs Porten, who had been the guardian of his tender years; for though his father was in town awaiting his arrival, he knew not how he ſhould be received by a parent who had parted with him in anger, and given him a ſtepmother in his abſence. His reception was more agreeable than he expected. His father received him as a man and a friend; and the manners of Mrs Gibbon were ſuch, that, after ſome reſerve on his ſide, ſhe and he eaſily adopted the tender names and genuine characters of mother and ſon; and, by the indulgence of theſe parents, he was left at liberty to conſult his own taſte or reaſon in the choice of place, of company, and of amuſements. In London he had few acquaintances, and hardly any friends; and being accuſtomed to a very ſmall ſociety at Lauſanne, he preferred the retirement of the country to the buſtle of that over-grown metropolis, where he found hardly any entertainment but in the theatres.

Before he left Lauſanne he had begun a work on the ſtudy of ancient literature, which was ſuggeſted by the deſire of juſtifying and praiſing the object of a favourite purſuit. "In France (ſays he), to which my ideas were confined, the learning and language of Greece and Rome were neglected by a philoſophic age. The guardian of thoſe ſtudies, the Academy of Inſcriptions, was degraded to the loweſt rank among the three royal ſocieties of Paris: The new appellation of *Erudits* was contemptuouſly applied to the ſucceſſors of Lipſius and Caſaubon; and I was provoked to hear *, that the exerciſe of the memory, their ſole merit, had been ſuperſeded by the nobler faculties of the imagination and the judgment

* *See Le Diſcours Preliminai par D'Alembert à l'Encyclop die.*

judgment. I was ambitious of proving by my own example, as well as by my precepts, that all the faculties of the mind may be exerciſed and diſplayed by the ſtudy of ancient literature." This laudable ambition continued; and in his father's houſe at Beriton in Hampſhire he finiſhed his *Eſſai ſur l' Etude de la Literature;* which, after being reviſed by Mallet the poet and Dr Maty of the Britiſh muſeum, was, in 1761, publiſhed in a ſmall 12mo volume.

The ſubjects of taſte, criticiſm, and philoſophy, which in this work came under our young author's conſideration, could hardly promiſe much novelty of remark. Some former obſervations, however, he appears to have placed in a new and pleaſing point of view; advancing, moreover, ſome ingenious conjectures, and diſplaying no inconſiderable erudition. Yet, by his own account, he was at this time almoſt a ſtranger to the writers of Greece; and when he quotes them, it is probable that the quotations are given at ſecond hand. To this eſſay was prefixed a dedication to his father in the Engliſh language, which exhibits the author himſelf in a very amiable light; but if his reputation had depended ſolely upon this youthful attempt, the name of Gibbon would have been loſt in oblivion. Yet he ſeems, even in his riper years, to have been delighted with it himſelf, and to have conſidered its merits as equal to thoſe of his later productions; but Milton, it is ſaid, preferred the Paradiſe Regained to the Paradiſe Loſt.

Before the publication of this eſſay, the author, at his own deſire, had been appointed a captain in the South Hampſhire militia, in which he ſerved upwards of two years. At firſt, the company of ruſtic and illiterate officers, and the buſtle of a military life, were extremely diſagreeable to him, as they interrupted his ſtudies; but he admits, that his military ſervices, his bloodleſs and inglorious campaigns, as he calls them, were, on the whole, beneficial, as they brought him acquainted with Engliſh manners, Engliſh parties, and Engliſh principles, to which his foreign education and reſerved temper had hitherto kept him an entire ſtranger. In the camp and in quarters he had even found leiſure, after the firſt ſeven or eight months of his ſervice, to read a great deal of Greek, and to plan different hiſtorical works, to the compoſition of which he ſeems to have thought that he was born with an innate propenſity. He always talks of himſelf as a philoſopher; but ſurely a more unphiloſophical perſuaſion than this has ſeldom been admitted.

At the end of the war he went again abroad, and reached Paris on the 28th of January 1763, only 36 days after the diſbanding of the militia in which he had borne the commiſſion of a captain. In that metropolis he ſtaid not long. He viſited palaces, churches, gardens, and theatres, and was introduced to D'Alembert and Diderot, then conſidered as at the head of French ſcience. From Paris he proceeded to Switzerland, and once more took up his reſidence at his favourite Lauſanne. Voltaire's impieties had forced him from that town to his own caſtle at Ferney, where our author once viſited him, without (he ſays) courting his more intimate acquaintance.

The ſociety in which Mr Gibbon moſt delighted during his ſecond reſidence at Lauſanne was a very ſingular one. "It conſiſted of fifteen or twenty unmarried ladies of genteel families; the eldeſt perhaps about twenty, all agreeable, ſeveral handſome, and two or three of exquiſite beauty. At each other's houſes they aſſembled almoſt every day, without the controul, or even the preſence of a mother or an aunt; they were truſted to their own prudence, among a crowd of young men of every nation in Europe. They laughed, they ſung, they danced, they played at cards, they acted comedies; but in the midſt of this careleſs gaiety, they reſpected themſelves, and were reſpected by the men; the inviſible line between liberty and licentiouſneſs was never tranſgreſſed by a geſture, a word, or a look, and their virgin chaſtity was never ſullied by the breath of ſcandal or ſuſpicion."

We readily agree with our author that this ſingular inſtitution was expreſſive of the innocent ſimplicity of Swiſs manners; and we only regret that he had not the ſame reſpect for the ladies of his own country as for thoſe frolic females of Switzerland. He would not, in that caſe, have ſtained ſome of his moſt brilliant pages with obſcene ribaldry.

We ſhall not follow him in his ramble through Italy, or repeat his remarks on the towns which he viſited. It is ſufficient, in ſuch a ſketch as this, to inform our readers, that it was at Rome on the 15th of October 1764, as he ſat muſing amidſt the ruins of the Capitol, that the idea of his great work firſt ſtarted into his mind. But his original plan was circumſcribed to the decay of the city rather than of the empire.

From carrying even this contracted plan into execution he was for ſome years diverted. On the 25th of June 1765 he arrived from Italy at his father's houſe in Hampſhire, and found that he had filial duties to perform which interrupted his ſtudies and diſturbed his quiet. His father had involved himſelf in difficulties from which he could be extricated only by ſelling or mortgaging part of his eſtate; and to ſuch ſale or mortgage our author cheerfully conſented. He regrets on this occaſion that he had not "embraced the lucrative purſuits of the law or of trade, the chances of civil office or India adventure, or even the fat ſlumbers of the church;" and it is to be hoped that, when he thought even of *ſlumbering* in the church, he had ſtill ſome faith in revealed religion. He waſted ſome time in planning a hiſtory of the revolutions of Switzerland, and even wrote part of it in the French language, which, by the advice of friends, he however ſuppreſſed. We next find him engaged with a friend in a Journal entitled *Memoires Literaires de la Grande Bretagne*, of which two volumes for the years 1767 and 1768 were publiſhed, and a third almoſt completed, when his friend, a native of Switzerland, was engaged, through his intereſt, as travelling governor to Sir Richard Worſley, and the Journal was, of courſe, abandoned. He then entered the liſts with Warburton; whoſe interpretation of the ſixth book of the Æneid he attacked with great petulance and with much ſucceſs. The biſhop of Gloceſter was by this time in a ſtate of great mental decay, which was peculiarly unfortunate for our author; for had his Lordſhip enjoyed his priſtine vigour, he would probably have given Mr Gibbon ſuch a chaſtiſement as might have made him more modeſt afterwards when writing the hiſtory of the Decline and Fall of the Roman Empire.

To that great work he now ſat down ſeriouſly; and the hiſtory which he gives of his preparatory ſtudies ſufficiently accounts for the inaccuracy of his quotations. Through the darkneſs of the middle ages he explored his way in the annals and antiquities of Italy by the learned Muratori and other moderns; and ſeems to acknowledge that, from the beginning to the end of his work, he frequently contented himſelf with authorities furniſhed at ſecond hand.

At laſt, in 1776, the firſt volume of his hiſtory was publiſhed by Cadell the bookſeller and Strahan the printer; and the ſucceſs of it far ſurpaſſed his expectation. The encomiums laviſhed on it by Dr Robertſon and Mr Hume in letters to the author, and the fulſome compliments which thoſe three eminent hiſtorians paid to each other, are melancholy ſpecimens of lettered littleneſs and vanity. The ſecond and third volumes appeared in 1781; the fourth, fifth, and ſixth in 1787; and Mr Gibbon's fame was eſtabliſhed as a hiſtorian. The work was admired both by natives and by foreigners, and tranſlated into ſeveral of the languages of Europe. Dr Zimmerman repreſents the author as excelling perhaps Hume and Robertſon, who were hiſtorians of the firſt rank. All the dignity (he adds), all the charms of hiſtoric ſtyle, are united in Gibbon: his periods are melody itſelf, and all his thoughts have nerve and vigour." This praiſe, however, muſt not be admitted without exception. Few writers, indeed, were poſſeſſed of ſuch popular talents as our hiſtorian. The acuteneſs of his penetration, and the fertility of his genius, have been ſeldom equalled, and ſcarcely ever ſurpaſſed. He ſeizes, with ſingular felicity, on all the moſt intereſting facts and ſituations; and theſe he embelliſhes with the utmoſt luxuriance of fancy and elegance of ſtyle. His periods are full and harmonious; his language is always well choſen, and is frequently diſtinguiſhed by a new and peculiarly happy adaptation. His epithets, too, are in general beautiful and happy; but he is rather too fond of them. The uniform ſtatelineſs of his diction ſometimes imparts to his narrative a degree of obſcurity, unleſs he deſcends to the miſerable expedient of a note, to explain the minuter circumſtances. His ſtyle, on the whole, is much too artificial; and this gives a degree of monotony to his periods, which extends, we had almoſt ſaid, to the turn of his thoughts.

A more ſerious objection is his attack upon Chriſtianity; the looſe and diſreſpectful manner in which he mentions many points of morality regarded as important on the principles of natural religon; and the indecent alluſions and expreſſions which too often occur in the work. .

An attack upon Chriſtianity is not cenſurable merely as ſuch; it may proceed from the pureſt and moſt virtuous motives: but, in that caſe, the attack will never be carried on in an inſidious manner, and with improper weapons, and Chriſtianity itſelf, ſo far from dreading, will invite every mode of fair and candid diſcuſſion. Our hiſtorian, it muſt be confeſſed, often makes, when he cannot readily find, an opportunity to inſult the Chriſtian religion. Such, indeed, is his eagerneſs in the cauſe, that he ſtoops to the moſt deſpicable pun, or to the moſt awkward perverſion of language, for the pleaſure of turning the ſcripture into ribaldry, or calling Jeſus an impoſtor.

Yet of the Chriſtian religion has Mr Gibbon himſelf obſerved, that it "contains a pure, benevolent, and univerſal ſyſtem of ethics, adapted to every duty and every condition of life." Such an acknowledgment, and from ſuch a writer, too, ought to have due weight with a certain claſs of readers, and of authors likewiſe, and lead them ſeriouſly to conſider, how far it is conſiſtent with the character of good citizens, to endeavour, by ſly inſinuations, oblique hints, indecent ſneer, and profane ridicule, to weaken the influence of ſo *pure* and *benevolent* a ſyſtem as that of Chriſtianity, acknowledgd to be admirably calculated for promoting the happineſs of individuals, and the welfare of ſociety.

Mr Hayley, in his poetical Eſſay on Hiſtory, after a ſplendid panegyric on the arduous labours of his friend, laments the irreligious ſpirit by which he was actuated.

> Think not my verſe means blindly to engage
> In raſh defence of thy profaner page!
> Though keen her ſpirit, her attachment fond,
> Baſe ſervice cannot ſuit with Friendſhip's bond;
> Too firm from Duty's ſacred path to turn,
> She breathes an honeſt ſigh of deep concern,
> And pities Genius, when his wild career
> Gives Faith a wound, or Innocence a tear.
> Humility herſelf divinely mild,
> Sublime religion's meek and modeſt child,
> Like the dumb ſon of Crœſus, in the ſtriſe,
> Where force aſſail'd his father's ſacred life,
> Breaks ſilence, and with filial duty warm,
> Bids thee revere her parent's hallowed form (B)!

The part of the hiſtory which gave ſuch offence to his own friend, as well as to the friends of the Chriſtian religion in general, was the account which our hiſtorian has given of the progreſs and eſtabliſhment of Chriſtianity in the two laſt chapters of his firſt volume; in which he endeavours to prove, that the wonderful triumph of that religion over all the eſtabliſhed religions of the earth, was not owing to any miraculous atteſtations to its truth, but to five ſecondary cauſes which he enumerates; and that Chriſtianity, of courſe, could not be of divine origin. Several anſwers appeared on this occaſion, written, as we may naturally ſuppoſe, with different degrees of temper and ability (C).

One of them only, Mr Davis, who had undertaken to point out various inſtances of miſrepreſentation, inaccuracy, and even plagiariſm in his account, did our hiſtorian condeſcend particularly to anſwer, and that in a tone of proud contempt and confident ſuperiority. To this

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(B) Herodotus relates, that a Perſian ſoldier, at the ſtorming of Sardis, was preparing to kill Crœſus, whoſe perſon he did not know, and who, giving up all as loſt, neglected to defend his own life. A ſon of the unfortunate monarch, who had been dumb from his infancy, and who never ſpoke afterward, found utterance in that trying moment, and preſerved his father by exclaiming, 'O kill not Crœſus!'

(C) Dr Chelſum, Dr Randolph, Dr Watſon (biſhop of Llandaff), Lord Hailes, Dr White, Mr Apthorpe, Mr Davis, and Mr Taylor, the author of 'The Letters of Ben Mordecai.'

this Mr Davis replied ; and it is but juſtice to obſerve, that his reply bears evident marks of learning, judgment, and critical acumen, and that he has convicted our author of ſometimes quoting inaccurately to ſerve a purpoſe. At his other anſwerers Mr Gibbon merely glanced, treating Dr Watſon, however, with particular reſpect ; but his poſthumous memoirs ſhew how much he felt the attacks made on him by Lord Hailes, Dr White of Oxford, and Mr Taylor. To Dr Prieſtley, who, in his *Hiſtory of the Corruptions of Chriſtianity*, threw down his gauntlets at once to Biſhop Hurd and the hiſtorian of the Roman empire, and who preſented the latter with a copy of his book, declaring at the ſame time, that he ſent it not as a gift but as a *challenge ;* he wrote in ſuch terms as produced a correſpondence, which certainly added not to the honour of the diſſenting divine.

At the beginning of the memorable conteſt between Great Britain and America, our author was returned, by the intereſt of Mr Eliot (now Lord Eliot), for the borough of Liſkeard, and ſupported, with many a ſincere and ſilent vote, the rights, though not, perhaps, the intereſt, of the mother country. " After a fleeting illuſive hope, prudence condemned me (ſays he) to acquieſce in the humble ſtation of a mute. I was not armed by Nature and education with the intrepid energy of mind and voice.

Vincentem ſtrepitus, et natum rebus agendis.

Timidity was fortified by pride ; and even the ſucceſs of my pen diſcouraged the trial of my voice."

That pen, however, was uſeful to the miniſtry whom he could not ſupport by his eloquence in the houſe. At the requeſt of the Lord Chancellor and Viſcount Weymouth, then ſecretary of ſtate, he vindicated, in a very able manner, againſt the French manifeſto, the juſtice of the Britiſh arms ; and his *Memoire Juſtificatif* was delivered as a ſtate paper to the courts of Europe. He was rewarded for this ſervice with the place of one of the lords commiſſioners of trade and plantations; and kept it, till the board was aboliſhed by Mr Burke's reform bill. For accepting this place he was ſeverely, but moſt unjuſtly, blamed by ſome of the leaders of the oppoſition, as if he had deſerted a party in which he had never enliſted, and to the principles of which he was rendered inimical both by family prepoſſeſſion and by his own judgment.

On the downfal of Lord North's adminiſtration, Mr Gibbon was of courſe in the oppoſition deprived of an office, without the ſalary of which he could not conveniently ſupport the expence of living in London. The coalition was indeed ſoon formed, and his friends were again in power ; but having nothing to give him immediately, they could not detain him in parliament or even in England. He was tired of the buſtle of the metropolis, and ſighed once more for the retirement of Lauſanne, at which he arrived before the overthrow of the coalition miniſtry, and where he lived happily till the laſt years of his life. It was in this retreat that he wrote the fourth, fifth, and ſixth volumes of his hiſtory; and he left it only for a year to ſuperintend the publication of theſe volumes in London. This great work being concluded, he returned to the banks of the Leman lake, but found his enjoyments damped by the diſtreſs, and ſoon afterwards by the death, of his oldeſt and deareſt Swiſs friend. Lauſanne had now loſt much of its attraction ; the French revolution had crowded it with unfortunate emigrants, who could not be cheerful themſelves or excite the cheerfulneſs of others ; and the demons of democracy had begun to poiſon the minds of the ſober citizens with principles which Mr Gibbon had always held in abhorrence. Speaking of theſe principles and their effects in Switzerland, he adds, " I beg leave to ſubſcribe my aſſent to Mr Burke's creed on the revolution of France. I admire his eloquence, I approve his politics, I adore his chivalry, and I can almoſt excuſe his reverence for church eſtabliſhments. While the ariſtocracy of Berne protects the *happineſs*, it is ſuperfluous to inquire whether it be founded in the *rights* of men : the economy of the ſtate is liberally ſupplied without the aid of taxes ; and the magiſtrates *muſt* reign with prudence and equity, ſince they are unarmed in the midſt of an armed nation."

It was againſt the beneficent and mild government of Berne that the emiſſaries of France contrived to excite the diſcontents of the people, by inſtilling into their ſimple and untutored minds their own wild notions of liberty and equality. From the effects of this Gallic frenzy, which began to be very viſible ſo early as the beginning of the year 1792, Mr Gibbon reſolved to take ſhelter in England, and to abandon, for ſome time at leaſt, what he called his paradiſe at Lauſanne. Difficulties intervened, and forced him to poſtpone his journey from week to week, and from month to month ; but on receiving the accounts of Lady Sheffield's death, he haſtened to adminiſter conſolation to his friend, and arrived ſafe in London in the beginning of June 1793.

He continued in good health and ſpirits through the whole of the ſummer ; but his conſtitution had ſuffered much from repeated attacks of the gout, and from an incipient dropſy in his ancles. The ſwelling of his ancles, however, ſubſided ; but it was only in conſequence of the water flowing to another place : and being repeatedly tapped for a *hydrocele*, he at laſt ſunk under it, and died at his lodgings in St James's ſtreet, London, on the 16th of January 1794.

To draw a character at once general and juſt of this extraordinary man, would be difficult perhaps to one who had enjoyed the pleaſure of his acquaintance, and muſt be impoſſible to thoſe to whom his perſon was a ſtranger. Of the extent of his erudition there can be but one opinion ; but various opinions may be held reſpecting the accuracy of his knowledge. Lord Sheffield, who knew him well, and loved him much, aſſures us, that his converſation was ſtill more captivating than his writings : but this could not reſult from the brilliancy of his wit ; for of wit he declares himſelf that he had none. His memory was capacious and retentive, his penetration uncommon, and his colloquial eloquence ready and elegant ; ſo that he could illuſtrate almoſt any topic of converſation from the copious ſtores of his own mind. From his private correſpondence, and a journal not written for the public eye, he appears to have been a dutiful ſon, a loyal ſubject, and an affectionate and ſteady friend ; but it is difficult to reconcile with ſo much moral and political worth his unfair and unmanly ſneers at the religion of his country.

GIBRALTAR is a fortreſs of immenſe ſtrength, of which a very full account has been given in the *Encyclopædia.*

cyclopædia. Nothing, however, is in that article ſaid of the natural hiſtory of the mountain on which the fortreſs is built, though, to men of ſcience, that ſubject muſt be as intereſting as a detail of ſieges. This defect we are enabled to ſupply by means of Major Imrie's mineralogical deſcription of Gibraltar, which is publiſhed in the fourth volume of the Tranſactions of the Royal Society of Edinburgh; and, we are perſuaded, the following abſtract of that elegant memoir will afford rational entertainment to many of our readers.

"The form of this mountain is oblong; its ſummit a ſharp craggy ridge; its direction is nearly from north to ſouth; and its greateſt length, in that direction, falls very little ſhort of three miles. Its breadth varies with the indentations of the ſhore, but it nowhere exceeds three quarters of a mile. The line of its ridge is undulated, and the two extremes are ſomewhat higher than its centre.

"The ſummit of the Sugar Loaf, which is the point of its greateſt elevation towards the ſouth, is 1439 feet; the Rock Mortar, which is the higheſt point to the north, is 1350; and the Signal Houſe, which is nearly the central point between theſe two, is 1276 feet above the level of the ſea. The weſtern ſide of the mountain is a ſeries of rugged ſlopes, interſperſed with abrupt precipices. Its northern extremity is perfectly perpendicular, except towards the north-weſt, where what are called the Lines intervene, and a narrow paſſage of flat ground that leads to the iſthmus, and is entirely covered with fortification. The eaſtern ſide of the mountain moſtly conſiſts of a range of precipices; but a bank of ſand, riſing from the Mediterranean in a rapid acclivity, covers a third of its perpendicular height. Its ſouthern extremity falls, in a rapid ſlope from the ſummit of the Sugar Loaf, into a rocky flat of conſiderable extent, called Windmill Hill.

"The principal maſs of the mountain rock conſiſts of a grey, denſe (what is generally called primary) marble; the different beds of which are to be examined in a face of 1350 feet of perpendicular height, which it preſents to Spain in a conical form. Theſe beds, or ſtrata, are of various thickneſs, from 20 to upwards of 40 feet, dipping in a direction from eaſt to weſt, nearly at an angle of 35 degrees. In ſome parts of the ſolid maſs of this rock are found teſtaceous bodies entirely tranſmuted into the conſtituent matter of the rock, and their interior hollows filled up with calcareous ſpar; but theſe do not occur often in its compoſition, and its beds are not ſeparated by any intermediate ſtrata.

"The caves of Gibraltar are many, and ſome of them of great extent. That which moſt deſerves attention and examinatinn is called St Michael's Cave, which is ſituated upon the ſouthern part of the mountain, almoſt equally diſtant from the Signal Tower and the Sugar Loaf. Its entrance is 1000 feet above the level of the ſea: This entrance is formed by a rapid ſlope of earth, which has fallen into it at various periods, and which leads to a ſpacious hall, incruſted with ſpar, and apparently ſupported in the centre by a large maſſy ſtalactitical pillar. To this ſucceeds a long ſeries of caves of difficult acceſs. In theſe cavernous receſſes, the formation and proceſs of ſtalactites is to be traced, from the flimſy quilt-like cone, ſuſpended from the roof, to the robuſt trunk of a pillar, three feet in dimeter, which riſes from the floor, and ſeems intended by Nature to ſupport the roof from which it originated.

"The only inhabitants of theſe caves are bats, ſome of which are of a large ſize. The ſoil, in general, upon the mountain of Gibraltar is but thinly ſown; and in many parts that thin covering has been waſhed off by the heavy autumnal rains, which have left the ſuperficies of the rock, for a conſiderable extent, bare and open to inſpection. In thoſe ſituations, an obſerving eye may trace the effects of the ſlow, but conſtant, decompoſition of the rock, cauſed by its expoſure to the air, and the corroſion of ſea-ſalts, which, in the heavy gales of eaſterly winds, are depoſited with the ſpray on every part of the mountain. Thoſe uncovered parts of the mountain rock alſo expoſe to the eye a phenomenon worthy of ſome attention, as it tends clearly to demonſtrate, that, however high the ſurface of this rock may now be elevated above the level of the ſea, it has once been the bed of agitated waters. This phenomenon is to be obſerved in many parts of the rock, and is conſtantly found in the beds of torrents. It conſiſts of potlike holes, of various ſizes, hollowed out of the ſolid rock, and formed apparently by the attrition of gravel or pebbles, ſet in motion by the rapidity of rivers or currents in the ſea.

"Upon the weſt ſide of the mountain, towards its baſe, ſome ſtrata occur, which are heterogenial to the mountain rock: the firſt, or higheſt, forms the ſegment of a circle; its convex ſide is towards the mountain, and it ſlopes alſo in that direction. This ſtratum conſiſts of a number of thin beds; the outward one, being the thinneſt, is in a ſtate of decompoſition, and is mouldering down into a blackiſh brown or ferruginous coloured earth. The beds, inferior to this, progreſſively increaſe in breadth to 17 inches, where the ſtratification reſts upon a rock of an argillaceous nature.

"This laſt bed, which is 17 inches thick, conſiſts of quartz of a blackiſh blue colour, in the ſepta or cracks of which are found fine quartz cryſtals, colourleſs, and perfectly tranſparent. Theſe cryſtals are compoſed of 18 planes, diſpoſed in hexangular columns, terminated at both extremities by hexangular pyramids. The largeſt of thoſe that Major Imrie ſaw did not exceed one-fourth of an inch in length: They, in general, adhere to the rock by the ſides of the column, but are detached without difficulty. Their great degree of tranſparency has obtained them the name of *Gibraltar diamonds*."

Much has been ſaid of the foſſil bones found in the rock of Gibraltar; and the general idea which exiſts concerning them is, that they are found in a petrified ſtate, and encloſed in the ſolid calcareous rock; but this, ſays Major Imrie, is a miſtake, which could ariſe only from inaccurate obſervation and falſe deſcription.

"In the perpendicular fiſſures of the rock, and in ſome of the caverns of the mountain (all of which afford evident proofs of their former communication with the ſurface), a calcareous concretion is found, of a reddiſh brown ferruginous colour, with an earthy fracture, and conſiderable induration, encloſing the bones of various animals, ſome of which have the appearance of being human. Theſe bones are of various ſizes, and lie in all directions, intermixed with ſhells of ſnails, fragments of the calcareous rock, and particles of ſpar; all of which materials are ſtill to be ſeen in their natural uncombined ſtates,

ſtates, partially ſcattered over the ſurface of the mountain. Theſe having been ſwept, by heavy rains at different periods, from the ſurface into the ſituations above deſcribed, and having remained for a long ſeries of years in thoſe places of reſt, expoſed to the permeating action of water, have become inveloped in, and cemented by, the calcareous matter which it depoſits.

“ The bones, in this compoſition, have not the ſmalleſt appearance of being petrified; and if they have undergone any change, it is more like that of calcination than that of petrifaction, as the moſt ſolid parts of them generally admit of being cut and ſcraped down with the ſame eaſe as chalk,

“ Bones combined in ſuch concretions are not peculiar to Gibraltar: they are found in ſuch large quantities in the country of Dalmatia, and upon its coaſts in the iſlands of Cherſo and Oſero, that ſome naturaliſts have been induced to go ſo far as to aſſert, that there has been a regular ſtratum of ſuch matter in that country, and that its preſent broken and interrupted appearance has been cauſed by earthquakes, or other convulſions, experienced in that part of the globe. But, of late years, a traveller (Abbé Alberto Fortis) has given a minute deſcription of the concretion in which the bones are found in that country: And by his account it appears, that with regard to ſituation, compoſition, and colour, it is perfectly ſimilar to that found at Gibraltar. By his deſcription, it alſo appears that the two mountain rocks of Gibraltar and Dalmatia conſiſt of the ſame ſpecies of calcareous ſtone; from which it is to be preſumed, that the concretions in both have been formed in the ſame manner and about the ſame periods.

“ Perhaps if the fiſſures and caves of the rock of Dalmatia were ſtill more minutely examined, their former communications with the ſurface might yet be traced, as in thoſe deſcribed above; and, in that caſe, there would be at leaſt a ſtrong probability, that the materials of the concretions of that country have been brought together by the ſame accidental cauſe which has probably collected thoſe found in the caverns of Gibraltar. Major Imrie traced, in Gibraltar, this concretion, from the loweſt part of a deep perpendicular fiſſure, up to the ſurface of the mountain. As it approached to the ſurface, the concretion became leſs firmly combined, and, when it had no covering of the calcareous rock, a ſmall degree of adheſion only remained, which was evidently produced by the argillaceous earth, in its compoſition, having been moiſtened by rain and baked by the ſun.

“ The depth at which theſe materials had been penetrated by that proportion of ſtalactitical matter, capable of giving to the concretion its greateſt adheſion and ſolidity, he found to vary according to its ſituation, and to the quantity of matter to be combined. In fiſſures, narrow and contracted, he found the concretion poſſeſſing a great degree of hardneſs at ſix feet from the ſurface; but in other ſituations more extended: and where a larger quantity of the materials had been accumulated, he found it had not gained its greateſt degree of adheſion at double that depth. In one of the caves, where the maſs of concretion is of conſiderable ſize, he perceived it to be divided into different beds, each bed being covered with a cruſt of the ſtalactitical ſpar, from one inch to an inch and a half in thickneſs; which ſeems to indicate, that the materials have been carried in at various periods, and that thoſe periods have been very remote from each other.

“ At Roſia Bay, upon the weſt ſide of Gibraltar, this concretion is found in what has evidently been a cavern, originally formed by huge unſhapely maſſes of the rock which have tumbled in together. The fiſſure, or cavern formed by the diſruption and ſubſidence of thoſe maſſes, has been entirely filled up with the concretion, and is now expoſed to full view by the outward maſs having dropped down in conſequence of the encroachments of the ſea. It is to this ſpot that ſtrangers are generally led to examine the phenomenon; and the compoſition, having here attained to its greateſt degree of hardneſs and ſolidity, the haſty obſerver, ſeeing the bones incloſed in what has ſo little the appearance of having been a vacuity, examines no further, but immediately adopts the idea of their being incaſed in the ſolid rock. The communication from this former chaſm to the ſurface from which it has received the materials of the concretion, is ſtill to be traced in the face of the rock, but its opening is at preſent covered by the baſe of the line wall of the garriſon. Here bones are found that are apparently human; and thoſe of them that appear to be of the legs, arms, and vertebræ of the back, are ſcattered among others of various kinds and ſizes, even down to the ſmalleſt bones of ſmall birds. Major Imrie found here the complete jaw-bone of a ſheep; it contained its full complement of teeth, the enamel of which was perfect, and its whiteneſs and luſtre in no degree impaired. In the hollow parts of ſome of the large bones was contained a minute cryſtallization of pure and colourleſs calcareous ſpar; but, in moſt, the interior part conſiſted of a ſpary cruſt of a reddiſh colour, ſcarcely in any degree tranſparent.

“At the northern extremity of the mountain, the concretion is generally found in perpendicular fiſſures. The miners there, employed upon the fortifications in excavating one of thoſe fiſſures, found, at a great depth from the ſurface, two ſkulls, which were ſuppoſed to be human; but, to the Major, one of them, if not both, appeared to be too ſmall for the human ſpecies. The bone of each was perfectly firm and ſolid; from which it is to be preſumed, that they were in a ſtate of maturity before they were incloſed in the concretion. Had they appertained to very young children, perhaps the bone would have been more porous, and of a leſs firm texture. The probability is, that they belonged to a ſpecies of monkey, which ſtill continues to inhabit, in conſiderable numbers, thoſe parts of the rock which are to us inacceſſible.

“This concretion varies, in its compoſition, according to the ſituation in which it is found. At the extremity of Princes Lines, high in the rock which looks towards Spain, it is found to conſiſt only of a reddiſh calcareous earth, and the bones of ſmall birds cemented thereby. The rock around this ſpot is inhabited by a number of hawks, that, in the breeding ſeaſon, neſtle here and rear their young; the bones in this concretion are probably the remains of the food of thoſe birds. At the baſe of the rock, below King's Lines, the concretion conſiſts of pebbles of the prevailing calcareous rock. In this concretion, at a very conſiderable depth under the ſurface, was found the under parts of a glaſs bottle, uncommonly ſhaped, and of great thickneſs; the colour of the glaſs was of a dark green.”

Major Imrie makes an apology for giving ſo minute a deſcription of theſe foſſil bones; but, in our opinion, the public is indebted to him for beſtowing ſo much attention on a ſubject which all muſt admit to be curious, and which, from the ſtrange inferences drawn from ſimilar phenomena by modern philoſophers, has become important as well as curious.

We cannot diſmiſs this article without noticing the ſubterraneous galleries conſtructed in the rock not only for the protection of the men during a ſiege, but alſo for placing cannon, to annoy the enemy, in ſituations inacceſſible but by ſuch means. The idea of forming theſe galleries was conceived by the late Lord Heathfield when governor, and by him, in ſome meaſure, carried into execution; though the plan was not completed till lately by General O'Hara. Of theſe galleries we have in the *Monthly Magazine* for April 1798 an animated account, which we ſhall inſert in the writer's own words.

“ The ſubterraneous galleries are very extenſive, pierce the rock in ſeveral places and in various directions, and at various degrees of elevation; all of them have a communication with each other, either by flights of ſteps cut in the rock, or by wooden ſtairs where the paſſages are required to be very perpendicular.

“ The centinels may now be relieved during a ſiege from one poſt to another in perfect ſafety; whereas, previouſly to the conſtructing of theſe galleries, a vaſt number of men were killed by the Spaniards while marching to their ſeveral ſtations. The width of theſe galleries is about twelve feet, their height about fourteen. The rock is broken through in various places, both for the purpoſe of giving light and for placing the guns to bear on the enemy. In different parts there are ſpacious receſſes, capable of accommodating a conſiderable number of men. To theſe receſſes they give names, ſuch as St Patrick's Chamber, St George's Hall, &c. The whole of theſe ſingular ſtructures have been formed out of the ſolid rock by blaſting with gunpowder. Through the politeneſs of an officer on duty, a place called Smart's Reſervoir was opened for our inſpection, which is a great curioſity, and not generally permitted to be ſhewn. It is a ſpring at a conſiderable depth in the body of the rock, and is above 700 feet above the level of the ſea; we deſcended into the cavern that contains it by a rope ladder, and with the aid of lighted candles proceeded through a narrow paſſage over cryſtallized protuberances of the rock till we came to a hollow, which appears to have been opened by ſome convulſion of Nature. Here, from a bed of gems, ariſes the ſalutary fount, clear as the brilliant of the eaſt, and cold as the icicle. We hailed the nymph of the grot, and, proſtrating ourſelves, quaffed hygean nectar from her ſparry urn. When reſtored to the light of day, we obtained, through the medium of the ſame gentleman, the key of St George's Hall, at which we arrived by a very intricate and gloomy path to the ſpacious excavation, which is upwards of an hundred feet in length, its height nearly the ſame. It is formed in a ſemicircular part of the rock; ſpacious apertures are broken through, where cannons of a very large calibre command the iſthmus, the Spaniſh lines, and a great part of the bay. The top of the rock is pierced through, ſo as to introduce ſufficient light to enable you to view every part of it. It appears almoſt incredible that ſo large an excavation could be formed by gunpowder, without blowing up the whole of that part of the rock, and ſtill more ſo, that they ſhould be able to direct the operations of ſuch an inſtrument, ſo as to render it ſubſervient to the purpoſe of elegance. We found in the hall a table, placed, I ſuppoſe, for the conveniency of thoſe who are traverſing the rock. The cloth was ſpread, the wine went round, and we made the vaulted roof reſound with the accents of mirth and the ſongs of conviviality.”

Theſe excavations are indeed very extraordinary works; but as the whole rock abounds with caverns, we wiſh that our author had inquired more particularly than he ſeems to have done, whether St George's Hall be wholly the work of art. From one of the paſſages which we have extracted from Major Imrie's memoir, we are led to think that it is not, or at leaſt, that the concretion removed had not acquired the conſiſtence of the more ſolid parts of the rock. If this was the caſe, much of the wonder will vaniſh, ſince the pick-axe and chiſel were probably employed to give elegance to the vault, and even, in ſome degree, to direct the operation of the gunpowder.

GIMBOLS, are the braſs rings by which a ſea-compaſs is ſuſpended in its box that uſually ſtands in the binacle.

GIRT, in timber-meaſuring, is the circumference of a tree, though ſome uſe this word for the quarter or 4th part of the circumference only, on account of the great uſe that is made of it; for the ſquare of this 4th part is eſteemed and uſed as equal to the area of the ſection of the tree; which ſquare therefore multiplied by the length of the tree, is accounted the ſolid content. This content, however, is always about one-fourth part leſs than the true quantity; being nearly equal to what this will be after the tree is hewed ſquare in the uſual way: ſo that it ſeems intended to make an allowance for the ſquaring of the tree.

GIRT *Line*, is a line on the common or carpenter's ſliding rule, employed in caſting up the contents of trees by means of their girt.

GLASS ETCHING, or *Engraving upon*, is in the article CHEMISTRY (*Encycl.*) ſaid to be a new art; and as that acid which diſſolves ſiliceous earth, and alſo glaſs, was firſt diſcovered in the year 1771 by Scheele, one might naturally imagine that the art of etching with it upon glaſs could not be older. By many others, as well as by us, it has indeed been noticed as a new invention; yet Profeſſor Beckmann, whoſe laborious reſearches have brought many things to light, has proved, that ſo early as the year 1670 the art of etching upon glaſs was diſcovered by Henry Schwanhard, ſon of George Schwanhard, who was a celebrated glaſs cutter, patronized by the Emperor Ferdinand III. about the middle of the laſt century. At the time of his death, 1667, the father practiſed his art at Prague and Ratiſbon. Whether the ſon followed the ſame buſineſs at the ſame towns, or removed to Nuremberg, is not very evident from the profeſſor's hiſtory; but in the year above-mentioned, ſome *aqua regia (nitro muriatic acid)* having accidentally fallen on his ſpectacles, he was ſurpriſed to find the glaſs corroded by it, and become quite ſoft. He thus found himſelf in poſſeſſion of a liquid by which he could etch writing and figures upon plates of glaſs.

Such is our information; but if it be admitted (and it would diſplay unreaſonable ſcepticiſm to queſtion it), Schwanhard muſt either have improved the nitro-muriatic acid by ſome means or other unknown to us, or have confined his etchings to ſome particular kinds of glaſs; for the *fluoric* is the only acid, with which we are acquainted, that corrodes all glaſs. (See CHEMISTRY-*Index* in this *Supplement*). M. Beckmann indeed ſeems to think that he had diſcovered the fluoric acid itſelf; for in the year 1725 there appeared in a periodical work the following receipt for making a powerful acid, by which figures of every kind can be etched upon glaſs.

“When the *ſpiritus nitri per diſtillationem* has paſſed into the recipient, ply it with a ſtrong fire, and when well dephlegmated, pour it, as it corrodes ordinary glaſs, into a Weldenburg flaſk. Then throw into it a pulveriſed green Bohemian emerald, otherwiſe called *heſphorus* (which, when reduced to powder, and heated, emits in the dark a green light), and place it in warm ſand for 24 hours. Take a piece of glaſs well cleaned, and freed from all greaſe by means of a ley; put a border of wax round it, about an inch in height, and cover it all over with the above acid. The longer you let it ſtand ſo much the better; and at the end of ſome time the glaſs will be corroded, and the figures which have been traced out with ſulphur and varniſh will appear as if raiſed above the pane of glaſs.”

That the Bohemian emerald or *heſphorus* mentioned in this receipt is green ſparry fluor, cannot, ſays the profeſſor, be doubted; and he ſeems to have as little doubt of the receipt itſelf having paſſed from Schwanhard and his ſcholars to the periodical work of 1725, from which it has been lately inſerted in the Œkonomiſche Encyclopedie of Krunitz. This ſuppoſition certainly acquires a conſiderable degree of probability from the ſimilarity of Schwanhard's method of etching to that which is here recommended, and which is ſo different from what is now followed. At preſent, the glaſs is covered with a varniſh either of iſinglaſs diſſolved in water, or of turpentine oil mixed with a little white lead, through which the figures to be etched are traced as on copper; but Schwanhard, when he had drawn his figures, covered them with varniſh, and then by his liquid corroded the glaſs around them. His figures, therefore, when the varniſh was removed, remained ſmooth and clear, appearing raiſed from a dim or dark ground; and M. Beckmann, who perſuaded ſome ingenious artiſts to make trial of this antient method of etching, declares, that ſuch figures have a much better effect than thoſe which are cut into the glaſs.

Before concluding this article, it may be worth while juſt to mention a propoſal which has been lately made to employ glaſs inſtead of copper for throwing off prints in the rolling preſs. That it is poſſible to uſe glaſs plates of great thickneſs for this purpoſe, it would be raſh to deny; but the ſuperiority of ſuch plates to thoſe of copper we cannot conceive. If not broken in pieces in the rolling preſs, they would doubtleſs laſt longer; but the expence of them at firſt would probably be greater, and the engraving on them could not be ſo fine.

GLOSSOCOMMON, in mechanics, is a name given by Heron to a machine compoſed of divers dented wheels with pinions, ſerving to raiſe huge weights.

GLUCINA (A), a peculiar earth diſcovered by Vauquelin in the beryl and the emerald. Its general properties are as follows: 1. It is white; 2. Inſipid; 3. Inſoluble in water; 4. Adheſive to the tongue; 5. Infuſible; 6. Soluble in the fixed alkalis; 7. Inſoluble in ammoniac; 8. Soluble in the carbonat of ammoniac; 9. Soluble in almoſt every one of the acids (except the carbonic and phoſphoric acids), and forming ſalts of a ſaccharine taſte; 10. Fuſible with borax into a tranſparent glaſs; 11. Abſorbs one fourth of its weight of carbonic acid; 12. Decompoſes the aluminous ſalts; 13. Is not precipitable by well ſaturated hydro-ſulphurets.

The ſpecific characters of glucina, which are united in none of the other known earths, are: 1. Its ſalts are ſaccharine, and ſlightly aſtringent; 2. It is very ſoluble in the ſulphuric acid by exceſs; 3. It decompoſes the aluminous ſalts; 4. It is ſoluble in the carbonat of ammoniac; 5. Is completely precipitated from its ſolutions by ammoniac; 6. Its affinity for the acids is intermediate between magneſia and alumine.

One hundred parts of beryl contain 16 of glucina; but for the beſt method of analyzing the beryl, and of courſe obtaining the earth, we muſt refer our readers to the article MINERALOGY in this *Supplement;* and ſhall conclude this ſhort article with a valuable and judicious remark of Vauquelin's.

“It almoſt always happens (ſays this able chemiſt), in the ſciences of obſervation, and even in the ſpeculative ſciences, that a body, a principle, or a property, formerly unknown, though it may often have been uſed, or even held in the hands, and referred to other ſimple ſpecies, may, when once diſcovered, be afterwards found in a great variety of ſituations, and be applied to many uſeful purpoſes. Chemiſtry affords many recent examples of this truth. Klaproth had no ſooner diſcovered the different ſubſtances with which he has enriched the ſcience, but they were found in various other bodies; and if I may refer to my own proceſſes, it will be ſeen, that after I had determined the characters of chrome, firſt found in the native red lead, I eaſily recognized it in the emerald and the ruby. The ſame has happened with regard to the earth of the beryl. I have likewiſe detected it in the emerald; in which, nevertheleſs, it was overlooked both by Klaproth and myſelf in our firſt analyſis: ſo difficult it is to be aware of the preſence of a new ſubſtance, particularly when it poſſeſſes ſome properties reſembling thoſe already known!”

GOLD, the moſt perfect of all the metals. See CHEMISTRY-*Index* in this *Supplement.*

It has been a very common opinion among metallurgiſts, that tin has the property of deſtroying the ductility of gold, on being melted with it even in very ſmall quantities; and Dr Lewis adds, that even the vapours which ariſe from tin in the fire, make gold ſo brittle, that it flies in pieces under the hammer. This opinion was controverted by Staneſby Alchorne, Eſq; of his Majeſty's mint, who made a ſet of experiments, which, in his opinion, authoriſe a very different concluſion, viz. that though tin, like other inferior metals,

will

(A) This name was given to the earth of beryl by the editors of the *Annales de Chimie.* Its moſt characteriſtic property being that it forms ſalts of a ſaccharine taſte, they gave it a name derived from γλυκαινω, *to render ſweet.* According to this etymology, ſhould not the name be *Glycina?*

will contaminate gold in proportion to the quantity mixed with it, yet there does not appear in tin any thing ſpecifically inimical to that precious metal.

As we have elſewhere (ſee CHEMISTRY, nº 1091, &c. *Encycl.*) enumerated theſe experiments, and admitted the concluſion drawn from them, it becomes our duty, in this place, to ſtate what has been urged againſt that concluſion.

M. Tillet, being in his own mind perſuaded that tin renders gold ſo brittle that it cannot be reduced to thin leaves, and far leſs be made to paſs through the wire-plate but by virtue of repeated annealing, and peculiar treatment, which gold of the uſual ductility does not require, determined, from reſpect to M. Alchorne, to repeat his experiments.

His firſt experiment* conſiſted in mixing 24 grains of fine gold with one of tin which contained no arſenic. He wrapped the grain of tin in the 24 grains of gold reduced to a very thin leaf, and placed the whole upon a piece of charcoal, ſo hollowed out as to ſupport the mixed metal during fuſion. He even ſprinkled a ſmall quantity of calcined borax upon the metal, in order that the fuſion might be more ſudden, that the metal might flow together, and the tin unite with the gold, without allowing time for it to become calcined. This alloy was ſpeedily fuſed by the enameller's lamp, and reduced into a ſmall button without any loſs of weight. It was then flattened carefully beneath the hammer; but, notwithſtanding his utmoſt precaution in this reſpect, it cracked, and at laſt broke into three pieces, its thickneſs then being a quarter of a line or thereabouts. He repeated this experiment with a double quantity as well of pure gold as of tin, and the reſult was the ſame.

He next alloyed 4 ounces of gold, of the fineneſs of 22 carats, with 1 gros 24 grains of tin deprived of arſenic, or, in other words, with 4 pennyweights of tin; and theſe two metals being reduced into ſmall pieces, were mixed together, put into a crucible, and urged by the ſtrong heat of a forge with two pair of bellows. When their fuſion appeared to be complete, he poured the metal into a ſmall ingot mould proportioned to the quantity.

The ingot thus obtained had loſt ſcarcely any thing of the weight of the two metals that compoſed it; which was a proof that the tin had united and incorporated with the four ounces of gold. But on attempting to bend the ingot, which was about ſix inches long, and not more than two or three lines thick, he remarked, contrary to the nature of gold of 22 carats, that it was rigid, and would have required a conſiderable effort to give it any degree of curvature, or bring it to the flexibility it would have poſſeſſed if no tin had entered into its compoſition. Not ſatisfied, however, with the inference naturally flowing from this circumſtance, he proceeded to the proper teſt by hammering, particularly with the edge of the hammer, in order that the bar might be lengthened, and by that means ſubmitted to the moſt deciſive proof. He did not obſerve, during the continuation of this proceſs, till the bar was reduced to about two-thirds of its firſt thickneſs, that its edges were cracked, or exhibited much of the appearance of brittleneſs; but as he was apprehenſive that this accident might happen by too long hammering, he divided the bar by cutting off the part which had been hammered out. This part was placed in the midſt of lighted charcoal, in order that, by a moderate annealing, it might recover the ſtate of malleability it poſſeſſed before it was hammered. But when he went to take it out of the fire, where it had undergone no greater heat than a cherry-red, he found it divided into two parts. After having ſuffered theſe to cool, he forged them again. They were extended with conſiderable eaſe, though with ſome cracks at the edges; but they did not yet ſatisfy the whole of his enquiries. He therefore annealed one of the two laſt mentioned pieces a ſecond time, and reſerved the other in its hard-hammered ſtate to be paſſed between the laminating rollers. The annealed part, which might have the thickneſs of about a ſhilling, broke in the fire, though the heat was very gentle, into four or five portions. The longeſt of theſe portions, which beſt reſiſted the action of the fire, bent and twiſted itſelf, and ſhewed, by this ſtate of ſtrong contraction in different directions, that it had tended to break and become divided into ſmall portions, ſimilar to thoſe which had already ſeparated from it.

Satisfied by this experiment that the piece of the mixed ingot which he had kept in its hammer-hardened ſtate would not bear annealing, he determined to extend it ſtill more between the rollers, ſetting them up very gradually, in order that the fracture, if it ſhould take place, might be principally owing to the brittleneſs of the material, and not to the force of compreſſion to which it was ſubjected. By this management he ſucceeded in extending the metal to double its length notwithſtanding its hardneſs, and rendering it as thin as ſtrong paper; though the edges were cracked through their whole length like the teeth of a ſaw. But this accident is not at all ſurpriſing, when it is conſidered that gold, though alloyed ſimply with copper, whatever may be the cauſe, does not poſſeſs its uſual ductility, particularly when it is laminated very thin, without repeated annealing as the metal becomes hard.

Aware that the fracture of the pieces of gold might be attributed to an incomplete fuſion, or unequal mixture of the two metals, he melted the whole ingot over again with the utmoſt precaution; but in vain. The metal was as brittle as formerly, and would not bear annealing.

He next fuſed ſix ounces of pure gold of 24 carats with 2 gros, or 6 penny-weights of tin, taking every poſſible precaution to have the metals completely mixed. When the whole was in perfect fuſion, he poured the mixture into an ingot mould, and obtained an ingot rather longer and cleaner than the two former. As ſoon as it was cold he forged one of its extremities with the edge of the hammer. It was lengthened without any perceptible crack; and when it was reduced to the thickneſs of one line, or thereabouts, he cut it off for ſeparate treatment. By moderate annealing it maintained its integrity; and, with the exception of a few cracks, it paſſed the laminating rollers without breaking. As he was fearful, nevertheleſs, that it might break in ſome part if he continued to laminate it, he gave it a ſlight annealing. It had ſcarcely acquired a cherry-redneſs between the charcoal, before it broke into five or ſix parts, ſome of which were ſimply bended or twiſted, and others flat as they quitted the rollers. Among the annealed pieces of this extremity

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* *Memoirs of the Academy of Sciences at Paris for the year* 1790.

extremity of the ingot, there was one ſufficiently long, though a little curled, which he laminated a ſecond time, with the determination of rendering it very thin without the leaſt annealing. It acquired at leaſt double the length it had at firſt without breaking; and, if we except the two ſides of this plate which were cracked, the body, or main piece, was entire. It was ſpongy, and might be conſidered as if formed out of an ingot of common gold containing no tin, but not poſſeſſing the whole of its natural ductility.

" It follows, ſays M. Tillet, from theſe experiments, that gold, whether fine or alloyed, when perfectly fuſed with a ſmall portion of the fineſt tin, acquires rigidity and hardneſs by the mixture; that it loſes ſomewhat of its diſtinguiſhing colour; and that it may, indeed, by careful management, be extended to a certain degree by the hammer, or ſtill better by the rollers; but that, as it cannot be annealed without danger of breaking, it is by this defect deprived of the eſſential advantage of recovering its original ſoftneſs after it has been ſtrongly hammer-hardened. It is not but by careful management in the uſe of the hammer, and by frequent annealing, that artiſts employed on works of gold and ſilver ſucceed in obtaining them without cracks, and bringing them to a ſtate of perfection, without being obliged to have recourſe to ſolder to repair the defects which exceſſive hardneſs under the hammer would occaſion. How much, therefore, ought gold-workers, who continually have this metal in their hands, to be attentive to prevent the introduction of tin in their workſhops, and never to employ ſuch compounds of gold as are ſubject to break, or even to warp, while annealing? The expence of refining, which they would pay for depurating ſuch compounds, would be of leſs conſequence to them than the loſs of time required for the careful management of ſuch gold contaminated by tin, even if they did ſucceed in uſing it, and were not often forced to abandon, after much labour, a work nearly finiſhed.

" If it be allowable (continues our author) to form conjectures on the cauſe of the fracture of plates of gold containing tin, when ſubjected to the annealing heat, it may be preſumed, ſince tin very ſpeedily melts, while gold requires a ſtrong heat for its fuſion, that the parts of the tin intermixed in a ſort of proportional equality with thoſe of the gold, tend to ſeparate by a ſpeedy fuſion and at a very gentle degree of heat; that they remain without conſiſtence between the parts of the gold, while the latter preſerve the whole of their ſolidity, and do not loſe it even by the annealing heat: whence it ſeems, that the parts of the precious metal, when ignited among the coals, having no longer the ſolid connection formed by the tin, but, on the contrary, having an infinite number of ſmall cavities occupied by particles of that metal in fuſion, muſt tend to diſunion; whereas the ſame accident does not take place in the pieces which have reſiſted the annealing, and have been laminated after cooling, becauſe the particles of tin have become ſolid by cooling, and have recovered their original ſtate of union with the gold.

" This fracture of the compound does not take place with an alloy of gold and copper, for an oppoſite reaſon to that which has here been explained; namely, becauſe theſe two metals require nearly the ſame heat for their fuſion. The effect of annealing being there- fore equal upon both, the metals, notwithſtanding this treatment, preſerve their natural conſiſtence, even tho' the heat be carried near the point of fuſion."

Gold-Leaf. See *Gold-Leaf* (*Encycl.*), where a full account is given from Dr Lewis of the proceſs of gold-beating. In that article we have ſaid that gold-leaf ought to be prepared from the fineſt gold; but Mr Nicholſon, who in all probability knows much more of the matter than the author from whom our account was copied, aſſures us that this is a miſtake, and that pure gold is too ductile to be worked between the gold-beater's ſkin. The neweſt ſkins will work the fineſt gold, and make the thinneſt leaf, becauſe they are the ſmootheſt. Old ſkins, being rough or foul, require coarſer gold. The finer the gold, the more ductile; inſomuch that pure gold, when driven out by the hammer, is too ſoft to force itſelf over the irregularities, but would paſs round them, and by that means become divided into narrow ſlips. The fineſt gold for this purpoſe has three grains of alloy in the ounce, and the coarſeſt twelve grains. In general, the alloy is ſix grains, or one-eightieth part. That which is called pale-gold contains three pennyweights of ſilver in the ounce. The alloy of leaf-gold is ſilver, or copper, or both, and the colour is produced of various tints accordingly. Two ounces and two pennyweights of gold is delivered by the maſter to the workman, who, if extraordinary ſkilful, returns two thouſand leaves, or eighty books of gold, together with one ounce and ſix pennyweights of waſte cuttings. Hence one book weighs 4.8 grains; and as the leaves meaſure 3.3 inches in the ſide, the thickneſs of the leaf is one two hundred and eighty-two thouſandth part of an inch.

The yellow metal called Dutch gold is fine braſs. It is ſaid to be made from copperplates, by cementation with calamine, without ſubſequent fuſion. Its thickneſs, compared with that of leaf gold, proved as 19 to 4, and under equal ſurfaces it is conſiderably more than twice as heavy as the gold. *Nicholſon's Journal*, vol. 1ſt.

GOLDONI (Charles), was born at Venice in the year 1707. He gave early indications of his humourous character, as well as his invincible propenſity to thoſe ſtudies which have rendered his name immortal. His father, perceiving that the darling amuſement of his ſon was dramatic performances, had a ſmall theatre erected in his own houſe, in which Goldoni, while yet an infant, amuſed himſelf with three or four of his companions, by acting comedies. Before he was ſent to ſchool, his genius prompted him to become an author. In the ſeventh and eighth years of his age, ere he had ſcarcely learned to read correctly, all his time was devoted to the peruſing comic writers, among whom was *Cicognini*, a Florentine, little known in the dramatic commonwealth. After having well ſtudied theſe, he ventured to ſketch out the plan of a comedy, which needed more than one eye-witneſs of the greateſt probity to verify its being the production of a child.

After having finiſhed his grammatical ſtudies at Venice, and his rhetorical ſtudies at the Jeſuit's college in Perugia, he was ſent to a boarding-ſchool at Rimini to ſtudy philoſophy. The impulſe of nature, however, ſuperſeded with him the ſtudy of Ariſtotle's works, ſo much in vogue in thoſe times. He frequented the theatres with uncommon curioſity; and paſſing gradually from the pit to the ſtage, entered into a familiar acquaintance with the actors. When the ſeaſon of comic performances was over, and the actors were to remove to Chiozza, young Goldoni made his eſcape in their company. This was the firſt fault he committed, which, according to his own confeſſion, drew a great many others after it. His father had intended him to be a phyſician, like himſelf: the young man, however, was wholly averſe to the ſtudy. He propoſed afterwards to make him an advocate, and ſent him to be a practitioner in Modena. An horrid ceremony of eccleſiaſtical juriſdiction, at which he was preſent, inſpired him with a melancholy turn, and he determined to become a capuchin.

His father, perceiving the whimſical, inconſtant humour of his ſon, feigned to ſecond this propoſal, and promiſed to go and preſent him to the guardian of the capuchins in Venice, in the hope that, after ſome ſtay in that extenſive and merry city, his melancholy fit would ceaſe. The ſcheme ſucceeded; for the young man, indulging in all the faſhionable diſſipation of the place, was cured of his fooliſh reſolution. It was however neceſſary for him to be ſettled in ſome employment; and he was prevailed upon by his mother, after the death of his father, to exerciſe the profeſſion of a lawyer in Venice. By a ſudden reverſe of fortune he was compelled to quit at once both the bar and Venice. He then went to Milan, where he was employed by the reſident of Venice in the capacity of ſecretary; where becoming acquainted with the manager of the theatre, he wrote a farce, entitled *Il Gondoliere Veneziano*, the Venetian Gondolier; which was the firſt comic production of his that was performed and printed. Some time after, Goldoni broke with the Venetian reſident, and removed to Verona.

There was in this place, at that time, the company of comedians of the theatre of St Samuel of Venice, and among them the famous actor *Coſali*, an old acquaintance of Goldoni, who introduced him to the manager. He began therefore to work for the theatre, and became inſenſibly united to the company, for which he compoſed ſeveral pieces. Having removed along with them to Genoa, he was for the firſt time ſeized with an ardent paſſion for a lady, who ſoon afterwards became his wife. He returned with the company to Venice, where he diſplayed, for the firſt time, the powers of his genius, and executed his plan of reforming the Italian ſtage. He wrote the *Momolo*, *Courtiſan*, the *Squanderer*, and other pieces, which obtained univerſal admiration.

Feeling a ſtrong inclination to reſide ſome time in Tuſcany, he repaired to Florence and Piſa, where he wrote *The Footman of Two Maſters*, and *The Son of Harlequin loſt and found again*. He returned to Venice, and ſet about executing more and more his favourite ſcheme of reform. He was now attached to the theatre of St Angelo, and employed himſelf in writing both for the company and for his own purpoſes. The conſtant toils he underwent in theſe engagements impaired his health. He wrote, in the courſe of twelve months, ſixteen new comedies, beſides forty-two pieces for the theatre; among theſe many are conſidered as the beſt of his productions. The firſt edition of his works was publiſhed in 1753, in 10 vols. 8vo. As he wrote afterwards a great number of new pieces for the theatre of St Luca, a ſeparate edition of theſe was publiſhed, under the title of *The New Comic Theatre*: among theſe was the *Terence*, called by the author his *favourite*, and judged to be the maſter-piece of his works. He made another journey to Parma, on the invitation of Duke Philip, and from thence he paſſed to Rome. He had compoſed 59 other pieces ſo late as the year 1761, five of which were deſigned for the particular uſe of Marque Albergati Capacelli, and conſequently adapted to the theatre of a private company. Here ends the literary life of Goldoni in Italy.

Through the channel of the French Ambaſſador in Venice, he had received a letter from Mr Zenuzzi, the firſt actor in the Italian theatre at Paris, containing a propoſal for an engagement of two years in that city. He accordingly repaired to Paris, where he found a ſelect and numerous company of excellent performers in the Italian theatre. They were, however, chargeable with the ſame faults which he had corrected in Italy; and the French ſupported, and even applauded in the Italians, what they would have reprobated on their own ſtage. Goldoni wiſhed to extend even to that country his plan of reformation, without conſidering the extreme difficulty of the undertaking. Scurrilities and jeſts, which are ever accompanied by actions, geſtures, and motions, are the ſame in all countries, and almoſt perfectly underſtood even in a foreign tongue: while the beauties of ſentiment and dialogue, and other things which lead to the underſtanding of characters and intrigues, require a familiar acquaintance with the tongue of the writer.

The firſt attempt of Goldoni towards his wiſhed-for reform, was the piece called *The Father for Love*; and its bad ſucceſs was a ſufficient warning to him to deſiſt from his undertaking. He continued, during the remainder of his engagement, to produce pieces agreeable to the general taſte, and publiſhed twenty-four comedies; among which *The Love of Zelinda and Lindor* is reputed the beſt.

The term of two years being expired, Goldoni was preparing to return to Italy, when a lady, reader to the dauphineſs, mother to the late king, introduced him at court, in the capacity of Italian maſter to the princeſſes, aunts to the king. He did not live in the court, but reſorted there at each ſummons, in a poſt-chaiſe ſent to him for the purpoſe. Theſe journeys were the cauſe of a diſorder in the eyes, which afflicted him the reſt of his life; for being accuſtomed to read while in the chaiſe, he loſt his ſight on a ſudden, and in ſpite of the moſt potent remedies, he could never afterwards recover it entirely. For about ſix months lodgings were provided him in the chateau of Verſailles. The death, however, of the dauphin, changed the face of affairs. Goldoni loſt his lodgings, and only, at the end of three years, received a bounty of 100 louis in a gold box, and the grant of a penſion of four thouſand livres a-year. This ſettlement would not have been ſufficient for him, if he had not gained, by other means, farther ſums. He wrote now and then comedies for the theatres of Italy and Portugal; and, during theſe occupations, was deſirous to ſhew to the French that he merited a high rank among their dramatic writers. For this purpoſe, he neglected nothing which could be of uſe to render himſelf maſter of the French language.

Goldoni, Good Hope

He heard, ſpoke, and converſed ſo much in it, that, in his 62d year, he ventured to write a comedy in French, and to have it repreſented in the court theatre, on the occaſion of the marriage of the king.

This piece was the *Bourru Bienfaiſant* ; and it met with ſo great ſucceſs, that the author received a bounty of 150 louis from the king, another gratification from the performers, and conſiderable ſums from the bookſellers who publiſhed it. He publiſhed, ſoon after, another comedy in French, called *L'Avare Faſtueux*. After the death of Louis XV. Goldoni was appointed Italian teacher to the Princeſs Clotilde, the preſent princeſs of Piedmont ; and after her marriage he attended the late unfortunate Princeſs Elizabeth in the ſame capacity.

The approach of old age obliged him to quit Verſailles, and to live in Paris, the air of which, leſs ſharp, was better adapted to his conſtitution. The laſt work of Goldoni was *The Volponi*, written after his retirement from court ; from which time he bade a laſting adieu to writing. Unfortunately for him, he lived to ſee his penſions cut off at the revolution, like others, and he ſpent his laſt days in poverty and diſtreſs. He died in 1792, at a criſis when, according to the expreſſion of a deputy in the Convention, the French nation was ready to repay him every debt of gratitude.

Goldoni is on a par with the greateſt comic poets of modern times, with regard to dramatic talents, and is thought ſuperior to them all with regard to the fertility of his genius. His works were printed at Leghorn in 1788—91, in 31 vols. 8vo. He has been generally called the Moliere of Italy ; and Voltaire, in one of his letters to Marquis Albergati, ſtyles him *The Painter of Nature*. Goldoni is one of thoſe authors whoſe writings will be reliſhed in the moſt remote countries, and by the lateſt poſterity.

GOOD-HOPE, or Cape of Good Hope, was taken by the Britiſh on 17th Auguſt 1796 with very little difficulty. At this we need not be much ſurpriſed, if to the diſcontent which muſt have prevailed among the planters and townſmen with the new order of things, be added the manners of the people. M. Vaillant, who was at the Cape during the laſt war, when the garriſon expected to be every day attacked by a Britiſh ſquadron, and when the people were not abſolutely diſguſted with their own government, repreſents them, however, as rendered ſo completely frivolous by imitating the manners of their French allies, that, though the place was ſtrongly fortified, it could hardly be expected to hold out long againſt a vigorous and well conducted ſiege.

"The females of the Cape (ſays he), when I ſaw them for the firſt time, had really excited my aſtoniſhment by their dreſs and their elegance ; but I admired in them, above all, that modeſty and reſerve peculiar to the Dutch manners, which nothing as yet had corrupted.

"In the courſe of ſix months, a great change had taken place. It was no longer the French modes that they copied ; it was a caricature of the French. Plumes, feathers, ribbons, and tawdry ornaments heaped together, without taſte, on every head, gave to the prettieſt figures a groteſque air, which often provoked a ſmile when they appeared. This mania had extended to the neighbouring plantations, where the women could ſcarcely be known. A mode of dreſs entirely new was everywhere introduced ; but ſo fantaſtical, that it would have been difficult to determine from what country it had been imported."

Good Hope

At that time a French and a Swiſs regiment were in the garriſon ; and though the town was occupied only with warlike preparations, and though an attack from the Britiſh fleet was every moment expected, the French officers had already introduced a taſte for pleaſure. Employed in the morning at their exerciſe, the French ſoldiers in the evening acted plays. A part of the barracks was transformed into a theatre ; and as women capable of performing female characters could not be found in the town, they aſſigned theſe parts to ſome of their comrades, whoſe youth, delicate features, and freſhneſs of complexion, ſeemed beſt calculated to favour the deception. Theſe heroines, of a new kind, heightened the curioſity of the ſpectators, and rendered the entertainment ſtill more lively and intereſting.

To add to the general pleaſure, ladies of the firſt rank conſidered it as incumbent on them to lend to the military actors and actreſſes, their laces, jewels, rich dreſſes, and moſt valuable ornaments. But ſome of them had cauſe to repent of their condeſcenſion ; for it happened more than once that the Counteſs of Almaviva having left in pledge at the ſuttling-houſe her borrowed decorations, the owner, to recover them, was obliged to diſcharge not only the bill due for brandy and tobacco, but all the other debts of the heroine.

During the intoxication and giddineſs occaſioned by theſe amuſements, Love alſo did not fail to act his part ; and certain little intrigues were, from time to time, brought to light, which gave employment to the tongue of ſcandal, and introduced unhappineſs into families. Hymen, it is true, amidſt theſe adventures, ſometimes intervened to repair the follies of his brother ; and many marriages, which reſtored every thing to order, were the reſult of his negotiations ; but the complaints, though ſtifled, did not leſs exiſt. The watchfulneſs of the mother was alert. The huſband, by ſo much the more ſecretly irritated as he ſaw himſelf obliged to conceal his jealouſy, curſed in his heart both actors and theatre ; while the matronly part of the community, leſs on the reſerve, declaimed with bitterneſs againſt the licentiouſneſs that prevailed, which they wholly imputed to this mode of theatrical entertainment. At laſt, to the great mortification of the young, but to the high ſatisfaction of the old women and huſbands, the theatre was on a ſudden ſhut up. The cauſe that affected this was altogether foreign to the complaints that were made, and of a nature that it was impoſſible to foreſee. Two of the French actors, who, it muſt be remembered, were officers in the army, thought proper to imitate the paper money of the company, and to put their forged notes in circulation. The forgery was detected, and traced to its authors ; the two theatrical heroes were baniſhed from the Cape ; and the company, aſhamed of the adventure, dared neither ſeek others to ſupply the vacant places, nor reſume their ſtage entertainments.

Intoxicating as were theſe pleaſures, government meanwhile had not been inattentive to the danger which threatened the colony. As they daily expected to be attacked by the Britiſh fleet, they had increaſed the means of defence, and ordered different works and new fortifications to be conſtructed.

At firſt, the buſineſs was carried on with activity and ardour; becauſe the inhabitants, inſtigated by their private intereſt, which was then conſidered as involved with that of the public, had voluntarily offered their ſervices, and mingled with the workmen. Young and old, ſoldiers and magiſtrates, ſailors and planters, all ſolicited the honour of co-operating for the general good and common ſafety. To behold this heterogeneous multitude—ſome loaded with pick-axes, and ſome with ſpades, or other ſimilar implements—marching out in the morning from the town, and proceeding in high ſpirits to the new fortifications, was a ſight truly admirable.

But this patriotic fervour was of no long continuance. Under pretence of ſparing their ſtrength, and that they might not weary themſelves to no purpoſe, they ſoon cauſed their ſlaves to follow them with the tools and inſtruments. In a little time they contented themſelves with ſending their ſlaves only; and at laſt theſe ſubſtitutes themſelves, in imitation of their maſters, or perhaps by their ſecret orders, gave over going alſo. Their enthuſiaſm, in ſhort, from the firſt moment of its breaking out till the period when it was thus entirely cooled, had been the affair of ſomething leſs than a fortnight.

This taſte for frivolity which, almoſt twenty years ago, was introduced among the Dutch in Cape-town by their good friends the French, ſpread rapidly thro' the planters, who are thus deſcribed by M. Vaillant, who certainly had the beſt opportunities of knowing them.

The planters of the Cape may be divided into three claſſes; thoſe who reſide in the vicinity of the Cape, within a diſtance of five or ſix leagues; thoſe who live farther off in the interior parts of the colony; and laſtly, thoſe who, more diſtant ſtill, are found at the extremity of the frontiers among the Hottentots.

The firſt, who are opulent proprietors, and have handſome country houſes, may be likened to what was formerly called in France *petits ſeigneurs terriers*, and differ extremely from the other planters in eaſe and luxury, and particularly in their manners, which are haughty and diſdainful. Such is the reſult of wealth. The ſecond, ſimple, kind, hoſpitable, are cultivators, who live upon the fruits of their labour. Here we have an example of the good effects of mediocrity. The laſt, poor enough, yet too indolent to derive ſubſiſtence from the ſoil, have no other reſource than the produce of ſome cattle, which they feed as they can. Like the Beduin Arabs, they think much of the trouble of driving them from canton to canton, and from one paſturage to another. This wandering life prevents them from building any ſettled habitations. When their flocks oblige them to ſojourn for a while in the ſame place, they conſtruct, in haſte, a rude kind of hut, which they cover with matts, after the manner of the Hottentots, whoſe cuſtoms they have adopted, and from whom they in no reſpect differ, but in their complexion and features. And here the evil is, that there is no preciſe ſituation in ſocial life to which theſe miſerable beings belong.

Theſe ſluggiſh tribes are held in horror by their induſtrious neighbours, who dread their approach, and remove as far from them as they can; becauſe, having no property of their own, they ſteal without ſcruple that of others, and, when in want of paſturage for their cattle, conduct them ſecretly to the firſt cultivated piece of ground that comes in their way. They flatter themſelves they ſhall not be diſcovered, and they remain till every thing is devoured. If detected in their thefts, ſquabbles and contentions enſue, and afterwards a ſuit at law, in which recourſe is had to the magiſtrate, and which commonly terminates in making three men enemies, the robber, the perſon robbed, and the judge.

Nothing can be ſo mean and cringing as the conduct of the firſt deſcription of planters, when they have any thing to tranſact with the principal officers of the company, who may have ſome influence over their lot; and nothing ſo abſurdly vain and ſo ſuperlatively inſolent as their behaviour to perſons from whom they have nothing to hope and nothing to fear. Proud of their wealth, ſpoiled by reſiding near a town, from whence they have imbibed only a luxury that has corrupted, and vices that have degraded them, it is particularly towards ſtrangers that they exerciſe their ſurly and pitiful arrogance. Though neighbours to the planters who inhabit the interior of the country, you muſt not ſuppoſe they regard them as brethren; on the contrary, in the true ſpirit of contempt, they have given them the name of Rauw-boer, a word anſwering to the loweſt deſcription of clown. Accordingly, when theſe honeſt cultivators come to the town upon any kind of buſineſs, they never ſtop by the way at the houſes of the gentry of whom we are ſpeaking; they know too well the inſulting manner in which they would be received. One might ſuppoſe them to be two inimical nations always at war, and of whom ſome individuals only met at diſtant intervals, upon buſineſs that related to their mutual intereſts.

What is the more diſguſting in the inſolence of theſe Africans is, that the majority of them are deſcended from that corrupt race of men, taken from priſons and hoſpitals, whom the Dutch company, deſirous of forming a ſettlement at the Cape, ſent thither to begin, at their riſk and pearl, the population of the country. This ſhameful emigration, of which the period is not ſo remote but that many circumſtances of it are remembered, ought to render particularly modeſt thoſe who are in the moſt diſtant manner related to it. On the contrary, it is this very idea that moſt contributes to their arrogance; as if they flattered themſelves that, under the guiſe of ſupercilious manners, they could hide the abjectneſs of their origin. If a ſtranger arrives at the Cape with the deſign of remaining and ſettling there, they conceive him to be driven from his country by the ſame wretched circumſtances which formerly baniſhed their fathers, and they treat him with the moſt ſovereign contempt.

This melancholy failing is the more to be lamented as the contagion has ſpread through almoſt every reſidence about the Cape, which is in reality a very charming canton. Embelliſhed by cultivation, by its numerous vineyards and pleaſant country houſes, it everywhere exhibits ſo varied and delicious a proſpect, that, were it occupied by other inhabitants, it would excite no ſenſations but thoſe of pleaſure.

As we advance into the country, the planters are a ſort of farmers; and conſtitute, by their manners, cuſtoms, and occupations, a claſs by themſelves, perfectly diſtinct from what we have been deſcribing. Situated farther from the Cape, and, of conſequence, not having the ſame opportunities for diſpoſing of their commodities, they are leſs rich than the firſt. We ſee among them none of thoſe agreeable country houſes, which, placed at different diſtances from the town, embelliſh the country as we paſs, and afford ſuch charming proſpects. Their habitation, which is about the ſize of a large coach-houſe, is covered with thatch, and divided into three rooms by means of two partitions, which reach only to a certain height. The middle apartment, in which is the entrance to the houſe, ſerves at once both as a parlour and eating-room. It is there that the family reſide during the day, and that they receive their tea and other viſitors. Of the two other rooms, one forms a chamber for the male children, and the other for the females, with the father and mother. At the back of the middle apartment is a farther room ſerving for a kitchen. The reſt of the building conſiſts of barns and ſtables.

Such is the diſtribution which is generally followed in the interior plantations of the colony; but nearer to the frontiers, where there does not prevail the ſame eaſe of circumſtances, the habitations are much leſs commodious. They are merely a barn, conſiſting of a ſingle room, without any diviſion, in which the whole family live together, without ſeparating either day or night. They ſleep upon ſheep ſkins, which ſerve them alſo for covering.

The dreſs of theſe planters is ſimple and ruſtic. That of the men conſiſts of a check ſhirt, a waiſtcoat with ſleeves, a large pair of trowſers, and a hat half unlooped. The women have a petticoat, a jacket fitted to their ſhape, and a little round bonnet of muſlin. Unleſs upon extraordinary occaſions, neither ſex wear ſtockings. During a part of the year, the women even walk with their feet quite naked. The occupations of the men require that theirs ſhould have ſome covering; and this covering they make from a piece of the hide of an ox, applied and ſhaped to the foot ſoon after the animal is killed, and while the hide is yet freſh. Theſe ſandals are the only article of their dreſs which they make themſelves; the reſt is the buſineſs of the women, who cut out and prepare their whole wardrobe. Though the equipment we have mentioned conſtitute the every-day dreſs of the planter, he has, however, a coat of handſome blue cloth, which he wears upon days of gala and ceremony. He has then alſo ſtockings and ſhoes, and is dreſſed exactly like an European. But this finery never makes its appearance but when he goes to the Cape; and then, indeed, is not put on till he arrives at the entrance of the town.

It is commonly in theſe journeys that they purchaſe ſuch things as they may want to refit their wardrobe. There is, at the Cape, as well as in Paris and London, a ſpecies of old-clothes-men, who deal in commodities of this ſort; and who, from their enormous profits, and the extortion they practiſe, they have obtained the name of *Capſe Smouſe*, or Cape Jews. Theſe traffickers contrive at all times to ſell their goods at a dear rate; but they vary their price in proportion as their ſtock is great or ſmall: of courſe they bear no fixed price; and the planter who comes from the deſert, and who can underſtand but little of this fluctuation, is ſure to be duped.

On the other hand, the regular ſhopkeeper, who knows the probity of theſe farmers, and how punctual they are in the payment of their debts, exerts every effort to prevail on them to open an account with him. He tempts them by the pretended cheap price and excellent quality of his ſtuffs, and offers to remit the payment till their next journey in the following year. It is ſeldom that theſe people, ſimple and unexperienced as they are, perceive the craft that is preſented to them under this guiſe of kindneſs and civility. If they ſuffer themſelves to be prevailed upon, they are ſhackled for life. Upon their return, there are new purchaſes to be made upon the ſame conditions; and thus, year after year, always in debt, always buying without prompt payment, they become the prey of an extortioner, who raiſes to himſelf a fortune out of their weakneſs.

It is true, theſe buyers, after being thus duped at the Cape, commonly return home only to make dupes of others. The cunning that has been employed to deceive them, they employ in their turn to tempt the Hottentots who are in their ſervice. The remnants of ſtuff, or the frippery garments which they bring back, are ſold to theſe unfortunate ſervants with ſo great a profit, that commonly the wages of a year are inadequate to the payment; and they find themſelves, like their maſters, in debt for the year that is to come. In the end, therefore, it is the poor Hottentot that pays for the extortion at the Cape.

Cuſtom has rendered the planters inſenſible to the want of fruit and pulſe, though the ſoil is admirably adapted to the cultivation of both. The facility with which they rear their cattle makes up for this privation, as their flocks afford them plenty of proviſion. The chief food is mutton; and their tables are loaded with ſuch profuſion as to diſguſt one at the ſight.

From this mode of living, cattle are in the colonies, as in other places, not only a uſeful object, but an article of the firſt neceſſity. The planter undertakes himſelf the care of watching over his flocks. Every evening, when they return from the field, he ſtands at his door, with a ſtick in his hand, and counts them over one by one, in order to be ſure that none of them are miſſing.

People who have no other employment than a little agriculture, and the ſuperintendance of a flock, muſt have long intervals of idleneſs. It is thus with the planters, particularly thoſe who live in the interior parts of the country, and who being unable, on account of their diſtance from the Cape, to diſpoſe of their corn, never raiſe more than is ſufficient for their own conſumption. From the profound inaction in which they live, one would ſuppoſe their ſupreme felicity to conſiſt in doing nothing. They ſometimes, however, viſit each other; and upon theſe occaſions the day is ſpent in ſmoking, and drinking tea, and in telling, or liſtening to tales of romance, that are equal neither in merit nor morality to the ſtory of Blue-beard.

As every man always carries with him, wherever he goes, both a pipe, and a tobacco-pouch made of the ſkin of the ſea-calf, he is ſure in theſe viſits to have one ſource of amuſement. When any one of the company is deſirous of lighting his pipe, he takes out his pouch, and, having filled, paſſes it to the reſt. This is a civility that is never omitted. However numerous may be the party, every body ſmokes: the conſequence of which is a cloud, that, riſing at firſt to the upper part of the room, increaſes, by degrees, till it fills the whole houſe, and becomes at laſt ſo thick that it is impoſſible for the ſmokers to ſee one another.

When a ſtranger travelling through the country is received by the maſter of a houſe, he inſtantly becomes a member of the family. Accuſtomed to a domeſtic life, the planters delight in the ties of affinity, and conſider in the light of a relative every perſon whom they love. Upon entering a houſe, the form of ſalutation is, to ſhake hands firſt with the maſter, and then with every male perſon in the company arrived at years of maturity. If there happens to be any one whom we do not like, the hand is refuſed to him; and this refuſal, of ſo common a teſtimony of friendſhip, is looked upon as a formal declaration that the viſitor conſiders him as his enemy. It is not the ſame with the females in the company. They are all embraced one after another; and to make an exception would be a ſignal affront. Old or young, all muſt be kiſſed. It is a benefice with the duties attached to it.

At whatever time of the day you enter the houſe of a planter, you are ſure to find the kettle and tea-things upon the table. This practice is univerſal. The inhabitants never drink pure water. If a ſtranger preſents himſelf, it is tea they offer him for refreſhment. This is their common liquor in the interval of meals, and in one ſeaſon of the year, when it often happens that they have neither beer nor wine, is their only beverage.

If a ſtranger arrives at dinner-time before the cloth is taken away, he ſhakes hands, embraces, and immediately ſeats himſelf at the table. If he wiſhes to paſs the night, he ſtays without ceremony, ſmokes, drinks tea, aſks the news, gives them all he knows in his turn; and the next day, the kiſſing and ſhaking hands being repeated, he goes on his way, to perform elſewhere the ſame ceremony.' To offer money on theſe occaſions would be regarded as an inſult.

Theſe particulars of a people, whoſe condition it is to be hoped that the generoſity of the Britiſh charac-
1799. ter, and the mildneſs of the Britiſh government, will
gradually meliorate, cannot but be acceptable to many of our readers. We ſhall, therefore, make no apology for the length of this article.

GOMASHTEH, in the language of Bengal, one cent.

GONIOMETRY, a method of meaſuring angles, ſo called by M. de Lagny, who gave ſeveral papers on this method in the Memoirs of the Royal Acad. anno 1724, 1725, 1729. M. de Lagny's method of goniometry conſiſts in meaſuring the angles with a pair of compaſſes, and that without any ſcale whatever, except an undivided ſemicircle. Thus, having any angle drawn upon paper to be meaſured, produce one of the ſides of the angle backwards behind the angular point; then with a pair of fine compaſſes deſcribe a pretty large ſemicircle from the angular point as a centre, cutting the ſides of the propoſed angle, which will intercept a part of the ſemicircle. Take then this intercepted part very exactly between the points of the compaſſes, and turn them ſucceſſively over upon the arc of the ſemicircle, to find how often it is contained in it, after which there is commonly ſome remainder: then take this remainder in the compaſſes, and, in like manner, find how often it is contained in the laſt of the integral parts of the firſt arc, with again ſome remainder: find, in like manner, how often this laſt remainder is contained in the former; and ſo on continually, till the remainder become too ſmall to be taken and applied as a meaſure. By this means he obtains a ſeries of quotients, or fractional parts, one of another, which being properly reduced into one fraction, give the ratio of the firſt arc to the ſemicircle, or of the propoſed angle to two right angles, or 180 degrees, and conſequently that angle itſelf in degrees and minutes.

We have given this account of goniometry from Dr Hutton, and frankly acknowledge that we had never thought of it till we peruſed his excellent Dictionary of Mathematics and Philoſophy. To have omitted the method when pointed out to us would have been wrong; though we miſtake much if mathematicians in general will not look upon it as a method of very little value.

GOTHIC ARCHITECTURE. See *Gothic* ARCHITECTURE in this *Suppl.* and ROOF, *Encycl.*

GOUVERNANTE, the Spaniſh name of a plant which the Indians of California uſe in decoction as a ſudorific drink for the cure of the venerial diſeaſe. It is thus deſcribed in the third volume (Engliſh tranſlation) of Perouſe's Voyage round the World.

Calyx quadrified, egg-ſhaped, of the ſame ſize with the corolla; placed beneath the fruit, deciduous. Corolla polypetalous; petals four, ſmall, entire, egg-ſhaped, fixed upon the receptacle. Stamina, eight, fixed to the receptacle, of the ſame length as the corolla: threads channelled, concave on the one ſide, and convex on the other; wings veiled, antheræ ſimple. Piſtil, germ oblong, covered, with five angles, and five cells; ſeeds oblong; pericarpium covered with fine hairs.

This plant is a ſhrub of middle ſize; the branches are angular and knotty, and covered with an adheſive varniſh; the lateral branches are alternate, and placed very near to each other: the leaves are ſmall, petiolated, bilobed, oppoſite, ſmooth on the upper ſide, the under ſide indiſtinctly veined; the bloſſoms are axillary, ſometimes terminating, pedunculated, ſolitary, but ſometimes in pairs.

From this deſcription, the gouvernante appears to be a new ſpecies of *daphne*.

GRAVIMETER, the name given by citizen Guyton (Morveau) to an inſtrument of glaſs, conſtructed in all reſpects on the principle of Nicholſon's Hydrometer, deſcribed in the article HYDROSTATICS, n° 18. *Encycl.* It is therefore needleſs to give a deſcription of this inſtrument here; as every artiſt in glaſs, who has ſeen Nicholſon's hydrometer, or underſtands our deſcription of it, may conſtruct the gravimeter of Morveau; and every man who has made himſelf maſter of our article SPECIFIC *Gravity*, may apply the gravimeter to every purpoſe to which it is applicable. It may juſt be proper to obſerve, that Morveau, having at firſt loaded the ſmall ſcale or baſon G (Plate 240, fig. 9. *Encycl.*) with a bulb of glaſs containing a ſufficient quantity of mercury, found it expedient afterwards to ſubſtitute in the place of this bulb a ſmall maſs of ſolid glaſs, brought to the proper form and weight by grinding. For a minute account of this inſtrument, if any of of our readers can be ſuppoſed to require a minute account of it, we muſt refer to the third number of Nicholſon's *Journal of Philoſophy, Chemiſtry, and the Arts.*

GREEN, though one of the ſeven original or priſmatic colours, is among dyers a compound of blue and yellow. Of the European methods of dyeing green, and of the principles on which theſe methods are founded, a ſufficient account will be found in the *Encyclopædia,* under the articles *Colour-Making* and Dyeing, and, in this *Supplement,* under *Animal and Vegetable Substances;* but it may be worth while, in this place, to inſert the method practiſed at Aſtracan, in giving to cotton yarn that beautiful green colour for which the oriental cotton is ſo juſtly admired.

The principal dye is the blue, which is employed both for cotton and ſilk. To prepare it, the indigo or blue dye-ſtuff is finely pounded, and diſſolved in water by a gentle heat in large earthen jars, ſeven of which ſtand in brick-work over the fire-place, at the diſtance of about an ell and a half from each other. About two pounds are put into each veſſel. Five pounds of ſoda finely pounded, together with two pounds of pure lime and one pound of clarified honey, are added to each; when theſe ingredients have been well mixed, the fire is ſtrengthened; and when the whole begins to boil, the dye is ſtirred carefully round in all the veſſels, that every thing may be completely diſſolved and mixed. After the firſt boiling the fire is ſlackened, and the dye is ſuffered to ſtand over a gentle heat, while it is continually ſtirred round: this is continued even after the furnace is cooled, till a thick ſcum ariſes in the neck of each jar, and ſoon after diſappears. The dye is then allowed to ſtand two days, until the whole is incorporated, and the dye thickens.

The dyers aſſert, that with this dye they can produce three ſhades of blue, and that, as the dyeing particles gradually diminiſh, they can dye alſo a green colour by the addition of yellow.

When a manufacturer gives cotton yarn to a blue dyer, he firſt boils it at home in a ley of ſoda (*kalakar*), then dries it, waſhes it, and dries it again. The blue dyer lays this yarn to ſteep in pure water, preſſes out the ſuperfluous water with the hands, and then immediately begins to dip it in the blue jar, often wringing it till it is completely penetrated by the dye. This firſt tint is generally given to yarn in ſuch jars as have had their colouring matter partly exhauſted. It is then dried, rinſed, and again dried; after which, it is put into the freſh blue dye, properly ſaturated; and, after the colour has been ſufficiently heightened, it is dried for the laſt time.

For a yellow dye, the dyers of Aſtracan employ partly ſaw-wort, brought from Ruſſia, and partly the leaves of the *kiſlar belge* or *ſumach.* The proceſs is as follows: The yarn is firſt boiled for an hour in a ſtrong ley of ſoda; it is then dried, afterwards rinſed and laid wet to ſteep for twelve hours in a ſolution of alum with warm water. When it has been dried in the air, it is laid to ſoak ſeveral times in troughs with the dye which has been boiled thick in kettles from the above-mentioned plants, till it has acquired the wiſhed-for colour, care being taken to dry it each time it is ſoaked. It is then rinſed in running water, and dried for the laſt time.

On this yellow colour a green is often dyed. After the yarn has been dyed yellow, it is given out to the blue dyer, who immediately dips it in the blue jars, the dye of which has been already partly exhauſted; and if the green colour is not then ſufficiently high, the operation is repeated, the yarn being dried each time. See *Neue Nordiſche Beytrage,* by Profeſſor Pallas; or *Philoſophical Magazine,* n° 2.

GREGORY (David), was a ſon of the Rev. John Gregory, miniſter of Drumoak, in the county of Aberdeen, and elder brother to Mr James Gregory, the inventor of the moſt common reflecting teleſcope. He was born about the year 1627 or 1628; and though he poſſeſſed all the genius of the other branches of his family, he was educated by his father for trade, and ſerved an apprenticeſhip to a mercantile houſe in Holland. Having a ſtronger paſſion, however, for knowledge than for money, he abandoned trade in 1655; and returning to his own country, he ſucceeded, upon the death of an elder brother, to the eſtate of Kinardie, ſituated about forty miles north from Aberdeen, where he lived many years, and where thirty-two children were born to him by two wives. Of theſe, three ſons made a conſpicuous figure in the republic of letters, being all profeſſors of mathematics at the ſame time in three of the Britiſh univerſities, viz. David at Oxford, James at Edinburgh, and Charles at St Andrews.

Mr Gregory, the ſubject of this memoir, while he lived at Kinardie, was a jeſt among the neighbouring gentlemen for his ignorance of what was doing about his own farm, but an oracle in matters of learning and philoſophy, and particularly in medicine, which he had ſtudied for his amuſement, and began to practiſe among his poor neighbours. He acquired ſuch a reputation in that ſcience, that he was employed by the nobility and gentlemen of that county, but took no fees. His hours of ſtudy were ſingular. Being much occupied through the day with thoſe who applied to him as a phyſician, he went early to bed, roſe about two or three in the morning, and, after applying to his ſtudies for ſome hours, went to bed again and ſlept an hour or two before breakfaſt.

He was the firſt man in that country who had a barometer; and having paid great attention to the changes in it, and the correſponding changes in the weather, he was once in danger of being tried by the preſbytery for witchcraft or conjuration. A deputation of that body waited upon him to enquire into the ground of certain reports that had come to their ears; but he ſatisfied them ſo far as to prevent the proſecution of a man known to be ſo extenſively uſeful by his knowledge of medicine.

About the beginning of this century he removed with his family to Aberdeen, and in the time of Queen Anne's war employed his thoughts upon an improvement in artillery, in order to make the ſhot of great guns more deſtructive to the enemy, and executed a model of the engine he had conceived. Dr Reid informs us, that he converſed with a clock-maker in Aberdeen who had been employed in making this model; but having made many different pieces by direction without knowing their intention, or how they were to be put together, he could give no account of the whole. After making ſome experiments with this model,

del, which ſatisfied him, the old gentleman was ſo ſanguine in the hope of being uſeful to the allies in the war againſt France, that he ſet about preparing a field equipage with a view to make a campaign in Flanders, and in the mean time ſent his model to his ſon the Savilian profeſſor, that he might have his and Sir Iſaac Newton's opinion of it. His ſon ſhewed it to Newton, without letting him know that his own father was the inventor. Sir Iſaac was much diſpleaſed with it, ſaying, that if it had tended as much to the preſervation of mankind as to their deſtruction, the inventor would have deſerved a great reward; but as it was contrived ſolely for deſtruction, and would ſoon be known by the enemy, he rather deſerved to be puniſhed, and urged the profeſſor very ſtrongly to deſtroy it, and if poſſible to ſuppreſs the invention. It is probable the profeſſor followed this advice. He died ſoon after, and the model was never found.

If this be a juſt account of the matter, and Dr Reid's veracity is unqueſtionable, we cannot help thinking that Newton's uſual ſagacity had, on that occaſion, forſaken him. Were the implements of war much more deſtructive than they are, it by no means follows that more men would be killed in battle than at preſent. Muſkets and cannons are ſurely more deſtructive weapons than javelines and bows and arrows; and yet it is a well known fact, that ſince the invention of gunpowder battles are not half ſo bloody as they were before that period. The oppoſite armies now ſeldom come to cloſe quarters, a few rounds of muſketry and artillery commonly decide the fate of the day; and had Mr Gregory's improvement been carried into effect, ſtill fewer rounds would have decided it than at preſent, and the carnage would conſequently have been leſs.

When the rebellion broke out in 1715, the old gentleman went a ſecond time to Holland, and returned when it was over to Aberdeen, where he died about 1720, aged 93, leaving behind him a hiſtory of his own time and country, which was never publiſhed.

GREGORY (Dr David). In addition to the account given in the *Encyclopædia* of this eminent mathematician, it may be proper to add, that he was a moſt intimate and confidential friend of Sir Iſaac Newton, and was intruſted with a manuſcript copy of the *Principia*, for the purpoſe of making obſervations on it. Of theſe Newton availed himſelf in the ſecond edition, they having come too late for his firſt publication, which was exceedingly hurried by Dr Halley, from fears that Newton's backwardneſs would not let it appear at all. There is a complete copy of theſe obſervations preſerved in the library of the univerſity of Edinburgh, preſented to it by Dr James Gregory, the preſent profeſſor of the practice of medicine. Theſe contain many ſublime mathematical diſcuſſions, many valuable commentaries on the *Principia*, and many intereſting anecdotes. There are in it ſome paragraphs in the hand-writing of Huyghens relative to his Theory of Light. It would appear that this work of confidential friendſhip was the foundation of that ſyſtem of phyſical and mathematical aſtronomy which has raiſed Dr Gregory to great eminence in the republic of letters.

GRINDING, in Cutlery, a well-known operation, by which edge-tools are ſharpened. As commonly practiſed, the grinding of tools is attended with great inconveniency, ariſing from the production or developement of heat by friction. The fact of ſparks flying from a dry grindſtone when a piece of iron or ſteel is applied to its ſurface during the rotation, has been ſeen by every one. The heat produced during this proceſs is ſuch that the ſteel very ſoon becomes ignited, and hard tools are very frequently ſoftened and ſpoiled, for want of care during the grinding. When a cylindrical ſtone is partly immerſed in a trough of water, the rotation muſt be moderate and the work ſlow, otherwiſe the water would ſoon be thrown off by the centrifugal force; and when this fluid is applied by a cock from above, the quantity is too ſmall to preſerve the requiſite low temperature. It is even found, that the point of a hard tool, ground under a conſiderable maſs of water, will be ſoftened, if it be not held ſo as to meet the ſtream; ſparks being frequently afforded even under the water.

To find a remedy for this, Mr Nicholſon was led, by ſome accounts which he received of German cutlery, to make the following experiment. He procured a Newcaſtle grindſtone of a fine grit and ten inches in diameter, and alſo a block of mahogany to be uſed with emery on its face. Both the ſtone and the wooden block were mounted on an axis, to be occaſionally applied between the centres of a ſtrong lathe. In this ſituation both were turned truly cylindrical, and of the ſame diameter. The face of the wood was grooved obliquely in oppoſite directions, to afford a lodgement for the emery. The face of the ſtone was left ſmooth, and there was a trough of proper ſize applied beneath the ſtone to hold water. The grindſtone was then uſed with water, and the wooden cylinder was faced with emery and oil. The inſtrument ground was a file, out of which it was propoſed to grind all the teeth. The rotation was produced by the mechaniſm of the lathe; the velocity being ſuch as to turn the grinding apparatus about five revolutions in a ſecond. The ſtone operated but ſlowly, and the water from the trough was ſoon exhauſted, with inconvenience to the workman, who could ſcarcely be defended from it but by ſlackening the velocity. The emery cylinder cut rather faſter. But notwithſtanding the friction was made to operate ſucceſſively and by quick changes on the whole ſurface of the file, it ſoon became too much heated to be held with any convenience; and when a cloth was uſed to defend the hand, the work not only became awkward, but the heat increaſed to ſuch a degree that the oil began to be decompoſed, and emitted an empyreumatic ſmell. The ſtone was then ſuffered to dry, and the file tried upon its face. It almoſt immediately became blue, and ſoon afterwards red-hot. Both the cylinders were then covered with tallow, by applying the end of a candle to each while revolving, and emery was ſprinkled upon the cylinder of wood. The ſame tool was then applied to the grindſtone in rapid motion. At the firſt inſtant the friction was ſcarcely perceptible; but very ſpeedily afterwards the zone of tallow preſſed by the tool became fuſed, and the ſtone cut very faſt. The tool was ſcarcely at all heated for a long time; and when it began to feel warm, its temperature was immediately lowered by removing

moving it to a new zone of the cylinder. The ſame effect took place when the experiment was repeated with the wooden cylinder.

It is not difficult to explain this by the modern doctrine of heat. When oil was uſed upon the wooden cylinder, the heat developed by the friction was employed in raiſing the temperature of the tool and of the fluid oil: but when tallow was ſubſtituted inſtead of the oil, the greateſt part of the heat was employed in fuſing this conſiſtent body. From the increaſed capacity of the tallow, when melted, this heat was abſorbed, and became latent, inſtead of being employed to raiſe the temperature: and whenever, by continuing the proceſs, the tallow already melted began to grow hot, together with the tool, it was eaſy to reduce the temperature again by employing the heat on another zone of conſiſtent tallow. He uſed theſe two cylinders, with much ſatisfaction, in a conſiderable quantity of work.

This promiſes to be a valuable diſcovery; and the public is obliged to the ingenious author of the Philoſophical Journal for being at ſo much pains on this, as well as on other occaſions, to render his ſcience ſubſervient to the uſeful arts.

GROSE (Francis, Eſq; F.A.S.) was born, we believe, in 1731. He was the ſon of Mr Francis Groſe of Richmond, jeweller, who filled up the coronation crown of George II. and died 1769. By his father he was left an independent fortune, which he was not of a diſpoſition to add to, or even to preſerve. He early entered into the Surrey militia, of which he became adjutant and paymaſter; but ſo much had diſſipation taken poſſeſſion of him, that in a ſituation which above all others required attention, he was ſo careleſs as to have for ſome time (as he uſed pleaſantly to tell) only two books of accounts, viz. his right and left hand pockets. In the one he received, and from the other paid; and this too with a want of circumſpection which may be readily ſuppoſed from ſuch a mode of book-keeping. His loſes on this occaſion rouſed his latent talents. With a good claſſical education he united a fine taſte for drawing; and encouraged by his friends, as well as prompted by his ſituation, he undertook the work from which he derived both profit and reputation; we mean, his Views of Antiquities in England and Wales, which he firſt began to publiſh in numbers in the year 1773, and finiſhed in the year 1776. The next year he added two more volumes to his Engliſh Views, in which he included the iſlands of Guernſey and Jerſey, which were completed in 1787. This work anſwered his moſt ſanguine expectations; and, from the time he began it to the end of his life, he continued without intermiſſion to publiſh various works (a liſt of which we ſubjoin), generally to the advantage of his literary reputation, and almoſt always to the benefit of his finances. His wit and good humour were the abundant ſource of ſatiſfaction to himſelf, and entertainment to his friends. He viſited almoſt every part of the kingdom, and was well received wherever he went. In the ſummer of 1789 he ſet out on a tour in Scotland; the reſult of which he began to communicate to the public in 1790 in numbers. Before he had concluded this work, he proceeded to Ireland, intending to furniſh that kingdom with views and deſcriptions of her antiquities, in the ſame manner he had executed thoſe of Great Britain; but ſoon after his arrival in Dublin, being at the houſe of Mr Horne there, he ſuddenly was ſeized at table with an apoplectic fit, on the 6th May 1791, and died immediately. He was interred in Dublin.

"His literary hiſtory (ſays a friend), reſpectable as it is, was exceeded by his good humour, conviviality, and friendſhip. Living much abroad, and in the beſt company at home, he had the eaſieſt habits of adapting himſelf to all tempers; and, being a man of general knowledge, perpetually drew out ſome converſation that was either uſeful to himſelf or agreeable to the party. He could obſerve upon moſt things with preciſion and judgment; but his natural tendency was to humour, in which he excelled both by the ſelection of anecdotes and his manner of telling them: it may be ſaid, too, that his figure rather aſſiſted him, which was in fact the very title-page to a joke. He had neither the pride nor malignity of authorſhip: he felt the independency of his own talents, and was ſatisfied with them, without degrading others. His friendſhips were of the ſame caſt; conſtant and ſincere, overlooking ſome faults, and ſeeking out greater virtues. He had a good heart; and, abating thoſe little indiſcretions natural to moſt men, could do no wrong."

He married at Canterbury, and reſided there ſome years, much beloved and reſpected for his wit and vivacity; "which (another friend obſerves), though he poſſeſſed in an extreme degree, was but little tinctured with the cauſtic ſpirit ſo prevalent among ſpirits of that claſs. His humour was of that nature which exhilarates and enlivens, without leaving behind it a ſting; and though perhaps none poſſeſſed more than himſelf the faculty of "ſetting the table in a roar," it was never at the expence of virtue or good manners. Of him indeed may be ſaid in the words of Shakeſpeare,

> ——— a merrier man,
> Within the limits of becoming mirth,
> I never ſpent an hour's talk withal:
> His eye begets occaſion for his wit;
> And every object that the one doth catch,
> The other turns to a mirth-moving jeſt.

"Of the moſt careleſs, open, and artleſs diſpoſition, he was often (particularly in the early part of his life) the prey of the deſigning; and has more than once (it is believed) embarraſſed himſelf by too implicit confidence in the probity of others. A tale of diſtreſs never failed to draw commiſeration from his heart; and often has the tear been diſcovered gliding down that cheek which a moment before was fluſhed with jocularity."

He was father of Daniel Groſe, Eſq; captain of the royal regiment of artillery (who, after ſeveral campaigns in America, was appointed in 1790 deputy governor of the new ſettlement at Botany Bay), and ſome other children.

His works are as follow:

1. The Antiquities of England and Wales, 8 vols. 4to and 8vo. 2. The Antiquities of Scotland, 2 vols. 4to and 8vo. 3. The Antiquities of Ireland, 2 vols. 4to and 8vo. 4. A Treatiſe on ancient Armour and Weapons, 4to, 1785. 5. A Claſſical Dictionary of the Vulgar Tongue, 8vo, 1785. 6. Military Antiquities; being a Hiſtory of the Engliſh Army from

the Conqueſt to the preſent time, 2 vols 4to, 1786, 1788. 7. The Hiſtory of Dover Caſtle, by the Rev. William Danell, 4to, 1786. 8. A Provincial Gloſſary, with a Collection of local Proverbs and popular Superſtitions, 8vo, 1788. 9. Rules for drawing Caricatures, 8vo, 1788. 10. Supplement to the Treatiſe on Ancient Armour and Weapons, 4to, 1789. 11. A Guide to Health, Beauty, Honour, and Riches; being a collection of humorous Advertiſements, pointing out the Means to obtain thoſe bleſſings; with a ſuitable introductory Preface, 8vo. 12. The Olio; being a Collection of Eſſays in 8vo, 1793.

GUERITE, in Fortification, a centry-box; being a ſmall tower of wood, or ſtone, uſually placed on the point of a baſtion, or on the angles of the ſhoulder, to hold a centinel, who is to take care of the ditch, and watch againſt a ſurpriſe.

GUILLOTINE, a new term introduced into the languages of Europe by the mournful effects of fanaticiſm in the holy cauſe of liberty. Our readers are not ignorant that this is the name given by the National Aſſembly of France to the engine of decapitation, which thoſe uſurpers of the legiſlative authority decreed to be the ſole puniſhment of thoſe condemned to death for their crimes. This decree was iſſued on March 20th 1792.

We do not imagine that the world will derive much uſeful inſtruction from a minute deſcription of this terrible inſtrument of public juſtice; and therefore content ourſelves with giving two figures of it, ſufficiently expreſſive of its conſtruction. It is only the revival of an inſtrument uſed in former times. The earlieſt accounts that we have of it is, that it was uſed in the barony of Halyfax in Yorkſhire. It was alſo ſet up in Scotland; but we have no certain information that it has ever been uſed; and it is ſtill ſhewn as a ſort of curioſity by the name of the *Mayden*. See MAIDEN, *Encycl.*

Plate XXIX.

Eratoſthenes could not think of a better way of handing down his name to future ages than by burning the temple of Diana at Epheſus; Dr Guillotin, phyſician at Lyons, and member of the ſelf-named National Aſſembly of France, thought himſelf honoured by the decree which aſſociated his name with this inſtrument of popular vengeance. It was indeed propoſed by him as an inſtrument of mercy, in a ſtudied harangue, filled with that ſentimental ſlang of philanthropy, which coſts ſo little, promiſes ſo much, and has now corrupted all the languages of Europe. His invention is indeed one of the moſt expenſive ſpecimens of Gallic philanthropy, whoſe tender mercies are cruel; and was accordingly received with loud applauſes, both from the houſe and from the galleries. To proceed, however, with impoſing dignity, it was referred to the conſideration of a committee, with injunctions to aſk the opinion of able ſurgeons of its efficiency. Mr Louis, a celebrated ſurgeon of Paris, declared it well fitted for the taſk, in a long pedantic diſſertation; in which he takes occaſion to deliver, with academic coldneſs, a theory of the operation of cutting inſtruments; and ſays that he had examined the edge of the guillotine, and other ſuch inſtruments, with a microſcope, and had diſcovered that the fineſt edges were toothed like a ſaw. M. Guillotin, he ſaid, had therefore with great judgment made the axe of his engine of death with a ſloping edge, by which means *il gliſſoit d'une façon infinitment plus douce.* This diſſertation was ſo much to the taſte of the humane legiſlature, that they rewarded Mr Louis with 2000 livres, and publiſhed it in the Paris Journals. As to the inventor, he reaped all the benefit from it which he ſo kindly intended for the nation, by the trial of it on his own perſon, when he fell under the diſpleaſure of Robeſpierre.

We acknowledge, that in as far as this inſtrument leſſens the duration of the horrid conflict with the king of terrors, and probably diminiſhes the corporeal ſufferance, it may be called merciful (alas! the day!); but we queſtion much, whether the dreadful agitation of ſoul is not rather increaſed by the long train of preparatory operations. The hands of the convict are tied behind his back: he is then ſtretched along on his face on a ſtrong plank, and his preciſe poſition adjuſted to the inſtrument. When faſtened to the plank, it is puſhed forward into its place under the fatal edge, his neck adjuſted to the block, and a baſket placed juſt before his eyes (for the face of Louis XVI. was not covered) to receive his head. This muſt employ a good deal of time, and every moment is terrible.

The conſtruction has received many alterations and refinements; and has at laſt been made ſo compendious and portable, as to become part of the travelling equipage of a commiſſioner from the National Aſſembly, ſent on a provincial or ſpecial viſitation. Thus did the ſovereign people become terrible in majeſty. So ſenſible was the aſſembly of the advantages of this awful impreſſion, or ſo intoxicated with the enjoyment of irreſiſtible power, that they have thought their coins ornamented by this attribute of their ſupremacy: and as Jupiter is diſtinguiſhed by his thunderbolt, ſo the majeſty of the people is diſtinguiſhed by the no leſs fatal axe. We have ſeen a piece of ten ſous, ſtruck at Mentz in 1793, and iſſued as current money, at the very time that they were planting the tree of liberty in that illuminated city by the hands of Cuſtine and his troops. The device is the faſces and axe of ancient Rome, crowned with a red cap, and ſurrounded by a laurel wreath. The inſcription is, *Republique Françoiſe*, 1793, *an.* 2d. Fully impreſſed with the ſame ſentiments, Lequinio, the ſentimental novelliſt of France, whom Mercier compares with the tender, the heart-touching Sterne—Lequinio, now commiſſioner, ſent by the National Aſſembly to regenerate Normandy and Brittany, writes to his maſters, that "he is very ſucceſsful in converſions from ſuperſtition to ſound reaſon." He oppoſes to the Bible and the relicts of the ſaints the conſtitution and the guillotine. "And you would wonder (ſays he) at my ſucceſs—The wiſe (but they are few) give up their prejudices at once; but the multitude, the ſtupid worſhippers of *Notre Dame*, look at our lady the guillotine; are ſilent, becomes ſerious, and their doubts vaniſh;—they are converted. This is your *labarum*—*in hoc ſigno vinces.*"

GULA, GUEULE, or GOLA, in Architecture, a wavy member whoſe contour reſembles the letter S, commonly called an Ogee.

GUNPOWDER, as we have obſerved in the *Encyclopædia* under the word GUN, has been known in the eaſt, and particularly in China, from a period of very remote antiquity. No man, however, ſeems to have ſuſpected that the knowledge of it was conveyed from the eaſt into Europe; but all have agreed to allow the merits of the invention both to friar Bacon and to Bartholomew Schwartz. This generally received opinion has been lately controverted by citizen Langles, who, in a memoir read in the French national inſtitute, contends, that the knowledge of gunpowder was conveyed to us from the Arabs, on the return of the Cruſaders to Europe. He aſſures us that the Arabs made uſe of it in 690 at the ſiege of Mecca; and he adds, that they derived it from the Indians, among whom it muſt have been known in the remoteſt ages, ſince their ſacred books (the Vedam) forbid the uſe of it in war.

It is indeed extremely probable, that the compoſition of gunpowder was known in India at a very early period; for in whatever country nature forms nitre in the greateſt plenty, there its deflagrating quality is moſt likely to be firſt obſerved; and a few experiments founded on that obſervation, will lead to the compoſition which produces ſuch ſudden and violent effects. "Nitre (ſays Sir George Staunton) is the natural and daily produce of China and India; and there accordingly the knowledge of gunpowder ſeems to be coeval with that of the moſt diſtant hiſtoric events. Among the Chineſe, it has been applied at all times to uſeful purpoſes; ſuch as blaſting rocks, and removing great obſtructions, and to thoſe of amuſement in making a vaſt variety of fire-works. It was alſo uſed as a defence by undermining the probable paſſage of the enemy, and blowing him up. But its force had not been directed through ſtrong metallic tubes as it was by Europeans ſoon after they had diſcovered it. And though, in imitation of Europe, it has been introduced into the armies of the Eaſt, other modes of warfare are ſometimes ſtill preferred to it."

Of gunpowder manufactured by thoſe who have manufactured it ſo long, it is deſirable to know the compoſition and the qualities. It was therefore natural for the Hon. George Napier, when ſuperintending the royal laboratory at Woolwich, and making experiments upon ſo neceſſary an implement of modern war, to procure ſome Chineſe powder from Canton.

This he did; and analyzing two ounces of it, he found, after repeating the operation ſix times, that the mean reſult gave the following proportions *. Nitre 1 oz. 10 dwts. charcoal 6 dwts. ſulphur 3 dwts. 14 grs. Here is a deficiency in weight of ten grains, which M. Napier ſuppoſes the conſequence of ſome defect in his proceſs; but as M. Baumé, a French chemiſt, made a variety of experiments to obtain a total ſeparation of the ſulphur from the charcoal of gunpowder, and was never able to effect it, one fourteenth part remaining united, three grains muſt be deducted from the charcoal and added to the ſulphur to give the accurate proportion of the ingredients; which by turning to the article GUNPOWDER, *Encycl.* the reader will perceive differs ſomewhat from the proportion of the ſame ingredients in the gunpowder of Europe. This Chineſe powder was uſually large-grained, and not ſtrong, but very durable. It had been made many years when our author got it; yet there was no viſible ſymptom of decay, the grain being hard, well coloured, and though angular, it was even-ſized, and in perfect preſervation.

When we conſider the operations in which gunpowder is employed, it is obvious that it muſt be an object of importance to aſcertain its exploſive force; and yet there is ſcarcely a ſubject concerning which the moſt approved writers have ſo much differed. Mr Robins, who has done more towards perfecting the art of gunnery than any other individual, ſtates the exploſive force of gunpowder to be 1000 times greater than the mean preſſure of the atmoſphere; while the celebrated Daniel Barnouilli determines it to be not leſs than 10,000 times this preſſure. Such a difference of opinion led Count Rumford to purſue a courſe of experiments, of which ſome were publiſhed in the Tranſactions of the Royal Society for the year 1781, and the remainder in the Tranſactions of the ſame Society for 1797; with the view principally of determining the initial expanſive force of gunpowder. By one of theſe experiments, it appeared, that calculating even on Mr Robins's own principles, the force of gunpowder, inſtead of being 1000 times, muſt at leaſt be 1308 times greater than the mean preſſure of the atmoſphere. From this experiment, the Count thought himſelf warranted in concluding that the principles aſſumed by Mr Robins were erroneous, and that his mode of aſcertaining the force of gunpowder could never ſatisfactorily determine it. Deſpairing of ſucceſs in that way, he reſolved to make an attempt for aſcertaining this force by actual meaſurement; and after many unſucceſsful experiments, he was at length led to conclude, that this force was at leaſt 50,000 times greater than the mean preſſure of the atmoſphere.

Mr Robins apprehends that the force of fired gunpowder conſiſts in the action of a permanently elaſtic fluid, ſimilar in many reſpects to common atmoſpherical air; and this opinion has been very generally received: but Count Rumford thinks, that though the permanently elaſtic fluids, generated in the combuſtion of gunpowder, aſſiſt in producing the effects which reſult from its exploſion, its enormous force, allowing it to be 50,000 times greater than the mean preſſure of the atmoſphere, cannot be explained, without ſuppoſing that it ariſes principally from the elaſticity of the aqueous vapour generated from the powder in its combuſtion.

"The brilliant diſcoveries of modern chemiſts (ſays he) have taught us, that both the conſtituent parts of which water is compoſed, and even water itſelf, exiſt in the materials which are combined to make gunpowder; and there is much reaſon to believe that water is actually formed, as well as diſengaged, in its combuſtion. M. Lavoiſier, I know, imagined that the force of fired gunpowder depends in a great meaſure upon the expanſive force of uncombined *caloric*, ſuppoſed to be let looſe in great abundance during the combuſtion or deflagration of the powder: but it is not only dangerous to admit the action of an agent whoſe exiſtence is not yet clearly demonſtrated; but it appears to me that this ſuppoſition is quite unneceſſary, the elaſtic force of the heated aqueous vapour, whoſe exiſtence can hardly be doubted, being quite ſufficient to account for all the phenomena. It is well known that the elaſticity of aqueous vapour is incomparably more augmented by any given augmentation of temperature than that of any permanently elaſtic fluid whatever; and thoſe who are acquainted with the amazing force of ſteam, when heated only to a few degrees above the boiling point, can eaſily perceive that its elaſticity muſt be almoſt infinite when greatly condenſed and heated to the

* *Tranſactions of the Royal Iriſh Academy.*

temperature of red-hot iron; and this heat it muſt certainly acquire in the exploſion of gunpowder. But if the force of fired gunpowder ariſes *principally* from the elaſtic force of heated aqueous vapour, a cannon is nothing more than a *ſteam engine* upon a peculiar conſtruction; and upon determining the ratio of the elaſticity of this vapour to its denſity, and to its temperature, a law will be found to obtain very different from that aſſumed by Mr Robins in his Treatiſe on Gunnery."

In order to meaſure the elaſtic force of fired gunpowder, Count Rumford adopted a new plan; and, inſtead of cauſing the generated elaſtic fluid to act on a moveable body through a determined ſpace, which he had found to be ineffectual to his purpoſe, he contrived an apparatus in which this fluid ſhould be made to act, "by a determined ſurface, againſt a weight, which, by being increaſed at pleaſure, ſhould at laſt be ſuch as would juſt be able to confine it, and which in that caſe would juſt counterbalance and conſequently *meaſure* the elaſtic force."

Having ſucceeded in ſetting fire to the powder, without any communication with the external air, "by cauſing the heat employed for that purpoſe to paſs through the ſolid ſubſtance of the barrel, it only remained to apply ſuch a weight to an opening made in the barrel, as the whole force of the generated elaſtic fluid ſhould not be able to lift, or diſplace." Many precautions were neceſſary. A ſolid block of very hard ſtone, four feet four inches ſquare, was placed upon a bed of ſolid maſonry, which deſcended ſix feet below the ſurface of the earth. Upon this block of ſtone, which ſerved as a baſe to the whole machinery, was placed the ſmall barrel, in which the exploſions were made, with its opening directly upwards. This opening was cloſed by a ſolid hemiſphere of hardened ſteel, on which the weight to be overcome by the exploſion was laid. Having charged the barrel with 10 grains of powder, its whole contents being about 28 grains, and a 24 pounder, weighing 8081 lbs. avoirdupois, being placed on its caſcabel ſo as by its weight to confine the generated elaſtic fluid, a heated iron ball was applied to the end of the vent tube (a ſmall ſolid projection from the centre of the bottom of the barrel). In a few moments the powder took fire, though the exploſion made a very feeble report; and when the weight was raiſed, the confined elaſtic vapour ruſhed out of the barrel. The ſlight effect produced by this exploſion induced ſome of the attendants on this occaſion to undervalue the importance of this experiment, and to form a very inadequate idea of the real force of the elaſtic fluid that had been thus almoſt inſenſibly diſcharged. In a ſecond experiment, the barrel was filled with powder, and the ſame weight laid on as before. The barrel was made of the beſt hammered iron, and uncommonly ſtrong. The charge of powder amounted to little more than $\frac{1}{16}$th of a cubic inch, which is not ſo much as would be required to load a ſmall pocket-piſtol, and not *one-tenth* part of the quantity frequently uſed for the charge of a common muſket. Yet this inconſiderable quantity of powder, when ſet on fire, exploded with a force that burſt the barrel, and with a loud report that alarmed the whole neighbourhood.

The author proceeds to make an eſtimate, from the known ſtrength of iron, and the area of the fracture of the barrel in the preceding experiment, of the real force employed by the elaſtic vapour to burſt it; and he computes that it muſt have been equal to the preſſure of a weight of 412529 lbs.; which, by another computation, he found to be 55024 times greater than the mean preſſure of the atmoſphere. By another proceſs, he inveſtigates the ſtrength of the iron of which the barrel was made; and he thence finds that the force required to burſt it was equal to the preſſure of a weight of 410624½ lbs. This weight, reduced into atmoſpheres, gives 54750 atmoſpheres for the meaſure of the force exerted by the elaſtic fluid in the preſent inſtance. This force muſt be conſiderably leſs than the initial force of the elaſtic fluid generated in the combuſtion of gunpowder, before it has begun to expand; "for it is more than probable (ſays Count Rumford) that the barrel was in fact burſt before the generated elaſtic fluid had exerted all its force, or that this fluid would have been able to have burſt a barrel ſtill ſtronger than that uſed in the experiment."

After having ſhewn the extreme force of fired gunpowder, the Count adverts to an objection which may be made againſt his deductions. How does it happen that fire-arms and artillery of all kinds, which certainly are not calculated to withſtand ſo enormous a force, are not always burſt when they are uſed? Inſtead of anſwering this queſtion, by aſking how it happened that the extremely ſtrong barrel uſed in his experiment could be burſt by the force of gunpowder, if this force be not in fact much greater than it has ever been ſuppoſed to be, he proceeds to ſhew that the combuſtion of gunpowder, inſtead of being inſtantaneous, as Mr Robins's theory ſuppoſes, is much leſs rapid than has hitherto been apprehended; an obſervation which, if eſtabliſhed, is certainly ſufficient to anſwer the objection.

He remarks, that it is a well-known fact that, on the diſcharge of fire-arms of all kinds, there is always a conſiderable quantity of unconſumed grains of gunpowder blown out of them; and what is very remarkable, as it leads directly to a diſcovery of the cauſe of this effect, theſe unconſumed grains are not merely blown out of the muzzles of fire-arms, but come out alſo by their vents or touch-holes, where the fire enters to inflame the charge, as many perſons who have had the misfortune to ſtand with their faces near the touch-hole of a muſket, when it has been diſcharged, have found to their coſt.

It appears extremely improbable to our author, if not abſolutely impoſſible, that a grain of gunpowder actually in the chamber of the piece, and completely ſurrounded by flame, ſhould, by the action of that very flame, be blown out of it without being at the ſame time ſet on fire. And, if this be true, he conſiders it as a moſt deciſive proof, not only that the combuſtion of gunpowder is leſs rapid than it has generally been thought to be, but that a grain of gunpowder actually on fire, and burning with the utmoſt violence over the whole of its ſurface, may be projected with ſuch a velocity into a cold atmoſphere, as to extinguiſh the fire, and ſuffer the remains of the grain to fall to the ground unchanged, and as inflammable as before.

This extraordinary fact was aſcertained beyond all poſſibility of doubt by the Count's experiments. Having procured from a powdermill in the neighbourhood of the city of Munich a quantity of gunpowder, all of the ſame maſs, but formed into grains of very different ſizes, ſome as ſmall as the grains of the fineſt Battel powder, he placed a number of vertical ſcreens of very thin paper, one behind another, at the diſtance of 12 inches from each other; and loading a common muſket repeatedly with this powder, ſometimes without and ſometimes with a wad, he fired it againſt the foremoſt ſcreen, and obſerved the quantity and effects of the unconſumed grains of powder which impinged againſt it. The ſcreens were ſo contrived, by means of double frames united by hinges, that the paper could be changed with very little trouble, and it was actually changed after every experiment.

The diſtance from the muzzle of the gun to the firſt ſcreen was not always the ſame; in ſome of the experiments it was only 8 feet, in others it was 10, and in ſome 12 feet.

The charge of powder was varied in a great number of different ways; but the moſt intereſting experiments were made with one ſingle large grain of powder, propelled by ſmaller and larger charges of very fine grained powder.

Theſe large grains never failed to reach the ſcreen; and though they ſometimes appeared to have been broken into ſeveral pieces by the force of the exploſion, yet they frequently reached the ſcreen entire; and ſometimes paſſed through all the ſcreens (five in number) without being broken.

When they were propelled by large charges, and conſequently with great velocity, they were ſeldom on fire when they arrived at the firſt ſcreen; which was evident, not only from their not ſetting fire to the paper (which they ſometimes did), but alſo from their being found ſticking in a ſoft board, againſt which they ſtruck, after having paſſed through all the five ſcreens; or leaving viſible marks of their having been impinged againſt it, and being broken to pieces and diſperſed by the blow. Theſe pieces were often found lying on the ground; and from their forms and dimenſions, as well as from other appearances, it was often quite evident that the little globe of powder had been on fire, and that its diameter had been diminiſhed by the combuſtion before the fire was put out, on the globe being projected into the cold atmoſphere.

That theſe globes or large grains of powder were always ſet on fire by the combuſtion of the charge, can hardly be doubted. This certainly happened in many of the experiments; for they arrived at the ſcreens on fire, and ſet fire to the paper; and in the experiments in which they were projected with ſmall velocities, they were often ſeen to paſs through the air on fire; and when this was the caſe, no veſtige was to be found. They ſometimes paſſed on fire through ſeveral of the foremoſt ſcreens without ſetting them on fire, and ſet fire to one or more of the hindmoſt, and then went on and impinged againſt the board which was placed at the diſtance of twelve inches behind the laſt ſcreen.

The Count then proceeds to mention another experiment, in which the progreſſive combuſtion of gunpowder was ſhewn in a manner ſtill more ſtriking, and not leſs concluſive.

A ſmall piece of red hot iron being dropped down into the chamber of a common horſe piſtol, and the piſtol being elevated to an angle of about 45 degrees, upon dropping down into its barrel one of the ſmall globes of powder (of the ſize of a pea), it took fire, and was projected into the atmoſphere by the elaſtic fluid generated in its own combuſtion, leaving a very beautiful train of light behind it, and diſappearing all at once like a falling ſtar. This amuſing experiment was repeated very often, and with globes of different ſizes. When very ſmall ones were uſed ſingly, they were commonly conſumed entirely before they came out of the barrel of the piſtol; but when ſeveral of them were uſed together, ſome, if not all of them, were commonly projected into the atmoſphere on fire.

As the ſlowneſs of the combuſtion of gunpowder is undoubtedly the cauſe which has prevented its enormous and almoſt incredible force from being diſcovered, our author deduces, as an evident conſequence, that the readieſt way to increaſe its effects, is to contrive matters ſo as to accelerate its inflammation and combuſtion. This may be done in various ways; but, in his opinion, the moſt ſimple and moſt effectual manner of doing it would be to ſet fire to the charge of powder, by ſhooting (through a ſmall opening) the flame of a ſmaller charge into the midſt of it.

He contrived an inſtrument on this principle for firing cannon three or four years ago; and it was found, on repeated trials, to be uſeful, convenient in practice, and not liable to accidents. It likewiſe ſuperſedes the neceſſity of uſing priming, of vent tubes, port-fires, and matches; and on that account he imagined it might be of uſe in the Britiſh navy, but it does not appear to have been received into practice.

Another infallible method of increaſing very conſiderably the effect of gunpowder in fire-arms of all ſorts and dimenſions, would be to cauſe the bullet to fit the bore exactly, or without windage, in that part of the bore at leaſt where the bullet reſts on the charge; for when the bullet does not completely cloſe the opening of the chamber, not only much of the elaſtic fluid, generated in the firſt moment of the combuſtion of the charge, eſcapes by the ſide of the bullet; but what is of ſtill greater importance, a conſiderable part of the unconſumed powder is blown out of the chamber along with it in a ſtate of actual combuſtion, and, getting before the bullet, continues to burn on as it paſſes through the whole length of the bore; by which the motion of the bullet is much impeded.

The loſs of force which ariſes from this cauſe, is in ſome caſes almoſt incredible; and it is by no means difficult to contrive matters ſo as to render it very apparent, and alſo to prevent it.

If a common horſe-piſtol be fired with a looſe ball, and ſo ſmall a charge of powder that the ball ſhall not be able to penetrate a deal board ſo deep as to ſtick in it when fired againſt it from the diſtance of ſix feet; the ſame ball, diſcharged from the ſame piſtol with the ſame charge of powder, may be made to paſs quite through one deal board, and bury itſelf in a ſecond placed behind it, merely by preventing the loſs of force which ariſes from what is called windage, as he found more than once by actual experiment.

The Count has in his poſſeſſion a muſket, from which, with a common charge of powder, he fires two bullets at once with the ſame velocity that a ſingle bullet is diſcharged from a muſket on the common conſtruction with the ſame quantity of powder. And, what renders the experiment ſtill more ſtriking, the diameter of the bore of his muſket is exactly the ſame as that of a common muſket, except only in that part of it where it joins the chamber, in which part it is juſt ſo much contracted, that the bullet, which is next to the powder, may ſtick faſt in it. He adds, that though the bullets are of the common ſize, and are conſequently conſiderably leſs in diameter than the bore, means are uſed which effectually prevent the loſs of force by windage; and to this laſt circumſtance he concludes, it is doubtleſs owing, in a great meaſure, that the charge appears to exert ſo great a force in propelling the bullets.

That the conical form of the lower part of the bore where it unites with the chamber has a conſiderable ſhare in producing this extraordinary effect, is, however, very certain, as he has found by experiments made with a view merely to aſcertain that fact.

At the cloſe of the Count's laſt memoir, we have a computation, deſigned to ſhew that the force of the elaſtic fluid generated in the combuſtion of gunpowder, enormous as it is, may be ſatisfactorily explained on the ſuppoſition that it depends *ſolely* on the elaſticity of watery vapour, or ſteam. From experiments made in France in the year 1790, it appears that the elaſticity of ſteam is doubled by every addition of temperature equal to 30° of Fahrenheit's thermometer. As the heat generated in the combuſtion of gunpowder cannot be leſs than that of red-hot iron, it may be ſuppoſed equal to 1000° of Fahrenheit's ſcale:—but the elaſtic force of ſteam is juſt equal to the mean preſſure of the atmoſphere, when its temperature is equal to that of boiling water, or to 212° of Fahrenheit's thermometer; conſequently $212^\circ + 30^\circ = 240^\circ$ will repreſent the temperature, when its elaſticity will be equal to the preſſure of two atmoſpheres; and, purſuing the calculation, at 602°, or 2° above the heat of boiling linſeed oil, its elaſticity will be equal to the preſſure of 8192 atmoſpheres, or above *eight times* greater than the utmoſt force of the fluid generated in the combuſtion of gunpowder, according to Mr Robins's computation: but the heat in this caſe is much greater than that of 602° of Fahrenheit; and therefore the elaſticity of the ſteam generated from the water contained in the powder muſt be much greater than the preſſure of 8192 atmoſpheres. At 722°, the elaſticity will be equal to the preſſure of 131,072 atmoſpheres; and this temperature is leſs than the heat of iron, which is viſibly red-hot in day-light, by 355°:—but the flame of gunpowder has been found to melt braſs, which requires a heat equal to that of 3807° of Fahrenheit; 2730° above the heat of red-hot iron, or 3805° higher than the temperature which gives to ſteam an elaſticity equal to the preſſure of 131,072 atmoſpheres. That there is in gunpowder water ſufficient for ſupplying the neceſſary quantity of ſteam, the author has very ſatisfactorily evinced; but we muſt not purſue his curious inveſtigations any farther. Thoſe who want a fuller account of them, will find it either in the original memoirs themſelves, or in a very accurate abridgment of theſe memoirs in the firſt volume of Nicholſon's *Journal of Natural Philoſophy*, &c.

We cannot conclude this article without mentioning a new kind of gunpowder, invented ſome years ago in France, in which the marine acid is ſubſtituted, in equal quantity, for nitre. Dr Hutton tried ſome of this new powder which was made at Woolwich, and found it of about double the ſtrength of the ordinary ſort; but it is not likely to come into common and general uſe, for the preparation of the acid is difficult and expenſive (See CHEMISTRY-*Index* in this *Suppl.*), and the powder which is made of it catches fire and explodes from the ſmalleſt degree of heat, and without the aid of a ſpark. It is to this circumſtance, however, that its ſuperior ſtrength ſeems to be in a great meaſure owing.

GUNTER's CHAIN. See GEOMETRY, *Encyclopædia*, Part II. chap. 1.

GUT-TIE, a dangerous diſeaſe to which oxen and male calves are rendered liable by an improper mode of caſtration. In ſome places, and particularly in Herefordſhire, the breeders of cattle, when they caſtrate their calves, open the *ſcrotum*, take hold of the teſticles with their teeth, and tear them out with violence; by which means all the veſſels thereto belonging are ruptured. The *vaſa deferentia*, entering by the holes of the tranſverſe and oblique muſcles into the abdomen, paſs over the ureters in acute angles; at which turning, by their great length and elaſtic force, the peritoneum is ruptured; the *vaſa deferentia* are ſevered from the teſticles, and, ſpringing back, form a kind of bow from the urethra, where they are united, over the ureters, to the tranſverſe and oblique muſcles, and there again unite, where they firſt entered the abdomen; the part of the gut that is tied is the jejunum, at its turning from the left ſide to the right, and again from the right to the left, forming right angles under the kidney, and attached to the duplicature of the peritoneum, to which it was united, where the rupture happened. There the bow of the gut hangs over the bow of the *vaſa deferentia*, which, by a ſudden motion, or turn of the beaſt, form a hitch or tie of the ſtring round the bow of the gut (filled with air), ſimilar to what a carter makes on his cart line. This cauſes a ſtoppage in the bowels, and brings on a mortification, which, in two days, or four at moſt, proves fatal: And to this accident is the beaſt, when caſtrated as above, liable from the day that he was caſtrated till the time of his being ſlaughtered.

The ſymptoms of the gut-tie are the ſame as theſe of an incurable colic, *volvulus*, or mortification of the bowels. The beaſt affected with this complaint will kick at its belly, lie down, and groan; it has alſo a total ſtoppage in its bowels (except blood and mucus, which it will void in large quantities), and a violent fever, &c. To diſtinguiſh with certainty the gut-tie from the colic, &c. the hand and arm of the operator muſt be oiled, and introduced into the anus, through the rectum, beyond the os pubis, turning the hand down to the tranſverſe and oblique muſcles, where the veſſels of the teſticles enter the abdomen. There the ſtring will be found united to the muſcles, and is eaſily traced to the ſtricture by the hand, without pain to the beaſt.

From the general view of the agriculture of the county of Hereford, drawn up by Mr Clark of Builth, Breconſhire, we learn that Mr Harris farmer at Wickton, near Leominſter, had been uncommonly ſucceſsful in the cure of the gut-tie. That gentleman informs us, that he had cut cattle for this diſeaſe from the age of three months to that of nine years; and as it is a matter of great importance, we ſhall ſtate his method of operating in his own words.

“ The only method of cure (ſays he) that can be ſafely ventured upon is, to make a perpendicular inciſion, four inches under the third vertebra of the loins, on the left ſide, over the paunch or ſtomach, and introduce the arm to find the part affected ; if poſſible, keep the beaſt ſtanding by the help of proper aſſiſtants. The knife I make uſe of to ſevere the ſtring is in the form of a large fiſh-hook, with an edge on the concave ſide : it is fixed to a ring, which fits the middle finger, which finger crooks round the back of the knife, the end of the thumb being placed on its edge. The inſtrument, by being thus held in the hand, is ſecured from wounding the ſurrounding inteſtines ; with it I divide the ſtring or ſtrings, and bring out one or both, as circumſtances require. Here it is to be obſerved, that great care muſt be taken by the operator not to wound or divide the ureters, which would be certain death. I then ſew up the divided lips of the peritoneum very cloſe, with a ſurgeon's needle threaded with ſtrong thread, eight or ten double, ſufficiently waxed ; I alſo ſew up the ſkin, leaving a vacancy at the top and bottom of the wound ſufficiently wide to introduce a tent of ſurgeon's tow, ſpread with common digeſtive and traumatic balſam ; covering the inciſion with a plaſter made of the whites of eggs and wheat flour. The wound, thus treated, and dreſſed every day, will be well in a fortnight. The medicine I give to remove the ſtoppage in the three ſtomachs occaſioned by the tie, and to carry off the fever, is four ounces of Glauber's ſalt, two ounces of cream of tartar, and one ounce of ſenna, infuſed in two pounds of boiling water, adding half a pound of olive-oil, and working it off with plenty of gruel, mixed with a large quantity of infuſion of mallows and elder-bark. I adminiſter the gruel and infuſion for at leaſt two or three days ; by which time the beaſt will be well, will eat his provender, and chew the cud, and will forever be relieved, and remain ſafe from this fatal diſorder.

“ The following ſimple and eaſy method of caſtration will effectually prevent the gut-tie. Open the ſcrotum, looſen out the teſticles, and tie the ſeveral veſſels with a waxed thread or ſilk ; or ſear them with a hot iron, to prevent their bleeding, as in the common way of cutting colts. This method can never diſplace the veſſels of the teſticles, bladder, kidneys, or inteſtines ; all of which remain covered or attached to the peritoneum, or lining of the abdomen of the beaſt, which renders it impoſſible that there ſhould ever be a ſtricture or tie on the gut.”

GUZ, an Indian meaſure, varying in different places, but which may be reckoned about an Engliſh yard, The guz of Akbar was 41 fingers.

H.

HANCES, Hanches, Haunches, or *Hanſes*, in architecture, are certain ſmall intermediate parts of arches between the key or crown and the ſpring at the bottom, being perhaps about one-third of the arch, and ſituated nearer the bottom than the top or crown ; and are otherwiſe called the *ſpandrels*. See Arch in this *Supplement*.

HANSPIKE, or Handspec, a lever or piece of ſtrong wood, for raiſing by the hand great weights, &c. It is five or ſix feet long, cut thin and crooked at the lower end, that it may get the eaſier between things that are to be ſeparated, or under any thing that is to be raiſed. It is better than a crow of iron, becauſe its length allows a better poiſe.

HARRIOT (Thomas) was a very eminent mathematician of the 16th and 17th centuries, of whom ſome account has been given in the *Encyclopædia Britannica*. In that article it has been ſhewn, that Des Cartes had ſeen ſome improvements of Harriot's in algebra, and publiſhed them to the world as his own ; but this piece of plagiariſm has been more completely proved in the Aſtronomical Ephemeris for the year 1788, by Dr Zache, aſtronomer to the Duke of Saxe-Gotha ; who likewiſe ſhews that Harriot was an aſtronomer as well as an algebraiſt.

“ I here preſent to the world (ſays the Doctor) a ſhort account of ſome valuable and curious manuſcripts, which I found in the year 1784 at the ſeat of the earl of Egremont, at Petworth in Suſſex.

“ A predeceſſor of the family of lord Egremont, viz. that noble earl of Northumberland, named Henry Percy, was not only a generous favourer of all good learning, but alſo a patron and Mæcenas of the learned men of his age. Thomas Harriot, the author of the ſaid manuſcripts, Robert Hues (well known by his Treatiſe upon the Globes), and Walter Warner, all three eminent mathematicians, who were known to the earl, received from him yearly penſions ; ſo that when the earl was committed priſoner to the Tower of London in the year 1606, our author, with Hues and Warner, were his conſtant companions ; and were uſually called the earl of Northumberland's three Magi.

“ Thomas Harriot is a known and celebrated mathematician among the learned of all nations, by his excellent work, *Artis Analyticæ Praxis, ad æquationes algebraicas nova expeditata & generali methodo, reſolvendas, Tractatus poſthumus* ; London 1631 : dedicated to Henry earl of Northumberland ; publiſhed after his death by Walter Warner. It is remarkable, that the fame and the honour of this truly great man were conſtantly attacked by the French mathematicians, who could not endure that Harriot ſhould in any way diminiſh the fame of their Vieta and Des Cartes, eſpecially the latter, who was openly accuſed of plagiariſm from our author.

“ Des Cartes publiſhed his Geometry ſix years after Harriot's work appeared, viz. in the year 1637. Sir Charles Cavendiſh, then ambaſſador at the French court at Paris, obſerved to the famous geometrician Roverval, that theſe improvements in analyſis had been already made theſe ſix years in England, and ſhewed him afterwards Harriot's *Artis Analyticæ Proxis;* which, as Roverval was looking over, at every page he cried out, *Oui! oui! il l'a vu! Yes! yes! he has ſeen it!* Des Cartes had alſo been in England before Harriot's death, and had heard of his new improvements and inventions in analyſis.

“ Now all this relates to Harriot the celebrated analyſt; but it has not hitherto been known that Harriot was an eminent aſtronomer, both theoretical and practical, which firſt appears by theſe manuſcripts; among which, the moſt remarkable are 199 obſervations of the ſun's ſpots, with their drawings, calculations, and determination of the ſun's rotation about his axis. There is the greateſt probability that Harriot was the firſt diſcoverer of theſe ſpots, even before either Galileo or Scheiner. The earlieſt intelligence we have of the firſt diſcovered ſolar ſpots is of one Joh. Fabricius Phryſius, who in the year 1611 publiſhed at Wittemberg a ſmall treatiſe, intitled, *De Maculis in Sole obſervatis & apparente earum cum Sole converſione narratio.* Galileo, who is commonly accounted the firſt diſcoverer of the ſolar ſpots, publiſhed his book, *Iſtoria e Dimonſtrazioni intorne alle Machie Solare e loro accidente*, at Rome in the year 1613. His firſt obſervation in this work is dated June 2d 1612. Angelo de Filiis, the editor of Galileo's work, who wrote the dedication and preface to it, mentions, page 3. that Galileo had not only diſcovered theſe ſpots in the month of April in the year 1611, at Rome, in the Quirinal Garden, but had ſhewn them ſeveral months before (*molti meſi innanzi*) to his friends in Florence; and that the obſervations of the diſguiſed Apelles (the Jeſuit Scheiner, a pretender to this firſt diſcovery) were not later than the month of October in the ſame year; by which the epoch of this diſcovery was fixed to the beginning of the year 1611. But a paſſage in the firſt letter of Galileo's works, pa. 11. gives a more preciſe term to this diſcovery. Galileo there ſays in plain terms, that he had obſerved the ſpots in the ſun 18 months before. The date of this letter is May 24. 1612; which brings the true epoch of this diſcovery to the month of November 1610. However, Galileo's firſt produced obſervations are only from June 2. 1612, and thoſe of father Scheiner of the month of October in the ſame year. But now it appears from Harriot's manuſcripts, that his firſt obſervations of theſe ſpots are of Dec. 8. 1610. It is not likely that Harriot could have this notice from Galileo, for I do not find this mathematician's name ever quoted in Harriot's papers: But I find him quoting book i. chap. 2. of Joſeph a Coſta's *Natural and Moral Hiſtory of the Weſt Indies;* in which he relates, that in Peru there are ſpots to be ſeen in the ſun which are not ſeen in Europe: and hence it is probable, that Harriot took the hint of looking for ſuch ſpots. Beſides, it is not unlikely, that living with ſo munificent a patron, Harriot got from Holland the new invented teleſcopes much ſooner than they could reach Galileo, who at that time lived at Venice. Harriot's very careful and exact obſervations of theſe ſpots, ſhew alſo that he was in poſſeſſion of the beſt and moſt improved teleſcopes of that time; for it appears he had ſome with magnifying powers of 10, 20, and 30 times. At leaſt there are no earlier obſervations of the ſolar ſpots extant than his; they run from December 8. 1610, till January 18. 1613. I compared the correſponding ones with theſe obſerved by Galileo, between which I found an exact agreement. Had Harriot had any notion about Galileo's diſcoveries, he certainly would have alſo known ſomething about the phaſes of Venus and Mercury, and eſpecially about the ſingular ſhape of Saturn, firſt diſcovered by Galileo; but I find not a word in all his papers concerning the particular figure of that planet.

“ I found likewiſe (continues Dr Zach) among the papers of Harriot a large ſet of obſervations on the ſatellites of Jupiter, with drawings of them, their poſitions, and calculations of their revolutions and periods. His firſt obſervation of thoſe diſcovered ſatellites, I find to be of January 16. 1610; and they go till February 26. 1612. Galileo pretends to have diſcovered them January 7. 1610; ſo that it is not improbable that Harriot was likewiſe the firſt diſcoverer of theſe attendants of Jupiter.

“ Among his other obſervations of the moon, of eclipſes, of the planet Mars, of ſolſtices, of refraction, of the declination of the needle, &c. there are remarkable ones of the comet of 1607, and the latter comet (for there were two) of 1618. They were all obſerved with a croſs-ſtaff, by meaſuring their diſtances from fixed ſtars; whence theſe obſervations are the more valuable, as comets had before been but groſsly obſerved. Kepler himſelf obſerved the comet of 1607 only with the naked eye, pointing out its place by a coarſe eſtimation, without the aid of an inſtrument; and the elements of their orbits could, in defect of better obſervations, be only calculated by them. The obſervations of the comet of the year 1607 are of the more importance, even now for modern aſtronomy, as this is the ſame comet that fulfilled Dr Halley's prediction of its return in the year 1759. That prediction was only grounded upon the elements afforded him by theſe coarſe obſervations; for which reaſon he only aſſigned the term of its return to the ſpace of a year. The very intricate calculations of the perturbations of this comet, afterwards made by M. Clairaut, reduced the limits to a month's ſpace. But a greater light may now be thrown upon this matter by the more accurate obſervations on this comet by Mr Harriot. In the month of October 1785, when I converſed upon the ſubject of Harriot's papers, and eſpecially on this comet, with the celebrated mathematician M. de la Grange, director of the Royal Academy of Sciences at Berlin, he then ſuggeſted to me an idea, which, if brought into execution, will clear up an important point in aſtronomy. It is well known to aſtronomers how difficult a matter it is to determine the maſs, or quantity of matter, in the planet Saturn; and how little ſatisfactory the notions of it are that have hitherto been formed. The whole theory of the perturbations of comets depending upon this uncertain datum, ſeveral attempts and trials have been made towards a more exact determination of it by the moſt eminent geometricians of this age, and particularly by la Grange himſelf; but never having been ſatisfied with the few and uncertain data heretofore obtained for the reſolution of this problem, he thought that Harriot's obſervations on the comet of 1607, and the modern ones of the ſame comet in 1759, would ſuggeſt a way of reſolving the problem *à poſteriori;* that of determining by by them the elements of its ellipſis. The retardation of the comet, compared to its period, may clearly be laid to the account of the attraction and perturbation it has ſuffered in the region of Jupiter and Saturn; and as the part of it belonging to Jupiter is very well known, the remainder muſt be the ſhare which is due to Saturn; whence the maſs of the latter may be inferred. In conſequence of this conſideration, I have already begun to reduce moſt of Harriot's obſervations of this comet, in order to calculate by them the true elements of its orbit on an elliptical hypotheſis, to complete M. de la Grange's idea upon this matter.

"I forbear to mention here any more of Harriot's analytical papers, which I found in a very great number. They contain ſeveral elegant ſolutions of quadratic, cubic, and biquadratic equations; with ſome other ſolutions and *loca geometrica*, that ſhew his eminent qualifications, and will ſerve to vindicate them againſt the attacks of ſeveral French writers, who refuſe him the juſtice due to his ſkill and accompliſhments, merely to ſave Des Cartes's honour, who yet, by ſome impartial men of his own nation, was accuſed of public plagiariſm."

HASSELQUIST (Frederick) was born in the province of Eaſt Gothland in 1722, and ſtudied medicine and botany in the univerſity of Upſal. Linnæus had in his lectures repreſented the extraordinary merits and great celebrity which a young ſtudent might obtain by travelling through Paleſtine, and by inquiring into and deſcribing the natural hiſtory of that country, which was till then unknown, and had become of the greateſt importance to interpret the bible, and to underſtand eaſtern philology. Haſſelquiſt was fired with ambition to accompliſh an object ſo important in itſelf, and ſo warmly recommended by his beloved maſter. There being no fund ariſing from the liberality of the crown, private collections were made, which poured in very copiouſly, eſpecially from the native country of the young traveller. All the faculties of the univerſity of Upſal alſo granted him a ſtipend.

Thus protected, he commenced his journey in the ſummer of 1749. By the interference of Lagerſtroem, he had a free paſſage to Smyrna in one of the Swediſh Eaſt Indiamen. He arrived there at the concluſion of the year, and was received in the moſt friendly manner by Mr A. Rydel, the Swediſh conſul. In the beginning of 1750 he ſet out for Egypt, and remained nine months at Cairo the capital. Hence he ſent to Linnæus, and to the learned ſocieties of his country, ſome ſpecimens of his reſearches. They were publiſhed in the public papers, and met with the greateſt approbation; and upon the propoſition of Dean Baeck and Dr Wargentin, ſecretary of the Royal Academy of Sciences, a collection of upwards of 10,000 dollars in copper money was made for the continuance of the travels of young Haſſelquiſt. Counſellors Lagerſtroem and Nordencrantz were the moſt active in raiſing ſubſcriptions at Stockholm and Gothenburgh. In the ſpring of 1751, he repaired to his deſtination, and paſſed through Jaffa to Jeruſalem, Jericho, &c. He returned afterwards through Rhodus and Scio to Smyrna. Thus he fulfilled all the expectations of his country, but he was not to reap the reward of his toils. The burning heat of the ſandy deſerts of Arabia had affected his lungs; he reached Smyrna in a ſtate of illneſs, in which he languiſhed for ſome time, and died February 9. 1752, in the 30th year of his age.

The fruits of his travels were, however, preſerved through the liberality of a great princeſs. He had been obliged to contract debts. The Turks, therefore, ſeized upon all his collections, and threatened to expoſe them to public ſale. The Swediſh conſul prevented it. He ſent, with the intelligence of the unhappy exit of his countryman, an account of the diſtreſſes under which he died;—and at the repreſentation of Dean Baeck, Queen Louiſa Ulrica granted the ſum of 14,000 dollars in copper ſpecie to redeem all his collections. They arrived afterwards in good preſervation at Stockholm; conſiſting of a great quantity of antiques, Arabian manuſcripts, ſhells, birds, ſerpents, inſects, &c. and were kept in the cabinets at Ulrichſdale and Drottningholm. The ſpecimens of the natural curioſities of theſe muſeums being double or treble in number, Linnæus obtained ſome of them, and publiſhed the voyage of his ill-fated friend, and honoured his memory with a plant which he called from his name *Haſſelquiſtia*. HASSELQUISTA, *Encycl.*

HAT-MAKING is a mechanical proceſs, which is detailed in the *Encyclopædia* from the beſt information that could then be obtained. We have lately learned, however, that our detail is ſometimes defective, and ſometimes erroneous; and it is our duty to ſupply thoſe defects, and to correct thoſe errors. But, ſtrangers as we are to the buſineſs of hat-making, we ſhould not perhaps have ſuſpected, that we had been miſled by the perſons whom we conſulted, had we not been informed by a very intelligent writer in Nicholſon's Philoſophical Journal, that the account of the manufacturing of hats, which is given in the *Encyclopædia*, is far from the truth. This information induced us to look through the Journal itſelf for a more accurate account of the proceſs; well convinced, that the liberal-minded author of that work would not have pointed out our miſtakes without making us welcome to avail ourſelves of his aid to correct them. Our readers will therefore be indebted only to Mr Nicholſon and his correſpondent for whatever inſtruction they may derive from this article; and as we wiſh not to deck ourſelves in borrowed plumes, we ſhall communicate that inſtruction in the words of its author.

Having viſited the manufactory of Meſſrs Collinſons, hatters in Gravel-lane, Southwark, Mr Nicholſon gives the following account of their procedure:

"The materials for making hats are rabbits fur cut off from the ſkin, after the hairs have been plucked out, together with wool and beaver. The two former are mixed in various proportions, and of different qualities, according to the value of the article intended to be made; and the latter our author believes to be univerſally uſed for facing the finer articles, and never for the body or main ſtuff. Experience has ſhewn, that theſe materials cannot be evenly, and well felted together, unleſs all the fibres be firſt ſeparated, or put into the ſame ſtate with regard to each other. This is the object of the firſt proceſs, called *bowing*. The material, without any previous preparation (A), is laid upon a platform of wood,

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(A) Some writers mention a partial wetting of the fur while on the ſkin, by lightly ſmearing it with a ſolution of nitrate of mercury to give it a curl. Meſſrs Collinſons do not uſe it, nor any other preparation.

or of wire, ſomewhat more than four feet ſquare, called a *hurdle*, which is fixed againſt the wall of the workſhop, and is enlightened by a ſmall window, and ſeparated by two ſide partitions from other hurdles which occupy the reſt of the ſpace along the wall. The hurdle, if of wood, is made of deal planks, not quite three inches wide, diſpoſed parallel to the wall, and at the diſtance of one-fortieth or one-fiftieth of an inch from each other, for the purpoſe of ſuffering the duſt, and other impurities of the ſtuff, to paſs through; a purpoſe ſtill more effectually anſwered by the hurdle of wire.

“ The workman is provided with a bow, a bow-pin, a baſket, and ſeveral cloths. The bow is a pole of yellow deal wood, between ſeven and eight feet long, to which are fixed two bridges, ſomewhat like that which receives the hair in the bow of the violin (B). Over theſe is ſtretched a catgut, about one-twelfth part of an inch in thickneſs. The bow-pin is a ſtick with a knob, and is uſed for plucking the bow-ſtring. The baſket is a ſquare piece of ozier work, conſiſting of open ſtrait bars with no croſſing or interweaving. Its length acroſs the bars may be about two feet, and its breadth eighteen inches. The ſides into which the bars are fixed are ſlightly bended into a circular curve, ſo that the baſket may be ſet upright on one of theſe edges near the right hand end of the hurdle, where it uſually ſtands. The cloths are linen. Beſides theſe implements, the workman is alſo provided with brown paper.

“ The *bowing* commences by ſhovelling the material towards the right hand partition with the baſket; upon which, the workman holding the bow horizontally in his left hand, and the bow-pin in his right, lightly places the bow-ſtring, and gives it a pluck with the pin. The ſtring, in its return, ſtrikes part of the fur, and cauſes it to riſe, and fly partly acroſs the hurdle in a light open form. By repeated ſtrokes, the whole is thus ſubjected to the bow; and this beating is repeated till all the original clots or maſſes of the filaments are perfectly opened and obliterated. The quantity thus treated at once is called a *batt*, and never exceeds half the quantity required to make one hat.

“ When the batt is ſufficiently bowed, it is ready for *hardening*; which term denotes the firſt commencement of felting. The prepared material being evenly diſpoſed on the hurdle, is firſt preſſed down by the convex ſide of the baſket, then covered with a cloth, and preſſed ſucceſſively in its various parts by the hands of the workman. The preſſure is gentle, and the hands are very ſlightly moved back and forwards at the ſame time through a ſpace of perhaps a quarter of an inch, to favour the hardening or entangling of the fibres (See FELTING in this *Suppl.*) In a very ſhort time, indeed, the ſtuff acquires ſufficient firmneſs to bear careful handling. The cloth is then taken off, and a ſheet of paper, with its corners doubled in, ſo as to give it a triangular outline, is laid upon the batt, which laſt is folded over the paper as it lies, and its edges, meeting one over the other, form a conical cap. The joining is ſoon made good by preſſure with the hands on the cloth. Another batt, ready hardened, is in the next place laid on the hurdle, and the cap here mentioned placed upon it, with the joining downwards. This laſt batt being alſo folded up, will conſequently have its place of junction diametrically oppoſite to that of the inner felt, which it muſt therefore greatly tend to ſtrengthen. The principal part of the hat is thus put together, and now requires to be worked with the hands a conſiderable time upon the hurdle, the cloth being alſo occaſionally ſprinkled with clear water. During the whole of this operation, which is called *baſoning* (C), the article becomes firmer and firmer, and contracts in its dimenſions. It may eaſily be underſtood, that the chief uſe of the paper is to prevent the ſides from felting together.

“ The baſoning is followed by a ſtill more effectual continuation of the felting, called *working* (D). This is done in another ſhop, at an apparatus called a *battery*, conſiſting of a *kettle* (containing water ſlightly acidulated with ſulphuric acid, to which, for beaver hats, a quantity of the grounds of beer is added, or elſe plain water for rinſing out), and eight *planks* of wood joined together in the form of a fruſtum of a pyramid, and meeting in the kettle at the middle. The outer or upper edge of each plank is about two feet broad, and riſes

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(B) Mr Nicholſon's correſpondent, who is himſelf a hatter, ſays that the bow is beſt made of aſh; that it is compoſed of the *ſtang* or handle; that the bridge at the ſmaller end, or that which is neareſt the window in the act of bowing, is called the *cock*; and that the other bridge, which is nearer to the workman's hand, is called the *breech*.

(C) Mr Nicholſon's correſpondent ſays, that after bowing, and previous to the baſoning, a *hardening ſkin*, that is, a large piece of ſkin, about four feet long and three feet broad, of leather alumed or half tanned, is preſſed upon the bat, to bring it by an eaſier gradation to a compact appearance; after which it is baſoned, being ſtill kept upon the hurdle. This operation, the baſoning, derives its name from the proceſs or *mode of working*, being the ſame as that practiſed upon a wool hat after bowing; the laſt being done upon a piece of caſt metal, four feet acroſs, of a circular ſhape, called a *baſon*: the joining of each batt is made good here by ſhuffling the hand, that is, by rubbing the edge of each batt folded over the other to excite the progreſſive motion of each of the filaments in felting, and to join the two together. Many journeymen, to hurry this work, uſe a quantity of vitriol (ſulphuric acid), and then, to make the nap riſe and flow, they kill the vitriol, and open the body again by throwing in a handful or two of oatmeal; by this means they get a great many made, though, at the ſame time, they leave them quite grainy from the want of labour. This, in handling the dry grey hat when made, may be in part diſcovered; but in part only.

(D) The intelligent writer who has been ſo often quoted, ſays, that before this operation is begun, the hat is dipped into the boiling kettle, and allowed to lie upon the plank until cold again; this is called *ſoaking*, that is, being perfectly ſaturated with the hot liquor: if they are put in too haſtily in this ſtate, for they are then only bowed and baſoned, they would burſt from the edges, each batt not being ſufficiently felted into the other.

riſes a little more than two feet and a half above the ground; and the ſlope towards the kettle is conſiderably rapid, ſo that the whole battery is little more than ſix feet in diameter. The quantity of ſulphuric acid added to the liquor is not ſufficient to give a ſour taſte, but only renders it rough to the tongue. In this liquor, heated rather higher than unpractiſed hands could bear, the article is dipped from time to time, and then worked on the planks with a roller, and alſo by folding or rolling it up, and opening it again; in all which, a certain degree of care is at firſt neceſſary, to prevent the ſides from felting together; of which, in the more advanced ſtages of the operation, there is no danger. The imperfections of the work now preſent themſelves to the eye of the workman, who picks out knots and other hard ſubſtances with a bodkin, and adds more felt upon all ſuch parts as require ſtrengthening. This added felt is patted down with a wet bruſh, and ſoon incorporates with the reſt. The beaver is laid on towards the concluſion of this kind of working. Mr Nicholſon could not diſtinctly learn why the beer grounds were uſed with beaver-hats. Some workmen ſaid, that by rendering the liquor more tenacious, the hat was enabled to hold a greater quantity of it for a longer time; but others ſaid, that the mere acid and water would not adhere to the beaver facing, but would roll off immediately when the article was laid on the plank. It is probable, as he obſerves, that the manufacturers who now follow the eſtabliſhed practice, may not have tried what are the inconveniences this addition is calculated to remove."

Our author's correſpondent, however, aſſigns ſeveral reaſons for the addition of thoſe dregs, which, he ſays, ought to be thick, and the ſoureſt that can be got. 1. Vitriol (ſulphuric acid) would harden the hat too much, which is kept mellow by the dregs. 2. The dregs are ſaid by the workmen to hold or fill the body, whilſt a little vitriol cleanſes it of the dirt, &c. that may be on the rabbit or other wools. 3. Another advantage attending the uſe of dregs, whether of beer, porter, or wine, is, that as the boiling of the dyeing does not draw out much of the mucilage from each hat when it comes to be ſtiffened, the dregs form a body within the hat, ſufficiently ſtrong or retentive to keep the glue from coming through amongſt the nap. 4. Vitriol (ſulphuric acid) alone purges or weakens the goods too much; conſequently half of the quantity does better with the addition of dregs, as it allows the body to be made cloſer by more work.

Of theſe four reaſons for the uſe of dregs, the laſt alone appears to us perſpicuous or at all ſatisfactory. But be this as it may, acid of ſome kind gives a roughneſs to the ſurface of the hair, which facilitates the mechanical action of felting; and Mr Collinſon informed Mr Nicholſon, that in a proceſs, called *carotting*, they make uſe of nitrous acid. In this operation, the material is put into a mixture of the nitrous and ſulphuric acids in water, and kept in the digeſting heat of a ſtove all night; by which means the hair acquires a ruddy or yellow colour, and loſes part of its ſtrength.

" It muſt be remembered, that our hat ſtill poſſeſſes the form of a cone, and that the whole of the ſeveral actions it has undergone have only converted it into a ſoft flexible felt, capable of being extended, though with ſome difficulty, in every direction. The next thing to be done is to give it the form required by the wearer. For this purpoſe, the workman turns up the edge or rim to the dipth of about an inch and a half, and then returns the point back again through the centre or axis of the cap, ſo far as not to take out this fold, but to produce another inner fold of the ſame depth. The point being returned back again in the ſame manner, produces a third fold; and thus the workman proceeds, until the whole has acquired the appearance of a flat circular piece, conſiſting of a number of concentric undulations or folds, with the point in the centre. This is laid upon the plank, where the workman, keeping the piece wet with the liquor, pulls out the point with his fingers, and preſſes it down with his hand, at the ſame time turning it round on its centre in contact with the plank, till he has, by this means, rubbed out a flat portion equal to the intended crown of the hat. In the next place, he takes a block, to the crown of which he applies the flat central portion of the felt, and by forcing a ſtring down the ſides of the block, he cauſes the next part to aſſume the figure of the crown, which he continues to wet and work, until it has properly diſpoſed itſelf round the block. The rim now appears like a flounced or puckered appendage round the edge of the crown; but the block being ſet upright on the plank, the requiſite figure is ſoon given by working, rubbing, and extending this part. Water only is uſed in this operation of faſhioning or blocking; at the concluſion of which it is preſſed out by the blunt edge of a copper implement for that purpoſe.

" Previous to the dyeing, the nap of the hat is raiſed or looſened out with a wire bruſh, or carding inſtrument. The fibres are too rotten after the dyeing to bear this operation. The dyeing materials are logwood, and a mixture of the ſulphates of iron and of copper, known in the market by the names of green copperas and blue vitriol. As the time of Mr Collinſon was limited, and my attention, ſays Mr Nicholſon, was more particularly directed to the mechanical proceſſes, I did not go into the dye-houſe; but I have no doubt that the hats are boiled with the logwood, and afterwards immerſed in the ſaline ſolution. I particularly aſked whether galls were uſed, and was anſwered in the negative.

" The dyed hats are, in the next place, taken to the ſtiffening ſhop. One workman, aſſiſted by a boy, does this part of the buſineſs. He has two veſſels, or boilers, the one containing the grounds of ſtrong beer, which coſts ſeven ſhillings per barrel, and the other veſſel containing melted glue, a little thinner than it is uſed by carpenters. Our author particularly aſked, whether this laſt ſolution contained any other ingredient beſides glue, and was aſſured that it did not. The beer grounds are applied in the inſide of the crown to prevent the glue from coming through to the face, and alſo, as he ſuppoſes, to give the requiſite firmneſs at a leſs expence than could be produced by glue alone. If the glue were to paſs through the hat in different places, it might, he imagines, be more difficult to produce an even gloſs upon the face in the ſubſequent finiſhing. The glue ſtiffening is applied after the beer grounds are dried, and then only upon the lower face of the flap, and the inſide of the crown. For this purpoſe the hat is put into another hat, called a ſtiffening hat, the crown of which is notched, or ſlit open in various directions. Theſe are then placed in a hole in a deal board, which ſupports the flap, and the glue is applied with a bruſh.

" The dry hat, after this operation, is very rigid, and its figure irregular. The laſt dreſſing is given by the application of moiſture and heat, and the uſe of the bruſh and a hot iron, ſomewhat in the ſhape of that uſed by tailors, but ſhorter and broader on the face. The hat being ſoftened by expoſure to ſteam, is drawn upon a block, to which it is ſecurely applied by the former method of forcing a ſtring down from the crown to the commencement of the rim. The judgment of the workman is employed in moiſtening, bruſhing, and ironing the hat, in order to give and preſerve the proper figure. When the rim of the hat is not intended to be of an equal width throughout, it is cut by means of a wooden, or perhaps metallic pattern ; but as no ſuch hats are now in faſhion, Mr Nicholſon ſaw only the tool for cutting them round. The contrivance is very ingenious and ſimple. A number of notches are made in one edge of a flat piece of wood for the purpoſe of inſerting the point of a knife, and from one ſide or edge of this piece of wood there proceeds a ſtraight handle, which lies parallel to the notched ſide, forming an angle ſomewhat like that of a carpenter's ſquare. When the legs of this angle are applied to the outſide of the crown, and the board lies flat on the rim of the hat, the notched edge will lie nearly in the direction of the radius, or line pointing to the centre of the hat. A knife being therefore inſerted in one of the notches, it is eaſy to draw it round by leaning the tool againſt the crown, and it will cut the border very regular and true. This cut is made before the hat is quite finiſhed, and is not carried entirely through ; ſo that one of the laſt operations conſiſts in tearing off the redundant part, which by that means leaves an edging of beaver round the external face of the flap. When the hat is completely finiſhed, the crown is tied up in gauze paper, which is neatly ironed down. It is then ready for the ſubſequent operations of lining," &c.

Our author concludes his valuable memoir on the fabrication of hats, with ſome obſervations on the probable gain or loſs of employing machinery in the manufacture. Theſe obſervations, as they are ſtated in the original paper, we recommend to the ſerious attention of every judicious hat-maker, who carries on his buſineſs on a large ſcale ; for he will find them not the reveries of a raſh ſpeculatiſt, but the cool reflections of a real philoſopher, who is at the ſame time no ſtranger to the arts of life. They ſuggeſt the following ſubjects of inquiry : Whether carding, which is rapidly and mechanically done, be inferior to bowing, which does not promiſe much facility for mechanical operation ? Whether a ſucceſſion of batts or cardings might be thrown round a fluted cone, which rapidly revolving, in contact with three or more cylinders, might perform the hardening, and even the working, with much more preciſion and ſpeed than they are now done by hand ? Whether blocking or ſhaping be not an operation extremely well calculated for the operation of one or more machines ? Whether looſe weaving and ſubſequent felting might not produce a lighter, cheaper, and ſtronger article ? And how far the mechanical felting, which is not confined merely to the hairs of animals, might be applied to this art ?

Before we diſmiſs this ſubject, it may be worth while to ſtate Mr Dunnage's method of making *water-proof hats*, in imitation of beaver, for which, in November 1794, he obtained a patent. It is as follows : Let a ſhag be woven, of ſuch count in the reed, and cut over ſuch ſized wire, as will give the hats to be manufactured from it that degree of richneſs, or appearance of fur, which may be thought neceſſary. The materials of which this ſhag may be compoſed are various, and ſhould be accommodated to different kinds of hats, according to the degree of beauty and durability to be given them, and the price at which they are deſigned to be ſold ; that is to ſay, ſilk, mohair, or any other hair that is capable of being ſpun into an end fine enough for the purpoſe, cotton, inkle, wool, or a mixture of any, or all the above materials, as may ſuit the different purpoſes of the manufacturer. Thoſe anſwer beſt (ſays our author), which are made with two poles, either of Bergam, Piedmont, or Organzine ſilk, riſing alternately, in a reed of about nine hundred count to eighteen inches wide, with three ſhoots over each wire. This method of weaving diſtributes the ſilk (as it may be put ſingle into the harneſs), and prevents any ribby appearance which it might have if the ſilk were paſſed double, and the whole of the pole cut over each wire. This may be made either on a two or four thread ground of hard ſilk, ſhot with fine cotton, which he thinks preferable for ſhoot, to ſilk, inkle, or any other material, as it forms both a cloſe and fine texture. An inferior kind of hats may be made from any of the before-mentioned materials, and with cheaper ſilk. This ſhag ſhould be ſtretched on a frame, ſuch as dyers uſe to rack cloth ; then (having previouſly ſet the pile upright with a comb, to prevent its being injured or ſtuck together), go over the ground with thin ſize, laid on with a ſoft bruſh. For black, or dark colours, common ſize will do ; with white, or any light colour, uſe iſinglaſs, or a ſize made from white kid leather. Theſe, or gum, or any other mucilaginous matter, which, without altering the colour, will prevent oil from getting through the ground ſo as to injure the pile, will anſwer the purpoſe. Take care not to apply more of any material, as a preparation, than may be fully ſaturated with oil or varniſh, ſo that water will not diſcharge it from the ground. The ſize, or other glutinous matter, being dry, the pile muſt be teeſeled, or carded with a fine card, till the ſilk is completely taken out of the twiſt or throwing, when it will loſe its coarſe ſhaggy look, and aſſume the appearance of a very fine fur. It muſt now be once more ſet upright with a comb, and you may proceed to lay on your water-proof material ; this too may be varied according to circumſtances. For black, or any dark colour, linſeed oil well boiled with the uſual driers, and thickened with a ſmall quantity of any good drying colour, will do ; for white, or very fine colours, poppy or nut oil, or copal or other varniſhes, may be uſed. In this particular the manufacturer muſt judge what will beſt anſwer his purpoſe, taking care never to uſe any thing that will dry hard, or be ſubject to crack. Mr Dunnage has found good drying linſeed oil preferable to any other thing which he has uſed, and, with the precaution of laying on very little the firſt time, it will not injure the fineſt colours. When the firſt coat of oil is dry, go over it a ſecond and a third time, if neceſſary, till you are convinced the pores of the ground are fully cloſed up, and the ſtuff rendered impervious to water. It ſhould now ſtand ſeveral days, till the ſmell is ſufficiently gone off; and before it is taken from the frame, ſhould be gone over with ſome ox-gall or lime-water, to take off the greaſineſs, which would otherwiſe prevent the ſtiffening from adhering to the oil. The material being now ready to be formed into hats, ſhould be cut into proper ſhapes for that purpoſe. The crown ſhould be made up over a block, with needle and ſilk, the oiled ſide outwards. The ſeams ſhould then be rubbed with a piece of hard wood, bone, or ivory, to make them lie flat, and the edges of the ſtuff pared off very near the ſtitches, that no joint may appear on the right ſide. The ſeams ſhould then be carefully gone over with the prepared oil, till every crevice or hole made by the needle is completely filled up, and the crown rendered perfectly water-proof. The crown may then be turned and ſtiffened, by ſticking linen, leather, paper, or any other material that may be found to anſwer the purpoſe, to the inner or painted ſide, till it acquires about the ſame degree of ſtiffneſs, or reſiſtance to the touch, as a good beaver. The mucilaginous matter which he uſed to attach the ſtiffening to the crown, and the upper and under parts of the brim to each other, was compoſed of one pound of gum-arabic or ſenega, one pound of ſtarch, and a half a pound of glue, boiled up with as much water as reduced the whole to the conſiſtence of a thick paſte. A greater or leſs proportion of any of theſe ingredients may be uſed, and other glutinous and adheſive ſubſtances may anſwer the ſame purpoſes; or drying-oils may be made uſe of, inſtead of this or other mucilage; or any of the reſinous gums diſſolved in oil or ſpirits; only it ſhould be obſerved, in this caſe, the hats will require more time in the preparation, as the oily matter, unleſs expoſed to the air, will not readily dry; but he found by experience that the above mentioned compoſition does not dry hard or brittle, but retains that pleaſant flexibility which is agreeable to the touch, while it communicates to the other materials a ſufficient degree of elaſticity. Before the brim is perfectly dry, care ſhould be taken to form a neck or riſing round the hole where it is to be attached to the crown, by notching it round with a pair of ſciſſars, and then forcing it over a block ſomething larger than you have made the hole, ſo that the uncut ſtuff may turn up, under the lower edge of the crown, about a quarter of an inch. Before you join the crown and brim together, go over the outſide of the neck of the brim, and the inſide of the crown, as high as the neck will come (which ſhould be about half an inch), with the prepared oil; and when they are nearly dry, ſo as to adhere to the finger on touching them, put the crown over the neck of the brim, and let them be ſewed ſtrongly together, taking care to ſew down as little of the pile as poſſible, and uſing the ſame precaution of oiling, where the needle has been through, as was obſerved in making up the crown. The hat is now ready for dreſſing; which operation may be performed over a block, with a hot iron, bruſh, &c. in the ſame manner as thoſe commonly called felts. When putting in the lining, be very careful to let the needle only take hold of the under ſurface of the brim; for ſhould it perforate the upper one, the water will find its way through, and the hat be of no value. Though we have already declared how little we are acquainted with the operation of hat-making, we cannot help ſuggeſting the inquiry, whether theſe water-proof hats might not be improved both in ſtrength and beauty, by a ſlight felting before the application of the ſize by the bruſh. Such of them as are compoſed of wool or hair, or contain a mixture of theſe materials, are unqueſtionably ſuſceptible of felting.

HAWKINS (Sir John), was the youngeſt ſon of a man who, though deſcended from Sir John Hawkins the memorable admiral and treaſurer of the navy in the reign of Queen Elizabeth, followed at firſt the occupation of a houſe-carpenter, which he afterwards exchanged for the profeſſion of a ſurveyor and builder. He was born in the city of London on the 30th day of March 1719; and after having been ſent firſt to one ſchool, and afterwards to a ſecond, where he acquired a tolerable knowledge of Latin, he went through a regular courſe of architecture and perſpective, in order to fit him for his father's profeſſion of a ſurveyor. He was, however, perſuaded, by a near relation, to abandon the profeſſion of his firſt choice, and to embrace that of the law; and was accordingly articled to Mr John Scott an attorney and ſolicitor in great practice. In this ſituation his time was too fully employed in the actual diſpatch of buſineſs to permit him, without ſome extraordinary means, to acquire the neceſſary knowledge of his profeſſion by reading and ſtudy; beſides that, his maſter is ſaid to have been more anxious to render him a good copying clerk, by ſcrupulous attention to his hand-writing, than to qualify him by inſtruction to conduct buſineſs. To remedy this inconvenience, therefore, he abridged himſelf of his reſt, and riſing at four in the morning, found opportunity of reading all the neceſſary and moſt eminent law writers, and the works of our moſt celebrated authors on the ſubjects of verſe and proſe. By theſe means, before the expiration of his clerkſhip, he had rendered himſelf a very able lawyer, and had acquired a love for literature in general, but particularly for poetry and the polite arts; and the better to facilitate his improvement, he occaſionally furniſhed to the Univerſal Spectator, the Weſtminſter Journal, the Gentleman's Magazine, and other periodical publications of the time, eſſays and diſquiſitions on ſeveral ſubjects. The firſt of theſe is believed to have been an Eſſay on *Swearing*; but the exact time of its appearance, and the paper in which it was inſerted, are both unknown. It was, however, re-publiſhed ſome years before his death (without his knowledge till he ſaw it in print) in one of the newſpapers. His next production was an Eſſay on *Honeſty*, inſerted in the Gentleman's Magazine for March 1739; and which occaſioned a controverſy, continued through the Magazines for ſeveral ſucceeding months, between him and a Mr Calamy, a deſcendant of the celebrated Dr Edmund Calamy, then a fellow-clerk with him.

About the year 1741, a club having been inſtituted by ſeveral amateurs of muſic, under the name of the Madrigal Society, to meet every Wedneſday evening, and his clerkſhip being now out, he became a member of it, and continued ſo many years. Purſuing his inclination for muſic ſtill farther, he became alſo a member of the Academy of Ancient Muſic, which uſed to meet every Thurſday evening at the Crown and Anchor in the Strand, but ſince removed to Freemaſons Hall; and

and of this he continued a member till a few years before its removal.

Impelled by his own taſte for poetry, and excited to it by his friend Foſter Webb's example, who had contributed to the Gentleman's Magazine many very elegant poetical compoſitions, he had, before this time, himſelf become an occaſional contributor in the ſame kind, as well to that as to ſome other publications. The earlieſt of his productions of this ſpecies, now known, is ſuppoſed to be a copy of verſes "To Mr George Stanley, occaſioned by looking over ſome Compoſitions of his lately publiſhed," which bears date 19th February 1740, and was inſerted in the Daily Advertiſer for February 21. 1741; but, about the year 1742, he propoſed to Mr Stanley the project of publiſhing, in conjunction with him, ſix cantatas for a voice and inſtruments, the words to be furniſhed by himſelf, and the muſic by Mr Stanley. The propoſal was accepted, the publication was to be at their joint expence, and for their mutual benefit; and accordingly, in 1742, ſix cantatas were thus publiſhed, the five firſt written by Mr Hawkins, the ſixth and laſt by Foſter Webb; and theſe having ſucceeded beyond the moſt ſanguine expectations of their authors, a ſecond ſet of ſix more, written wholly by himſelf, was in like manner publiſhed a few months after, and ſucceeded equally well.

As theſe compoſitions, by being frequently performed at Vauxhall, Ranelagh, and other public places, and at many private concerts, had become favourite entertainments, many perſons, finding the author alſo a modeſt well-informed young man of unexceptionable morals, were become deſirous of his acquaintance. Among theſe was Mr Hare of Limehouſe, a brewer, who being himſelf a muſical man, and having met him at Mr Stanley's at muſical parties, gave him an invitation to his houſe; and, to forward him in his profeſſion, introduced him to a friend of his, Peter Storer of Highgate, Eſq; which proved the means of making his fortune.

In the winter of the year 1749, Doctor, then Mr Johnſon, was induced to inſtitute a club to meet every Tueſday evening at the King's Head, in Ivy lane, near St Paul's. It conſiſted only of nine perſons; and Mr Hawkins was one of the firſt members About this time, as it is ſuppoſed, finding his father's houſe, where he had hitherto reſided, too ſmall for the diſpatch of his buſineſs, now very much increaſing, he, in conjunction with Dr Munckley, a phyſician with whom he had contracted an intimacy, took a houſe in Clements-lane, Lombard-ſtreet. The ground-floor was occupied by him as an office, and the firſt floor by the Doctor as his apartment. Here he continued till the beginning of 1753, when, on occaſion of his marriage with Sidney, the youngeſt of Mr Storer's daughters, who brought him a conſiderable fortune, he took a houſe in Auſtin Friars, near Broad-ſtreet, ſtill continuing to follow his profeſſion of an attorney.

Having received, on the death of Peter Storer, Eſq; his wife's brother, in 1759, a very large addition to her fortune, he quitted buſineſs to Mr Clark, afterwards Alderman Clark, who had a ſhort time before completed his clerkſhip under him, diſpoſed of his houſe in Auſtin Friars, and purchaſed a houſe at Twickenham. Soon afterwards he bought the leaſe of one in Hatton-ſtreet, London, for a town reſidence.

From a very early period of his life he had entertained a ſtrong love for the amuſement of angling; and his affection for it, together with the vicinity of the river Thames, was undoubtedly his motive to a reſidence at this village. He had been long acquainted with Walton's Complete Angler; and had, by obſervation and experience, become himſelf a very able proficient in the art. Hearing, about this time, that Mr Moſes Browne propoſed to publiſh a new edition of that work, and being himſelf in poſſeſſion of ſome material particulars reſpecting Walton, he, by letter, made Mr Browne an offer of writing, for his intended edition, Walton's Life. To this propoſal no anſwer was returned, at leaſt for ſome time; from which circumſtance Mr Hawkins concluded, as any one reaſonably would, that his offer was not accepted; and, therefore, having alſo learnt that Mr Browne meant not to publiſh the text as the author left it, but to modernize it, in order to file off the ruſt, as he called it, he wrote again to tell Mr Browne that he underſtood his intention was to ſophiſticate the text, and that therefore he, Mr Hawkins, would himſelf publiſh a correct edition. Such an edition, in 1760, he accordingly publiſhed in octavo with notes, adding to it a Life of Walton by himſelf, a Life of Cotton, the author of the ſecond part, by the well-known Mr Oldys; and a ſet of cuts deſigned by Wale, and engraved by Ryland.

His propenſity to muſic, manifeſted by his becoming a member and frequenter of the ſeveral muſical ſocieties before mentioned, and alſo by a regular concert at his houſe in Auſtin Friars, had led him, at the time that he was endeavouring to get together a good library of books, to be particularly ſolicitous for collecting the works of ſome of the beſt muſical compoſers; and, among other acquiſitions, it was his ſingular good fortune to become poſſeſſed by purchaſe of ſeveral of the moſt ſcarce and valuable theoretical treatiſes on the ſcience any where extant, which had formerly been collected by Dr Pepuſch. With this ſtock of erudition, therefore, he, about this time, at the inſtance of ſome friends, ſet about procuring materials for a work then very much wanted, a Hiſtory of the Science and Practice of Muſic, which he afterwards publiſhed.

At the recommendation of the well-known Paul Whitehead, to the Duke of Newcaſtle, then Lord-lieutenant for Middleſex, his name was, in 1761, inſerted in the commiſſion of the peace for that county; and having, by the proper ſtudies, and a ſedulous attendance at the ſeſſions, qualified himſelf for the office, he became an active and uſeful magiſtrate in the county (A). Obſerving, as he had frequent occaſion to do in the courſe of his duty, the bad ſtate of highways, and

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(A) When he firſt began to act, he formed a reſolution of taking no fees, not even the legal and authoriſed ones, and purſued this method for ſome time, till he found that it was a temptation to litigation, and that every trifling ale-houſe quarrel produced an application for a warrant. To check this, therefore, he altered his mode, and received his due fees, but kept them ſeparately in a purſe; and at the end of every ſummer, before he left the country for the winter, delivered the whole amount to the clergyman of the pariſh, to be by him diſtributed among ſuch of the poor as he judged fit.

and the great defect in the laws for amending and keeping them in repair, he ſet himſelf to reviſe the former ſtatutes, and drew an act of parliament conſolidating all the former ones, and adding ſuch other regulations as were neceſſary. His ſentiments on this ſubject he publiſhed in octavo, in 1763, under the title of "Obſervations on the State of Highways, and on the Laws for amending and keeping them in Repair;" ſubjoining to them the draught of the act before mentioned; which bill being afterwards introduced into parliament, paſſed into a law, and is that under which all the highways in England are at this time kept repaired. Of this bill, it is but juſtice to add, that, in the experience of more than thirty years, it has never required a ſingle amendment.

Johnſon, and Sir Joſhua, then Mr Reynolds, had, in the winter of this year (1763) projected the eſtabliſhment of a club to meet every Monday evening at the Turk's Head, in Gerard-ſtreet; and, at Johnſon's ſolicitation, Mr Hawkins became one of the firſt members.

An event of conſiderable importance engaged him, in the year 1764, to ſtand forth as the champion of the county of Middleſex, againſt a claim then for the firſt time ſet up, and ſo enormous in its amount as juſtly to excite reſiſtance. The city of London finding it neceſſary to rebuild the gaol of Newgate, the expence of which, according to their own eſtimates, would amount to L.40,000, had this year applied to parliament, by a bill brought into the Houſe of Commons, in which, on a ſuggeſtion that the county priſoners removed to Newgate for a few days previous to their trials at the Old Bailey, were as two to one to the London priſoners conſtantly confined there, they endeavoured to throw the burthen of two-thirds of the expence on the county, while they themſelves propoſed to contribute one-third only. This attempt the magiſtrates for Middleſex thought it their duty to oppoſe; and accordingly a vigorous oppoſition to it was commenced and ſupported under the conduct of Mr Hawkins, who drew a petition againſt the bill, and a caſe of the county, which was printed and diſtributed amongſt the members of both houſes of parliament. It was the ſubject of a day's converſation in the Houſe of Lords; and produced ſuch an effect in the Houſe of Commons, that the city, by its own members, moved for leave to withdraw the bill. The ſucceſs of this oppoſition, and the abilities and ſpirit with which it was conducted, naturally attracted towards Mr Hawkins the attention of his fellow-magiſtrates; and the chairman of the quarter ſeſſions dying not long after, he was, on the 19th day of September 1765, elected his ſucceſſor.

In the year 1771 he quitted Twickenham, and ſold his houſe there to Mr Vaillant; and in the ſummer of the next year, for the purpoſe of obtaining, by ſearches in the Bodleian and other libraries, farther materials for his hiſtory of muſic, he made a journey to Oxford, carrying with him an engraver from London, to make drawings from the portraits in the muſic ſchool.

On occaſion of actual tumults or expected diſturbances, he had more than once been called into ſervice of great perſonal danger. When the riots at Brentford had ariſen, during the time of the Middleſex election in the year 1768, he and ſome of his brethren attended to ſuppreſs them; and, in conſequence of an expected riotous aſſembly of the journeymen Spitalfield weavers in Moorfields in 1769, the magiſtrates of Middleſex, and he at their head, with a party of guards, attended to oppoſe them; but the mob, on ſeeing them prepared, thought it prudent to diſperſe. In theſe and other inſtances, and particularly in his conduct as chairman, having given ſufficient proof of his activity, reſolution, abilities, integrity, and loyalty, he, on the 23d of October 1772, received from his majeſty the honour of knighthood.

In 1773, Dr Johnſon and Mr Stevens publiſhed, in 10 vols 8vo, their firſt joint edition of Shakeſpeare, to which Sir John Hawkins contributed ſuch notes as are diſtinguiſhed by his name, as he afterwards did a few more on the republication of it in 1778. An addreſs to the king from the county of Middleſex, on occaſion of the American war, having, in 1774, been judged expedient, and at his inſtance voted, he drew up ſuch an addreſs, and, together with two of his brethren, had, in the month of October in that year, the honour of preſenting it.

After ſixteen years labour, he, in 1776, publiſhed, in five volumes quarto, his General Hiſtory of the Science and Practice of Muſic; which, in conſequence of permiſſion obtained in 1773, he dedicated to the king, and preſented it to him at Buckingham Houſe on the 14th of November 1776, when he was honoured with an audience of conſiderable length both from the king and queen.

Not long after this publication, that is to ſay in November 1777, he was induced, by an attempt to rob his houſe, which, though unſucceſsful, was made three different nights with the interval of one or two only between each attempt, to quit his houſe in Hatton-ſtreet; and, after a temporary reſidence for a ſhort time in St James's Place, he took a leaſe of one, formerly inhabited by the famous Admiral Vernon, in the ſtreet leading up to Queen Square, Weſtminſter, and removed thither.

By this removal he became a conſtant attendant on divine worſhip at the pariſh-church of St Margaret, Weſtminſter; and having learnt, in December 1778, that the ſurveyor to the board of ordnance was, in defiance of a proviſo in the leaſe under which they claimed, carrying up a building at the eaſt end of the church, which was likely to obſcure the beautiful painted glaſs window over the altar there, Sir John Hawkins, with the concurrence of ſome of the principal inhabitants, wrote to the ſurveyor, and compelled him to take down two feet of the wall, which he had already carried up above the ſill of the window, and to ſlope off the roof of his building in ſuch a manner, as that it is not only no injury, but, on the contrary, a defence to the window.

In the month of December 1783, Dr Johnſon having diſcovered in himſelf ſymptoms of a dropſy, ſent for Sir John Hawkins, and telling him the precarious ſtate of his health, declared his deſire of making a will, and requeſted him to be one of his executors. Sir John accepted the office; inſtructed the Doctor how to make his will; and on his death undertook to be his biographer, and the guardian of his fame, by publiſhing a complete edition of his works.

Not three months after the commencement of this undertaking, he met with the ſevereſt loſs of almoſt any that a literary man can ſuſtain, ſhort of that of his friends or relations, in the deſtruction, by fire, of his library; conſiſting of a numerous and well-choſen collection

lection of books, ancient and modern, in many languages, and on moſt ſubjects, which it had been the buſineſs of above 30 years at intervals to get together. Of this loſs, great as it was in pecuniary value, and compriſing in books, prints, and drawings, many articles that could never be replaced, he was never heard in the ſmalleſt degree to complain; but having found a temporary reception in a large houſe in Orchard-ſtreet, Weſtminſter, he continued there a ſhort time, and then took a houſe in the Broad Sanctuary, Weſtminſter.

This event, for a ſhort time, put a ſtop to the progreſs of his literary purſuits. As ſoon, however, as he could ſufficiently collect his thoughts, he recommenced his office of biographer of Johnſon; and completed his intention by publiſhing, in 1787, the life and works, in eleven volumes octavo, which he dedicated to the king.

With this production he terminated his literary labours; and having for many years been more particularly ſedulous in his attention to the duties of religion, and accuſtomed to ſpend all his leiſure from other neceſſary concerns in theological and devotional ſtudies, he now more cloſely addicted himſelf to them, and ſet himſelf to prepare for that event, which he ſaw could be at no great diſtance; and the better to accompliſh this end, in the month of May 1788, he, by a will and other proper inſtruments, made ſuch an arrangement of his affairs as he meant ſhould take place after his deceaſe.

In this manner he ſpent his time till about the beginning of May 1789, when, finding his appetite fail him in a greater degree than uſual, he had recourſe, as he had ſometimes had before on the ſame occaſion, to the waters of the Iſlington Spa. Theſe he drank for a few mornings; but on the 14th of that month, while he was there, he was, it is ſuppoſed, ſeized with a paralytic affection, as, on his returning to the carriage which waited for him, his ſervants perceived a viſible alteration in his face. On his arrival at home, he went to bed, but got up a few hours after, intending to receive an old friend, from whom he expected a viſit in the evening. At dinner, however, his diſorder returning, he was led up to bed, from which he never roſe, on the 21ſt of the ſame month, about two in the morning, dying of an apoplexy. He was interred on the 28th in the cloiſters of Weſtminſter Abbey, in the north walk near the eaſtern door into the church, under a ſtone, containing, by his expreſs injunctions, no more than the initials of his name, the date of his death, and his age; leaving behind him a high reputation for abilities and integrity, united with the well-earnt character of an active and reſolute magiſtrate, an affectionate huſband and father, a firm and zealous friend, a loyal ſubject, and a ſincere Chriſtian.

Such is the character of him in the Biographical Dictionary, which we have neither right no inclination to controvert. With none of his works are we acquainted but his edition of *Walton's Complete Angler*, and his *Life of Johnſon*. The former is a very pleaſing book; and in the latter are collected many intereſting anecdotes of literature and literary men; but they are not well arranged, and the ſtyle of the compoſition is coarſe and ſlovenly. Sir John, we doubt not, was a man of worth, and his reflections on the ſentimental ſlang of Sterne and others, ſhew that he had ſucceſsfully ſtudied human nature; but he certainly was not a man of general taſte.

HEAT. See in this Supplement, CHEMISTRY, Part I. chap. v. where we have endeavoured to eſtabliſh the modern doctrine reſpecting *Caloric* or latent heat. In n°·309, &c. of that article, we have given an account of Count Rumford's ingenious experiments, inſtituted with a view to determine whether or not caloric be a ſubſtance, and have ſtated our reaſons for diſſenting from his opinion. It has been ſuggeſted to us, however, by a friend, to whoſe judgment we are inclined to pay great deference, that it would be proper, in this place, to give the Count's arguments at full length, and in his own words; and the propriety of this is the more apparent, that in the ſupplementary article ELECTRICITY, we have hinted our own ſuſpicions of the non-exiſtence of an *electrical fluid*. The Count then reaſons from his experiments in the following words:

"By meditating on the reſults of all theſe experiments, we are naturally brought to that great queſtion which has ſo often been the ſubject of ſpeculation among philoſophers, namely, What is heat?—Is there any ſuch thing as an *igneous fluid?*—Is there any thing that can with propriety be called caloric?

"We have ſeen that a very conſiderable quantity of heat may be excited in the friction of two metallic ſurfaces, and given off in a conſtant ſtream or flux *in all directions*, without interruption or intermiſſion, and without any ſigns of diminution or exhauſtion.

"From whence came the heat which was continually given off in this manner in the foregoing experiments? Was it furniſhed by the ſmall particles of metal detached from the larger ſolid maſſes on their being rubbed together? This, as we have already ſeen, could not poſſibly have been the caſe.

"Was it furniſhed by the air? This could not have been the caſe; for in three of theſe experiments, the machinery being kept immerſed in water, the acceſs of the air of the atmoſphere was completely prevented.

"Was it furniſhed by the water which ſurrounded the machinery? That this could not have been the caſe is evident; *firſt*, becauſe this water was continually *receiving heat* from the machinery, and could not at the ſame time be *giving to* and *receiving heat from* the ſame body; and, *ſecondly*, becauſe there was no chemical decompoſition of any part of this water. Had any ſuch decompoſition taken place (which indeed could not reaſonably have been expected), one of its compound elaſtic fluids (moſt probably inflammable air) muſt at the ſame time have been ſet at liberty, and, in making its eſcape into the atmoſphere, would have been detected; but though I frequently examined the water to ſee if any air bubbles roſe up through it, and had even made preparations for catching them, in order to examine them if any ſhould appear, I could perceive none; nor was there any ſign of decompoſition of any kind whatever, or other chemical proceſs going on in the water.

"Is it poſſible the heat could have been ſupplied by means of the iron bar to the end of which the blunt ſteel borer was fixed? or by the ſmall neck of gun-metal by which the hollow cylinder was united to the cannon? Theſe ſuppoſitions appear more improbable even than either of thoſe before mentioned; for heat was continually going off or *out of the machinery*, by both theſe laſt paſſages, during the whole time the experiment laſted.

"And, in reaſoning on this ſubject, we muſt not forget to conſider that moſt remarkable circumſtance, that the ſource of the heat generated by friction in theſe experiments appeared evidently to be inexhauſtible.

"It is hardly neceſſary to add, that any thing which any *inſulated* body or ſyſtem of bodies can continue to furniſh *without limitation*, cannot poſſibly be a *material ſubſtance*; and it appears to me to be extremely difficult, if not quite impoſſible, to form any diſtinct idea of any thing capable of being excited and communicated in the manner the heat was excited and communicated in theſe experiments, except it be motion.

"But although the mechaniſm of heat ſhould in fact be one of thoſe myſteries of nature which are beyond the reach of human intelligence, this ought by no means to diſcourage us, or even leſſen our ardour, in our attempts to inveſtigate the laws of its operations. How far can we advance in any of the paths which ſcience has opened to us, before we find ourſelves enveloped in thoſe thick miſts which on every ſide bound the horizon of the human intellect? But how ample and intereſting is the field that is given us to explore!

"Nobody, ſurely, in his ſober ſenſes has ever pretended to underſtand the mechaniſm of gravitation; and yet what ſublime diſcoveries was our immortal Newton enabled to make, merely by the inveſtigation of the laws of its action! The effects produced in the world by the agency of heat are probably *juſt as extenſive* and quite as important, as thoſe which are owing to the tendency of the particles of matter towards each other; and there is no doubt but its operations are in all caſes determined by laws equally immutable."

HELENA, or St Helena. In addition to the account of this iſland in the *Encyclopædia*, the following particulars from Sir George Staunton deſerve a place in this *Supplement*, becauſe ſome of them are important in themſelves, while others correct one or two miſtakes into which we had fallen, by adopting, implicitly, the narrative of Forſter.

The circumference of St Helena meaſures ſomewhat leſs than twenty-eight miles. Along the whole coaſt to leeward, or to the northward, ſhips may anchor in perfect ſecurity in all ſeaſons of the year, but the bank ſhelves ſo abruptly afterwards, that the anchorage, being in deep water, is inſecure. The tide ſeldom riſes above three feet and a half; but the ſurge of the ſea is ſometimes tremendous; and ſeveral accidents happened in approaching or quitting the ſhore, until a wharf was erected lately, which renders the arrival there, and departure from it, perfectly ſafe. In the immediate neighbourhood of the iſland, ſtorms are little known, thunder is rarely heard, and lightning is ſeldom perceived.

The ſteep eminences which intervene between the valleys, that are the chief ſeats of population, render the communication from one part of this little ſpot to another ſlow and difficult. Planters on the windward ſide of the iſland conſider a journey to the leeward, or ſeat of government, as a ſerious undertaking. Several of them take that opportunity of paying their reſpects to the governor, which is called there ſometimes "going to court." There are St Helena planters who have not travelled ſo far. At preſent, by order of the governor, there are ſignals ſo placed all over the iſland, as to give inſtant notice of the approach of veſſels to any part of it.

In the *Encyclopædia*, it is ſaid that peaches are the only European fruits which thrive in St Helena; but this appears to be a miſtake Several ſorts of fruit trees imported into the iſland had been deſtroyed by a particular inſect; but encouragement has been given for the cultivation of thoſe which that miſchievous animal is known to ſpare, ſuch as the apple, for example, with all the varieties of which it is ſuſceptible. The plantain and banana, or the two ſpecies of the *muſa*, thrive alſo remarkably well. The ground is fertile, and in favourable ſeaſons produces, in ſome inſtances, double crops within the year. Plantations, however, of cotton, indigo, or canes, were not found to anſwer; though ſome good coffee has been produced in it. A botanic garden has been eſtabliſhed near the governor's country houſe. An intelligent gardener has been ſent to take care of it by the company; and a vaſt variety of trees, plants, and flowers of different, and ſometimes oppoſite climates, are already collected in it. The ſurrounding ſea abounds in eſculent fiſh; and ſeventy different ſpecies, including turtle, have been caught upon the coaſts. Whales are ſeen in great numbers playing round the iſland, where it is ſuppoſed the ſouthern whale fiſhery might be carried on to great national advantage.

The country is chiefly cultivated by blacks. Perſons of that colour were brought in a ſtate of ſlavery to it by its firſt European ſettlers; and it ſeldom happens that white men will ſubmit to common work where there are black ſlaves to whom it may be transferred. Theſe were for a long time under the unlimited dominion of their owners, until a repreſentation of the abuſes made of that power induced the India Company to place them under the immediate protection of the magiſtracy, and to enact various regulations in their favour; which have contributed to render them, in a great degree, confortable and ſecure. Theſe regulations may have hurt, at firſt, the feelings of the owners of ſlaves, but not their real intereſt; for it appears, that before their introduction there was a loſs, upon an average, of about ten in a hundred ſlaves every year, to be ſupplied at a very heavy expence; whereas, under the preſent ſyſtem, they naturally increaſe. All future importation of ſlaves into the iſland is prohibited.

Beſides the blacks in a ſtate of ſlavery, there are ſome who are free. The labour of theſe tending to diminiſh the value of that of ſlaves, the free blacks became once obnoxious to ſome ſlave owners; who had ſufficient influence, in a grand jury, to preſent them as without viſible means of gaining a livelihood, and liable to become burdenſome to the community; but upon examination, it appeared that all free blacks of age to work were actually employed; that not one of them had been tried for a crime for ſeveral years, nor had any of them been upon the pariſh. They are now by the humane interpoſition of the company placed under the immediate protection of the government, and put nearly upon a footing with the other free inhabitants, who, when accuſed of crimes, have the privilege of a jury, as well as in civil cauſes.

The principal ſettlement of St Helena has the peculiar advantage of uniting the ſhelter of a leeward ſituation with the coolneſs of windward gales. The ſouth-eaſt wind blows conſtantly down the valley, rendering a reſidence in it pleaſant as well as healthy.

The country is ſo fertile, and the climate ſo congenial to the human feelings, that perhaps it would be difficult to find out a ſpot where perſons, not having acquired a reliſh for the enjoyments of the world, or already advanced in life, and ſurfeited with them, could have a better chance of protracting their days in eaſe, health, and comfort.

HELICOID Parabola, or the *Parabolic Spiral*, is a curve ariſing from the ſuppoſition that the common or Apollonian parabola is bent or twiſted, till the axis come into the periphery of a circle, the ordinates ſtill retaining their places and perpendicular poſitions with reſpect to the circle, all theſe lines ſtill remaining in the ſame plane.

HELISPHERICAL Line, is the Rhumb line in Navigation; being ſo called, becauſe on the globe it winds round the pole helically or ſpirally, coming ſtill nearer and nearer to it.

HENIOCHAS, or Heniochus, a northern conſtellation, the ſame as Auriga, which ſee *Encycl.*

HERSCHEL, the name by which the French, and moſt other European nations, call the new planet diſcovered by Dr Herſchel in the year 1781. Its mark or character is ♅. The Italians call it Ouranos, or Urania; but the Engliſh, the Georgian Planet, or Georgium Sidus.

HETERODROMUS Vectis, or Lever, in Mechanics, a lever in which the fulcrum, or point of ſuſpenſion, is between the weight and the power; being the ſame as what is otherwiſe called a lever of the firſt kind.

HINZUAN, the proper name of one of the Comora iſlands, which by different writers of different nations has been called *Anzuame*, *Anjuan*, *Juanny*, and *Johanna*, and which is deſcribed in the *Encyclopædia* under the name of St Joanna. In that article, it is obſerved, that an anonymous writer has cenſured the deſcriptions of this iſland given by the Abbé Reynal and Major Rooke, as being not only exaggerated, but erroneous; neither the country being ſo pictureſque as the former repreſents it, nor the inhabitants meriting the reſpectable character given of them by the latter.

There was not perhaps much propriety in admitting into ſuch a work as the *Encyclopædia Britannica*, the anonymous cenſure of deſcriptions, authenticated by the names of reſpectable authors; but the beſt reparation which we can make to thoſe authors is, to inform our readers, that their deſcriptions of Hinzuan are confirmed by Sir William Jones, whoſe teſtimony, we believe, no man will controvert. That accompliſhed ſcholar, who viſited the iſland on his voyage to India, thus deſcribes its appearance from the bay in which the ſhip rode at anchor.

"Before us was a vaſt amphitheatre, of which you may form a general notion by picturing in your minds a multitude of hills infinitely varied in ſize and figure, and then ſuppoſing them to be thrown together, with a kind of artleſs ſymmetry, in all imaginable poſitions. The back ground was a ſeries of mountains, one of which is pointed, near half a mile perpendicularly high from the level of the ſea, and little more than three miles from the ſhore: all of them richly clothed with wood, chiefly fruit trees, of an exquiſite verdure. I had ſeen many a mountain of ſtupendous height in Wales and Swiſſerland, but never ſaw one before, round the boſom of which the clouds were almoſt continually rolling, whiles it green ſummit roſe flouriſhing above them, and received from them an additional brightneſs. Next to this diſtant range of hills was another tier, part of which appeared charmingly verdant, and part rather barren; but the contraſt of colours changed even this nakedneſs into a beauty: nearer ſtill were innumerable mountains, or rather cliffs, which brought down their verdure and fertility quite to the beach; ſo that every ſhade of green, the ſweeteſt of colours, was diſplayed at one view by land and by water. But nothing conduced more to the variety of this enchanting proſpect, than the many rows of palm trees, eſpecially the tall and graceful *Arecas*, on the ſhores, in the valleys, and on the ridges of hills, where one might almoſt ſuppoſe them to have been planted regularly by deſign. A more beautiful appearance can ſcarce be conceived, than ſuch a number of elegant palms in ſuch a ſituation, with luxuriant tops, like verdant plumes, placed at juſt intervals, and ſhowing between them part of the remoter landſcape, while they left the reſt to be ſupplied by the beholder's imagination. The town of *Matſamúdò* lay on our left, remarkable at a diſtance for the tower of the principal moſque, which was built by Halímah, a queen of the iſland, from whom the preſent king is deſcended: a little on our right was a ſmall town, called *Bantáni*. Neither the territory of *Nice*, with its olives, date trees, and cypreſſes, nor the iſles of *Hieres*, with their delightful orange groves, appeared ſo charming to me as the view from the road of *Hinzúàn*."

Sir William Jones, ſpeaking of the inhabitants, takes notice of the *Lords*, *Dukes*, and *Princes*, of whom we have made mention after Major Rooke. "The frigate, (ſays he) was preſently ſurrounded with canoes, and the deck ſoon crowded with natives of all ranks, from the high born chief, who waſhed linen, to the half-naked ſlave, who only paddled. Moſt of them had letters of recommendation from Engliſhmen, which none of them were able to read, though they ſpoke Engliſh intelligibly; and ſome appeared vain of titles, which our countrymen gave them in play, according to their ſuppoſed ſtations: we had *Lords*, *Dukes*, and *Princes*, on board, ſoliciting our cuſtom, and importuning us for preſents. In fact, they were too ſenſible to be proud of empty ſounds, but juſtly imagined, that thoſe ridiculous titles would ſerve as marks of diſtinction, and, by attracting notice, procure for them ſomething ſubſtantial." He ſpeaks with great reſpect of the king, whoſe name was *Ahmed*, as well as of ſeveral chiefs whom he ſaw, and ſeems to have met with no man of rank on the iſland whoſe character was contemptible, but Selim the king's eldeſt ſon. For the behaviour of that prince, the old ſovereign made the beſt apology that he could, while he privately aſſured the interpreter, that he was much diſpleaſed with it, and would not fail to expreſs his diſpleaſure. He concluded his converſation with a long harangue on the advantage which the Engliſh might derive from ſending a ſhip every year from Bombay to trade with his ſubjects, and on the wonderful cheapneſs of their commodities, eſpecially of their cowries. Ridiculous as this idea might ſeem, it ſhowed (ſays Sir William) an enlargement of mind, a deſire of promoting the intereſt of his people, and a ſenſe of the benefits ariſing from trade, which could hardly have been expected from a petty African chief, and which, if he had been ſovereign of Yemen, might have been expanded into rational projects proportioned to the extent of his dominions.

The maſter of the frigate learned from one of the chiefs a few curious circumſtances concerning the government of *Hinzuan;* which he found to be a monarchy limited by an ariſtocracy. The king, he was told, had no power of making war by his own authority; but if the aſſembly of nobles, who were from time to time convened by him, reſolved on a war with any of the neighbouring iſlands, they defrayed the charges of it by voluntary contributions; in return for which, they claimed as their own all the booty and captives that might be taken. The hope of gain or the want of ſlaves is uſually the real motive for ſuch enterpriſes, and oſtenſible pretexts are eaſily found: at that very time, he underſtood they meditated a war, becauſe they wanted hands for the following harveſt. Their fleet conſiſted of ſixteen or ſeventeen ſmall veſſels, which they manned with about two thouſand five hundred iſlanders, armed with muſkets and cutlaſſes, or with bows and arrows. Near two years before they had poſſeſſed themſelves of two towns in *Mayáta*, which they ſtill kept and garriſoned. The ordinary expences of the government were defrayed by a tax from two hundred villages; but the three principal towns were exempt from all taxes, except that they paid annually to the chief *Mufti* a fortieth part of the value of all their moveable property; and from that payment neither the king nor the nobles claimed an exemption. The kingly authority, by the principles of their conſtitution, was conſidered as elective, though the line of ſucceſſion had not in fact been altered ſince the firſt election of a ſultan.

Sir William Jones concludes his remarks on this iſland with ſome reflections; of which, though they may be conſidered as digreſſive, we are perſuaded our readers will approve of our extending the circulation.

"We have lately heard of civil commotions in *Hinzuan*, which, we may venture to pronounce, were not excited by any cruelty or violence of Ahmed, but were probably occaſioned by the inſolence of an oligarchy naturally hoſtile to king and people. That the mountains in the *Comara* iſlands contain diamonds, and the precious metals, which are ſtudiouſly concealed by the policy of the ſeveral governments, may be true, though I have no reaſon to believe it, and have only heard it aſſerted without evidence; but I hope, that neither an expectation of ſuch treaſures, nor of any other advantage, will ever induce an European power to violate the firſt principles of juſtice by aſſuming the ſovereignty of *Hinzuan*, which cannot anſwer a better purpoſe than that of ſupplying our fleets with ſeaſonable refreſhment; and although the natives have an intereſt in receiving us with apparent cordiality, yet if we wiſh their attachment to be unfeigned and their dealings juſt, we muſt ſet them an example of ſtrict honeſty in the performance of our engagements. In truth, our nation is not cordially loved by the inhabitants of *Hinzuan*, who, as it commonly happens, form a general opinion from a few inſtances of violence or breach of faith. Not many years ago an European, who had been hoſpitably received and liberally ſupported at *Matſamudo*, behaved rudely to a young married woman, who, being of low degree, was walking veiled through a ſtreet in the evening; her huſband ran to protect her, and reſented the rudeneſs, probably with menaces, poſſibly with actual force; and the European is ſaid to have given him a mortal wound with a knife or bayonet, which he brought, after the ſcuffle, from his lodging. This foul murder, which the law of nature would have juſtified the magiſtrate in puniſhing with death, was reported to the king, who told the governor (I uſe the very words of Alwi, a couſin of the king's), that "it would be wiſer to huſh it up." Alwi mentioned a civil caſe of his own, which ought not to be concealed. When he was on the coaſt of Africa in the dominions of a very ſavage prince, a ſmall European veſſel was wrecked; and the prince not only ſeized all that could be ſaved from the wreck, but claimed the captain and the crew as his ſlaves, and treated them with ferocious inſolence. Alwi aſſured me, that, when he heard of the accident, he haſtened to the prince, fell proſtrate before him, and by tears and importunity prevailed on him to give the Europeans their liberty; that he ſupported them at his own expence, enabled them to build another veſſel, in which they ſailed to *Hinzuan*, and departed thence for Europe or India: he ſhewed me the captain's promiſſory notes for ſums, which to an African trader muſt be a conſiderable object, but which were no price for liberty, ſafety, and, perhaps, life, which his good, though diſintereſted, offices had procured. I lamented that, in my ſituation, it was wholly out of my power to aſſiſt Alwi in obtaining juſtice; but he urged me to deliver an *Arabic* letter from him, incloſing the notes, to the governor general, who, as he ſaid, knew him well; and I complied with his requeſt. Since it is poſſible, that a ſubſtantial defence may be made by the perſon thus accuſed of injuſtice, I will not name either him or the veſſel which he had commanded; but, if he be living, and if this paper ſhould fall into his hands, he may be induced to reflect how highly it imports our national honour, that a people, whom we call ſavage, but who adminiſter to our convenience, may have no juſt cauſe to reproach us with a violation of our contracts."

HIPS, in architecture, are thoſe pieces of timber placed at the corners of a roof. Theſe are much longer than the rafters, becauſe of their oblique poſition. Hip means alſo the angle formed by two parts of the roof, when it riſes outwards.

Hip-Roof, called alſo Italian roof, is one in which two parts of the roof meet in an angle, riſing outwards: the ſame angle being called a valley, when it ſinks inwards.

HIRCUS, in aſtronomy, a fixed ſtar of the firſt magnitude, the ſame with capella.

HIRCUS is alſo uſed by ſome writers for a comet, encompaſſed as it were with a mane, ſeemingly rough and hairy.

HIRUDO. See *Encycl.* A new ſpecies of this inſect was diſcovered in the South Sea by Le Martiniere, naturaliſt in Perouſe's voyage of diſcovery. He found it buried about half an inch in a ſhark's liver, but could not conceive how it had got thither. It was ſomething more than an inch long, of a whitiſh colour, and compoſed of ſeveral rings ſimilar to thoſe of the tænia. The ſuperior part of its head was furniſhed with four ſmall ciliated mamillæ, by which it took its food; under each mamilla on both ſides was a ſmall oblong pouch, in the form of a cup; and in the form of its *inſtrumenta cibaria*, it very nearly reſembles the animal which has been ſuppoſed to be the cauſe of meaſles in ſwine. Both theſe ſpecies are referable to the genus *hirudo*, the characters of which, as given by Linnæus, ſtand (ſays Martiniere) in need of reformation.

HIRUNDO Esculenta (ſee Hirundo, *Encycl.* nº 3.), is thus deſcribed in the *Tranſactions of the Batavian Society in the Iſland of Java*, vol. iii. ; and the deſcription confirms the ſagacious conjecture of Mr Latham reſpecting the ſize of the bird, which the reader will find in our article referred to.

“ The hirundo eſculenta is of a blackiſh grey colour, inclining a little to green ; but on the back to the tail, as well as on the belly, this blackiſh colour gradually changes into a mouſe colour. The whole length of the bird from the bill to the tail is about four inches and a half, and its height from the bill to the extremity of the middle toe three inches and a quarter. The diſtance from the tip of the one wing to that of the other, when extended, is ten inches and a quarter. The largeſt feathers of the wings are about four inches in length. The head is flat ; but, on account of the thickneſs of the feathers, appears round, and to be of a large ſize in proportion to the reſt of the body. The bill is broad, and ends in a ſharp extremity, bent downwards in the form of an awl. The width of it is increaſed by a naked piece of ſkin, ſomewhat like parchment, which, when the bill is ſhut, lies folded together ; but which, when the bill opens, is conſiderably extended, and enables the bird to catch with greater eaſe, while on wing, the inſects that ſerve it for food. The eyes are black, and of a conſiderable ſize. The tongue, which is not forked, is ſhaped like an arrow. The ears are flat, round, naked ſpots, with ſmall oblong openings, and are entirely concealed under the feathers of the head. The neck is very ſhort, as well as the legs and the bones of the wings. The thighs are wholly covered with feathers ; and the very tender lower parts of the legs, and the feet themſelves, are covered with a ſkin like black parchment. Each foot has four toes, three of which are before and one turned backwards. They are all detached from each other to the roots ; and the middle one, together with the claw, is fully as long as the lower part of the leg. Each toe is furniſhed with a black, ſharp, crooked claw of a conſiderable length, by which the animal can with great facility attach itſelf to crags and rocks. The tail is fully as long as the body together with the neck and the head. When expanded it has the form of a wedge, and conſiſts of ten large feathers. The four firſt on each ſide are long ; and, when the tail is cloſed, extend almoſt an inch beyond the reſt. The other feathers decreaſe towards the middle of the tail, and are equal to about the length of the body.”

There is a variety of this ſpecies of hirundo, with a ſpeckled breaſt, and white ſpots on the tail feathers ; and this, though leſs numerous than the other, and indeed not found at all in Java, appears to have been the only hirundo eſculenta known to Linnæus. For an account of the eatable neſts of theſe birds, and the manner of collecting them, ſee Cap and Button in this *Supplement*.

HISPANIOLA, or St Domingo, the largeſt of the Antilles or Caribbee iſlands, has been deſcribed, as it exiſted prior to the French revolution, in the *Encyclopædia*. Previous to the year 1789 the government of the French part of the iſland was adminiſtered by an officer called the Intendant, and a Governor-General, both nominated by the crown, and inveſted with authority for three years. Their powers were in ſome caſes diſtinct, and in others united; but though theſe powers were extenſive and almoſt abſolute, the attention which the old government of France paid to the character and rank of thoſe perſons whom it had placed over its foreign ſettlements, ſecured to the inhabitants of Hiſpaniola a very conſiderable ſhare of happineſs. In ſpite of what our reſtleſs innovators call political evils, ſigns of proſperity were everywhere viſible; their towns were opulent, their markets plentiful, their commerce extenſive, and their cultivation increaſing.

Such was, in 1788, the ſtate of the French colony, in the iſland of St Domingo; but in that eventful year, the flame, which had burſt forth in Europe, ſpread itſelf to the Weſt Indies. An aſſociation had been formed in France upon principles ſomewhat ſimilar to thoſe of our ſociety for the abolition of the ſlave trade ; but that aſſociation, which called itſelf *Amis des Noirs*, had much more dangerous deſigns than ours. Avowing its deteſtation of every kind of ſlavery, as well as of the African trade, and condemning thoſe abettors of liberty who dared to declare themſelves poſſeſſors of men, its members kept up an intimate and clandeſtine connection with thoſe rich mulattoes who reſided in France for their education, and laboured to convince them that neither their colour nor their *ſpurious birth* ſhould make any civil or political diſtinction between them and the whites who were born in *wedlock*. To co-operate, as it were, with theſe factious and falſe doctrines, the National Aſſembly iſſued its famous declaration, in which it was maintained that all mankind are born, and continue free, and equal in their rights. The conſequence of this was ſuch as might have been expected. The mulattoes of Hiſpaniola, inſtructed in the French philoſophy of the rights of man, broke out into rebellion; but not acting in concert, they were quickly overpowered.

The ſpirit, however, which had been excited among them, ſtill continued to ferment ; and the National Aſſembly of France, taking the ſtate of the iſland into ſolemn conſideration, decreed, by a great majority, that its intention had never been to intermeddle with the internal affairs of the colony ; that their internal legiſlation was entirely their own ; and that the legiſlature of the mother country would make no innovation, directly or indirectly, in the ſyſtem of commerce in which the colonies were already concerned. However grateful this declaration might be to the whites of St Domingo, and in the then ſtate of things however wiſe in itſelf, it occaſioned diſcontent and remonſtrances on the part of the factious friends of the negroes. They regarded it as an unwarrantable ſanction of the African traffic, and a confeſſion that the planters of Hiſpaniola were not coloniſts, but an independent people.

The coloniſts themſelves, indeed, or rather their repreſentatives, ſeem to have thought that by this decree they were rendered independent ; for in their general aſſembly they paſſed an act debarring the king's delegate, the governor-general, from negativing any of their future acts. This violent meaſure was far from giving univerſal ſatisfaction. The weſtern pariſhes recalled their delegates, while thoſe of Cape François renounced their obedience to the whole aſſembly, and petitioned the governor to diſſolve it.

During theſe diſſenſions, the commander of a ſhip of the line, which lay in the harbour of Port-au-Prince, gave a ſumptuous entertainment to the friends of the governor ; on which account the ſeamen, who declared themſelves in the intereſt of the aſſembly, thought fit to mutiny; and the aſſembly, in return, voted their thanks to the mutineers. Some of their partizans, ſeizing at the ſame time a powder magazine, the governor declared them adherents to traitors, and called on all officers, civil and military, to bring them to puniſhment. This was the ſignal for civil inſurrection; armed troops took the field on both ſides; and war ſeemed inevitable, when the aſſembly reſolved to repair in a body to France, and juſtify their paſt conduct.

In the mean time the *Amis des Noirs* contrived to excite the people of colour to rebellion. They initiated in the doctrine of equality and the rights of man one James Oge, then reſiding in Paris in ſome degree of affluence. They perſuaded him to go to St Domingo, put himſelf at the head of his people, and deliver them from the oppreſſion of the whites; and in order to evade the notice of government, they undertook to procure for him arms and ammunition in America. He embarked accordingly, July 1790, for New England with money and letters of credit; but notwithſtanding the caution of the *Amis des Noirs*, his deſigns were diſcovered by the French government, and his portrait was ſent out before him to St Domingo. He landed on the iſland in October, and ſix weeks afterwards publiſhed a manifeſto, declaring his intention of taking up arms, if the privileges of whites were not granted to *all perſons without diſtinction*. He was joined by about 200 men of colour; and this little army of ruffians not only maſſacred the whites wherever they fell in with them in ſmall numbers, but, by a ſtill more unjuſtifiable mode of conduct, took vengeance on thoſe of their own colour who refuſed to join their rebellious ſtandard. They were, however, ſoon overpowered by the regular troops; and their leader, after diſcloſing, it is ſaid, ſome important ſecrets, ſuffered the puniſhment due to his treaſon.

While theſe things were going on in the iſland, the members of the Colonial Aſſembly arrived at Paris, where they were received by the repreſentatives of the French people with marked ſymptoms of averſion. The reſolutions compoſing their famous decree were pronounced improper; their vote of thanks to the mutineers was declared criminal; they were themſelves perſonally arreſted; orders were given for a new aſſembly to be called; and the king was requeſted to augment the naval and military force then at St Domingo.

The National Aſſembly of France having decreed that every perſon twenty-five years old and upwards, poſſeſſing property, or having reſided two years in the colony and paid taxes, ſhould be permitted to vote in the formation of the colonial aſſembly, the people of colour very naturally concluded that this privilege was conferred upon them. Such, however, we believe, was not the meaning of the National Aſſembly; but Gregoire, with the other friends of the negroes, at laſt prevailed, and mulattoes born of free parents were pronounced to be not only worthy of chooſing their repreſentatives, but alſo eligible themſelves to ſeats in the colonial aſſemblies. This decree ſacrificed at once all the whites in the iſland to the people of colour; and the indignation which filled the minds of both the royal and the republican parties ſeemed to have united them in one common cauſe. They reſolved to reject the civic oath; to confiſcate the French property in the harbour, on which they actually laid an embargo; to pull down the national colours, and to hoiſt the Britiſh ſtandard in their ſtead. The mulattoes in the mean time collected in armed bodies, and waited with anxious expectation to ſee what meaſures the colonial aſſembly would adopt.

During theſe diſſenſions, the negro ſlaves, into whoſe minds had been ſedulouſly inſtilled an opinion that their rights were equal to thoſe of their maſters, reſolved to recover their freedom. On the morning of the 23d of Auguſt 1791, the town of the Cape was alarmed by a confuſed report that the ſlaves in the adjoining pariſhes had revolted; and the tidings were ſoon confirmed by the arrival of thoſe who had narrowly eſcaped the maſſacre. The rebellion had broken out in the pariſh of Acul, nine miles from the city, where the whites had been butchered without diſtinction; and now the rebels proceeded from pariſh to pariſh, murdering the men, and raviſhing the unfortunate women who fell into their hands. In a ſhort time the ſword was accompanied with fire, and the cane-fields blazed in every direction. The citizens now flew to arms, and the command of the national troops was given to the governor, whilſt the women and children were put aboard the ſhips in the harbour for ſafety. In the firſt action the rebels were repulſed; but their numbers rapidly increaſing, the governor judged it expedient to act ſolely on the defenſive. In the ſpace of two months it was computed that upwards of 2000 white perſons periſhed; and of the inſurgents, who conſiſted as well of mulattoes as of negroes, not fewer than 10,000 died by famine and the ſword, and hundreds by the hands of the executioner.

When intelligence of theſe dreadful proceedings reached Paris, the Aſſembly began to be convinced that its equaliſing principles had been carried too far; and the famous decree, which put the people of colour on the ſame footing with the whites, was repealed. Three commiſſioners were likewiſe ſent to the colony to reſtore peace between the whites and the mulattoes; but two of them being men of bad character, and none of them poſſeſſing abilities for the arduous taſk of extinguiſhing the flames of a civil war, they returned to France without accompliſhing in any degree the object of their miſſion.

In the mean time the *Amis des Noirs* in the mother country had once more gained the aſcendant in the National Aſſembly; and three new commiſſioners, Santhonax, Polverel, and Ailhaud, with 6000 choſen men from the national guards, were embarked for St Domingo. It was ſtrongly ſuſpected that the object of theſe commiſſioners was to procure unqualified freedom for all the blacks in the iſland; but they ſolemnly ſwore that their ſole purpoſe was to eſtabliſh the rights of the mulattoes, as decreed by the law which had been lately repealed. The whites therefore expected that a colonial aſſembly would be convoked; but inſtead of this the commiſſioners nominated twelve perſons, of whom ſix had been members of the laſt aſſembly, and ſix were mulattoes, *Une Commiſſion Intermediaire*, with authority to raiſe contributions on the inhabitants, the application of which, however, they reſerved to themſelves. The governor finding that the commiſſioners uſurped all authority, complained that he was but a cypher in public affairs; his complaint was anſwered by an arreſt upon his perſon, and he was ſent a ſtate priſoner to France.

The tyranny of the commiſſioners did not ſtop here. They overawed the members of the commiſſion *intermediaire*, by arreſting four of their number; and diſagreeing among themſelves, Santhonax and Polverel diſmiſſed Ailhaud from their councils. War was by this time declared.

declared between the mother country and Great Britain, and prudence compelled the government of France to take ſome care of the injured colony. Galbaud, therefore, a man of fair character, was appointed governor, and ordered to put the iſland in a ſtate of defence againſt foreign invaſion; but poſſeſſing Weſt India property, which it ſeems was a legal diſqualification for the office of governor, the commiſſioners diſregarded his authority, and took up arms againſt him. Finding themſelves likely to be worſted, they offered to purchaſe the aid of the rebel negroes, by the offer of a pardon for their paſt conduct, freedom in future, and the plunder of the capital. Two of the negro chiefs, more honourable than the French commiſſioners, ſpurned at the baſe propoſal; but a third, after the governor had fled to the ſhips, entered the town with 3000 revolted negroes, and began an indiſcriminate maſſacre. The miſerable inhabitants fled to the ſhore, but their retreat was ſtopped by a party of mulattoes; and for two days the ſlaughter was inceſſant. The town was half conſumed by fire; and the commiſſioners, terrified at the work of their own hands, fled for protection to a ſhip of the line, and thence iſſued a manifeſto, which, while it tried to extenuate, evinced a conſciouſneſs of their guilt.

Thus was loſt the fineſt iſland in the Weſt Indies; an iſland which produced alone as much ſugar as all the Britiſh Weſt India poſſeſſions united; not to mention the coffee and indigo, which were in immenſe quantities cultivated in Hiſpaniola. Had it not been for the reſtleſs machinations of the *Amis des Noirs*, it does not appear that ſo general a revolt would have taken place among the ſlaves; for though the ſpirit of republicaniſm had found its way into the iſland, the republicans joined with the royaliſts to keep the negroes in proper ſubjection. The unſucceſsful attempt which, at the requeſt of the more reſpectable part of the inhabitants, the Britiſh government made to ſubdue the execrable commiſſioners and their adherents, is freſh in the memory of all our readers, and need not here be detailed at length. Suffice it to ſay, that after prodigies of valour, our troops were compelled, rather by diſeaſe than by the ſwords of the enemy, to abandon the iſland. Touſſaint L'Ouverture, a black chief, converted it into an independent republic, and continued to govern it undiſturbed, till the preliminaries of peace were ſigned between Britain and France in 1801. Immediately after that event, Bonaparte diſpatched a fleet from Breſt, with the permiſſion of our government, carrying a conſiderable army under the command of general Le Clerc. Touſſaint at firſt refuſed to ſubmit. Several bloody actions were fought between the French troops and the blacks, in which the former were uniformly ſucceſsful. The open country was ſoon abandoned by the negroes: ſeveral of Touſſaint's generals ſubmitted; and at laſt he himſelf was prevailed upon, by the addreſs and the magnificent promiſes of Le Clerc, not only to throw down his arms, but to put himſelf into the power of the French general. For ſome days theſe promiſes were religiouſly obſerved; but a pretence was ſoon found for breaking them. Touſſaint was ſtript of his immenſe property, and ſent priſoner to France. Thus was the colony recovered to France in a ſtill ſhorter time than it had been loſt. Since that event, nothing has tranſpired concerning the ſtate of the iſland, or the regulations which the French find it neceſſary to make. But it is obvious, that a conſiderable period muſt elapſe before it can be reſtored to that ſtate of proſperity which it formerly enjoyed.

HOLLOW, in architecture, a concave moulding, about a quarter of a circle, by ſome called a caſement, by others an abacus.

Hollow-Tower, in fortification, is a rounding made of the remainder of two briſures, to join the curtain to the orillon, where the ſmall ſhot are played, that they may not be ſo much expoſed to the view of the enemy.

HOMODROMUS Vectis, or *Lever*, in mechanics, is a lever in which the weight and power are both on the ſame ſide of the fulcrum as in the lever of the 2d and 3d kind; being ſo called, becauſe here the weight and power move both in the ſame direction, whereas in the heterodromus they move in oppoſite directions.

HOOKE (Dr Robert) is ſaid, in the account of him which is publiſhed in the *Encyclopædia*, to have laid claim to the inventions of others, and to have boaſted of many of his own, which he never communicated. We will not preſume to ſay that this charge is entirely groundleſs; but we know that it has been greatly exaggerated, and that many diſcoveries undoubtedly made by him have been claimed by others. Of this the reader will find one conſpicuous proof under the article Watch (*Encycl.*); and perhaps the following hiſtory of the inventions to which he laid claim may furniſh another. It would be harſh to charge him with falſity in any of them; that is to ſay, to imagine that he either ſtole them from others, or did not *think*, at leaſt, that he was *an* inventor. And, with reſpect to many of them, the priority of his claim is beyond diſpute.

1656, Barometer, a weather glaſs.

1657, A ſcapement, for maintaining the vibration of a pendulum.—And not long after, the regulating or balance ſpring for watches.

1658, The double barrelled air-pump.——The conical pendulum.—His firſt employment of the conical pendulum was no leſs ingenious and ſcientific than it was original. He employed it to repreſent the mutual gravitation of the planets; a fact which he had moſt ſyſtematically announced. He had ſhewn that a force, perfectly analogous to gravity on this earth, operated on the ſurface of the moon and of Jupiter. Conſidering the numerous round pits on the ſurface of the moon, ſurrounded with a ſort of wall, and having a little eminence in the middle, as the production of volcanoes, he inferred, that the ejected matter fell back again to the moon, as ſuch matter falls back again to the earth. He ſaw Jupiter ſurrounded with an atmoſphere, which accompanied him; and therefore preſſed on him, as our air preſſes on the earth:—He inferred, that it was the ſame kind of power that maintained the ſun and other planets in a round form. He inferred a force to the ſun from the circulation round him, and he called it a *gravitation*; and ſaid that it was not the earth which deſcribed the ellipſe, but the centre of gravity of the earth and moon. He therefore made a conical pendulum, whoſe tendency to a vertical poſition repreſented the gravitation to the ſun, and which was projected at right angles to the vertical plane; and ſhewed experimentally, how the different proportions of the projectile and centripetal tendencies produced various degrees of eccentricity in the orbit. He then added another pendulum, deſcribing a cone round the firſt, while this deſcribed a cone round the vertical line, in order to ſee what point between them deſcribed the ellipſe.

ellipſe. The reſults of the experiment were intricate and unſatisfactory ; but the thought was ingenious. He candidly acknowledged, that he had not diſcovered the true law of gravitation which would produce the deſcription of an ellipſe *round the focus*, owing to his want of due mathematical knowledge ; and therefore left this inveſtigation to his ſuperiors. Sir Iſaac Newton was the happy man who made the diſcovery, after having entertained the ſame notions of the forces which connected the bodies of the ſolar ſyſtem, before he had any acquaintance with Dr Hooke, or knew of his ſpeculations.

1660, The engine for cutting clock and watch wheels. —The chief phenomena of capillary attraction.—The freezing of water at a fixed temperature.

1663, The method of ſupplying air to a diving bell. —The number of vibrations made by a muſical chord.

1664, His Micrographia was, by the council of the Royal Society, ordered to be printed; but in that work are many juſt notions reſpecting reſpiration, the compoſition of the atmoſphere, and the nature of light, which were afterwards attributed as diſcoveries to Mayow and others, who, though we are far from ſuppoſing that they ſtole their diſcoveries from Dr Hooke, were certainly anticipated by him.

1666, A quadrant by reflection.

1667, The marine barometer.—The gage for ſounding unfathomable depths.

1668, The meaſurement of a degree of the meridian, with a view to determine the figure of the earth, by means of a zenith ſector.

1669, The fact of the *conſervatio virium vivarum*, and that in all the productions and extinctions of motion, the accumulated forces were as the ſquares of the final or initial velocities. This doctrine he announces in all its generality and importance, deducing from it all the conſequences which John Bernoulli values himſelf ſo highly upon, and which are the chief facts adduced by Leibnitz in ſupport of his doctrine of the forces of bodies in motion. But Hooke was perfectly aware of their entire correſpondence with the Carteſian, or common doctrine, and was one of the firſt in applying the celebrated 39th propoſition of Newton's Principia to his former poſitions on this ſubject, as a mathematical demonſtration of them.

1673, That the catenaria was the beſt form of an arch.

1674, Steam engine on Newcomen's principle.

1679, That the air was the ſole ſource of heat in burning: That combuſtion is the ſolution of the inflammable vapour in air ; and that in this ſolution the air gives out its heat and light. That nitre explodes and cauſes bodies to burn without air, becauſe it conſiſts of this air, accompanied by its heat and light in a condenſed or ſolid ſtate ; and air ſupports flame, becauſe it contains the ſame ingredients that gunpowder doth, that is, a nitrous ſpirit : That this air diſſolves ſomething in the blood while it is expoſed to it in the lungs in a very expanded ſurface, and when ſaturated with it, can no longer ſupport life nor flame ; but in the act of ſolution, it produces animal heat : That the arterial and venal blood differ on account of this ſomething being wanting in one of them. In ſhort, the fundamental doctrines of modern chemiſtry are ſyſtematically delivered by Dr Hooke in his Micrographia, publiſhed in 1664, and his Lampas, publiſhed in 1677.

1680, He firſt obſerved the ſecondary vibrations of elaſtic bodies, and their connection with harmonic ſounds. A glaſs containing water, and excited by a fiddleſtick, threw the water into undulations, which were ſquare, hexagonal, octagonal, &c. ſhewing that it made vibrations ſubordinate to the total vibration ; and that the fundamental ſound was accompanied by its octave, its twelfth, &c.

1681, He exhibited muſical tones by means of toothed wheels, whirled round and rubbed with a quill, which dropped from tooth to tooth, and produced tones proportioned to the frequency of the cracks or ſnaps.

1684, He read a paper before the Royal Society, in which he affirms, that ſome years before that period, he had propoſed a method of diſcourſing at a diſtance, not by ſound, but by ſight. He then proceeds to deſcribe a very accurate and complete telegraph, equal, perhaps, in all reſpects to thoſe now in uſe. But ſome years previous to 1684, M. Amontans had not invented his telegraph ; ſo that, though the Marquis of Worceſter unqueſtionably gave the firſt hint of this inſtrument, Dr Hooke appears to have firſt brought it to perfection. See Telegraph, *Encycl.* ; and a book, publiſhed 1726, entitled *Philoſophical Experiments and Obſervations* of the late eminent Dr Robert Hooke.

We are indebted to him for many other diſcoveries of leſſer note ; ſuch as the wheel barometer, the univerſal joint, the manometer, ſcrew divided quadrant, teleſcopic ſights for aſtronomical inſtruments, repreſentation of a muſcular fibre by a chain of bladders, experiments ſhewing the inflection of light, and its attraction for ſolid bodies, the curvilineal path of light thro' the atmoſphere.

HORNE (George, D. D.), late Lord Biſhop of Norwich, was a man of ſuch amiable diſpoſitions, primitive piety, and exemplary morals, that we wiſh it were in our power to do juſtice to his character. His life, it is true, has been already written, at conſiderable length, by two authors, poſſeſſed of erudition and of unqueſtionable integrity ; but mere erudition is by no means ſufficient to fit a man for diſcharging the duties of a biographer. It was not the learning of Johnſon, but his ſagacity, and intimate acquaintance with human nature, that placed him ſo far above his contemporaries in this department of literature.

Of Biſhop Horne's biographers, one poſſeſſed, indeed, the great advantage of having lived in habits of intimacy with him from his boyiſh years. In the authenticity of his narrative, therefore, the fulleſt confidence may be placed : and that narrative we ſhall faithfully follow ; reſerving, however, to ourſelves the liberty of ſometimes making reflections on the various incidents recorded, widely different from thoſe of the author.

George Horne was, in 1730, born at Otham in Kent, a village near Maidſtone, giving the name to a pariſh, of which his father was the rector. He was the ſecond of four ſons ; of whom the eldeſt died in very early life, and the youngeſt, who is ſtill alive, ſucceeded his father both in the rectory of Otham and in that of Breda in the county of Suſſex. He had likewiſe three ſiſters, of whoſe fortunes we know nothing.

Mr Horne, the father of the family, was of a temper ſo remarkably averſe from giving pain or trouble upon any occaſion, that he uſed to awake his ſon George, when an infant, by playing upon a flute, that the change from ſleeping to awaking might be gradual and pleaſant. Having been for ſome years a tutor at Oxford, he took upon himſelf the early part of the claſſical education of this favourite ſon; an office of which he was well qualified to diſcharge the duties. Uunder ſuch an inſtructor, the ſubject of this memoir led a very pleaſant life, and made a rapid progreſs in the Greek and Latin languages. By the perſuaſion of a friend, however, he was, at the age of thirteen, placed in the ſchool of Maidſtone, then under the care of a Mr Bye, eminent for his knowledge of ancient literature. And remaining with this gentleman two years, he added much to his ſtock of learning; and, among other things, a little elementary knowledge of the Hebrew tongue, which Mr Bye taught on the plan of Buxtorf. Though Dr Horne afterwards rejected that plan, he readily admitted, that the knowledge of it was of great advantage to him.

At the age of fifteen, he was removed from Maidſtone ſchool to Univerſity college Oxford, where his father had happily obtained for him a ſcholarſhip. At college his ſtudies were, in general, the ſame with thoſe of other virtuous and ingenious youths; while the vivacity of his converſation, and the propriety of his conduct, endeared him to all whoſe regard was creditable. About the time of his taking his bachelor's degree, he was choſen a fellow of Magdalen College; and ſoon afterwards, if not before, commenced author.

The hiſtory of his authorſhip is curious, and we ſhall give it at ſome length. While he was deeply engaged in the ſtudy of oratory, poetry, and every branch of polite literature, he was initiated by his faithful friend Mr Jones in the myſteries of Hutchinſonianiſm; but Mr Jones was not his preceptor. Indeed that gentleman informs us, that when he firſt communicated to Mr Horne the novelties with which his own mind was filled, he found his friend very little inclined to conſider them; and had the mortification to ſee, that he was himſelf loſing ground in Mr Horne's eſteem, even for making the attempt to convert him. At this we are not to be much ſurpriſed. Mr Horne, though, by his biographer's account, no deep Newtonian, ſaw, or thought he ſaw, the neceſſity of a *vacuum* to the poſſibility of *motion*; and as we believe that every man, who knows the meaning of the words *motion* and *vacuum*, and whoſe mind is not biaſſed in favour of a ſyſtem, ſees the ſame thing, it was not to be ſuppoſed, that a youth of ſound judgment would haſtily relinquiſh ſo natural a notion. By Mr Horne, however, it was at length relinquiſhed. Mr Jones introduced him to Mr George Watſon, a fellow of Univerſity college, whom he repreſents as a man of very ſuperior accompliſhments; and by Mr Watſon Mr Horne was made a Hutchinſonian of ſuch zeal, that at the age of nineteen, he implicitly adopted the wild opinion of the author of that ſyſtem, that Newton and Clarke had formed the deſign of bringing the Heathen *Jupiter*, or Stoical *anima mundi*, into the place of the God of the univerſe. With ſuch a conviction impreſſed upon his mind, it is not wonderful that he ſhould endeavour to diſcredit the ſyſtem of Newton. This he attempted, by publiſhing a parallel between that ſyſtem and the Heathen doctrines in the *Somnium Scipionis* of Cicero. That publication, which was anonymous, we have never ſeen; but Mr Jones himſelf admits it to have been exceptionable; and the amiable author ſeems to have been of the ſame opinion, for he never republiſhed it, nor, we believe, replied to the anſwers which it provoked.

He did not, however, deſert the cauſe, but publiſhed, ſoon afterwards, a mild and ſerious pamphlet, which he called *A Fair, Candid, and Impartial State of the Caſe between Sir Iſaac Newton and Mr Hutchinſon*. Even of this pamphlet we have not been able to procure a ſight; but Mr Jones aſſures us, that the author allows to Sir Iſaac the great merit of having ſettled laws and rules in natural philoſophy, and of having meaſured *forces* as a mathematician with ſovereign ſkill; whilſt he claims for Mr Hutchinſon the diſcovery of the true phyſiological cauſes, by which, under the power of the Creator, the natural world is moved and directed.

If this be a fair view of *the ſtate of the caſe*, it allows to Newton more than ever Newton claimed, or has been claimed for him by his fondeſt admirers; for the laws and rules, which he ſo faithfully followed in the ſtudy of philoſophy, were not ſettled by him, but by the illuſtrious Bacon. With reſpect to the *true* cauſes here mentioned, we have repeatedly had occaſion, during the courſe of this Work, to declare our opinion, that all men are equally ignorant of them, if they be conſidered as any thing diſtinct from the general *laws* by which the operations of nature are carried on. To the diſcovery of other phyſiological cauſes, Newton, in his greateſt work, made indeed no pretenſion; but it may be worth while, and can hardly be conſidered as a digreſſion, to conſider what are the pretenſions of Huchinſon, to which Meſſrs Horne and Jones gave ſo decided a preference.

Mr Hutchinſon himſelf writes ſo obſcurely, that we dare not venture to tranſlate his language into common Engliſh, leſt we ſhould undeſignedly miſrepreſent his meaning; but according to Mr Jones, who has ſtudied his works with care, his diſtinguiſhing doctrine in philoſophy is, that "The forces, of which the Newtonians treat, are not the forces of nature; but that the world is carried on by the action of the elements on one another, and all under God." What is here meant by the elements, we are taught by another eminent diſciple of that ſchool. "The great agents in nature, which carry on all its operations, are certainly (ſays Mr Parkhurſt) the *fluid* of the heavens; or, in other words, the fire at the orb of the ſun, the light iſſuing from it, and the ſpirit or groſs air conſtantly ſupporting, and concurring to the actions of the other two." (See CHERUBIM in this *Supplement*). Mr Horne adopted this ſyſtem in preference to the Newtonian; becauſe, ſays his biographer, "It appeared to him nothing better than raving, to give active powers to matter, ſuppoſing it capable of acting where it is not; and to affirm, at the ſame time, that all matter is inert, that is, inactive; and that the *Deity* cannot act but where he is *preſent*, becauſe his *power* cannot be but where his *ſubſtance* is."

That much impious arrogance has been betrayed, not by Newtonians only, but by philoſophers of every ſchool, when treating of the *modus operandi* of the Deity, we feel not ourſelves inclined to controvert; but we never knew a well-informed Newtonian, who ſpoke of the active powers of matter but in a metaphorical ſenſe; and ſuch language is uſed, and muſt be uſed, by the

the followers of Hutchinſon. Mr Jones ſpeaks of the *action* of the elements; and Mr Parkhurſt calls the fluid of the heavens, which, according to him, conſiſts of fire, light, and air, *agents*; but it would ſurely be uncandid to accuſe theſe two pious men of *animating* the elements, though we know that *action* and *activity*, in the literal ſenſe of the words, can be predicated only of living beings. With reſpect to giving active powers to matter, therefore, the followers of Hutchinſon rave juſt as much as thoſe of Newton; and we ſee not the raving of either in any other light than as the neceſſary conſequence of the poverty of language.

But the Newtonian makes matter act upon matter at a diſtance! No; the genuine Newtonian does not make matter *act* (in the proper ſenſe of the word) at all; but he believes, that God has ſo conſtituted matter, that the motions of different maſſes of it are affected by each other at a diſtance; and the Hutchinſonian holds the very ſame thing. As this celeſtial fluid of Mr Parkhurſt's conſiſts partly of air, we know, by the teſt of experiment, that it is elaſtic. The particles of which it is compoſed are therefore diſtant from each other; and yet they reſiſt compreſſion. How does the Hutchinſonian account for this fact? Perhaps he will ſay, that as matter is in itſelf equally indifferent to motion and reſt, God has ſo conſtituted the particles of this fluid, that though they poſſeſs no innate power or activity of their own, they are affected by each other at a diſtance, in conſequence of his fiat at the creation. This we believe to be the only ſolution of the difficulty which can be given by man; but it is the very anſwer given by the Newtonians to thoſe who object to them the abſurdity of ſuppoſing matter to be affected by matter at a diſtance. That the motions of the heavenly bodies are affected by the preſence of each other is a fact, ſay they, which appears incontrovertible. "We have aſcertained with preciſion the laws by which theſe motions are regulated; and without troubling ourſelves with the true phyſiological cauſes, have demonſtrated the agreement of the phenomena with the laws. The interpoſition of this celeſtial fluid removes not a ſingle difficulty with which our doctrine is ſuppoſed to be clogged. To have recourſe to it can therefore ſerve no purpoſe, even were the phenomena conſiſtent with the nature of an elaſtic fluid conſidered as a phyſical cauſe; but this is not the caſe. It is demonſtrable (ſee ASTRONOMY and DYNAMICS in this *Suppl.*) that the motions of the heavenly bodies are not conſiſtent with the mechaniſm of an elaſtic fluid, conſidered as the cauſe of theſe motions; and therefore, whether there be ſuch a fluid or not diffuſed through the ſolar ſyſtem, we cannot allow that it is the great agent in nature by which all its operations are carried on."

Such might be the reaſoning of a well-informed Newtonian in this controverſy; and it appears ſo concluſive againſt the objections of Hutchinſon to the Newtonian forces, as well as againſt the agents which he has ſubſtituted in their ſtead, that ſome of our readers may be diſpoſed to call in queſtion the ſoundneſs of that man's underſtanding who could become a Hutchinſonian ſo zealous as Mr Horne. But to theſe gentlemen we beg leave to reply, that the ſoundeſt and moſt upright mind is not proof againſt the influence of a ſyſtem, eſpecially if that ſyſtem has novelty to recommend it, and at the ſame time conſiſts of parts, of which, when taken ſeparately, many are valuable. Such was the ſyſtem of Hutchinſon when adopted by Mr Horne. It was then but very little known; it could be ſtudied only through the medium of Hebrew literature, not generally cultivated; and that literature, to the cultivation of which Mr Hutchinſon had given a new and a better turn, is in itſelf of the utmoſt importance. Let it be obſerved, too, that the Hutchinſonians have, for the moſt part, been men of devout minds, zealous in the cauſe of Chriſtianity, and untainted by Arianiſm, Socinianiſm, and the other hereſies which have ſo often divided the church of Chriſt:—and when all theſe circumſtances are taken into conſideration, it will not be deemed a proof of any defect in Mr Horne's underſtanding, that in early life he adopted the *whole* of a ſyſtem, of which ſome of the parts contain ſo much that is good; eſpecially when it is remembered, that at *firſt view* the agency of the celeſtial fluid appears ſo plauſible, that for a time it ſeems to have impoſed upon the mind of Newton himſelf.

But the truth is, that Mr Horne was at no period of his life a thorough-paced Hutchinſonian. It is confeſſed by Mr Jones, "that Mr Hutchinſon and his admirers laid too great a ſtreſs on the evidence of Hebrew etymology; and that ſome of them carried the matter ſo far, as to adopt a mode of ſpeaking, which had a nearer reſemblance to cant and jargon than to ſound ſenſe and ſober learning. Of this (continues he) Mr Horne was very ſoon aware; and he was in ſo little danger of following the example, that he uſed to diſplay the foibles of ſuch perſons with that mirth and good humour," which he poſſeſſed in a more exquiſite degree than moſt men. This ſeems to be complete evidence that he was never a friend to the etymological part of the ſyſtem; and the preſent writer can atteſt, that, in the year 1786, he ſeemed by his converſation to have loſt much of his conviction of the agency of the celeſtial fluid. He continued, indeed, to ſtudy the Hebrew Scriptures on the plan of Mr Hutchinſon, unincumbered with the Maſoretic points, or with rabbinical interpretations; and the fruits of his ſtudies are in the hands of the religious public, in works which, by *that* public, will be eſteemed as long as their language is underſtood.

Hitherto Mr Horne was a layman, but he intereſted himſelf in every thing connected with religion, as much as the moſt zealous dignitary of the church; and conſidering the *naturalization* of the Jews as a meaſure at leaſt indecent in a Chriſtian country, he publiſhed, in an evening paper, a ſeries of letters on that ſubject, both when the Jew-bill was depending, and after it had paſſed the houſe. The letters were anonymous; but they attracted much notice, and many groundleſs conjectures were made reſpecting their author. To the real author, the meaſure which they oppoſed was ſo very obnoxious, that he refuſed to dine at the table of a friend, only becauſe the ſon-in-law of Mr Pelham was to be there. And he was not much more friendly to the marriage-act than to the Jew-bill. If he conſidered the one as diſgraceful to religion, he probably thought that the other, with its numerous clauſes, might be made a ſnare for virtue.

The time now approached when he was to take holy orders, which to him was a very ſerious affair; and when he gave an account of his ordination to an intimate friend, he concluded the letter with the following reflections, which, even in an abſtract like this, it would be unpardonable to omit :

“ May he, who ordered Peter three times to *feed his lambs*, give me grace, knowledge, and ſkill, to watch and attend to the flock which he purchaſed upon the croſs, and to give reſt to thoſe who are under the burden of ſin and ſorrow. It hath pleaſed God to call me to the miniſtry in very troubleſome times indeed, when a lion and a bear have broken into the fold, and are making havoc among the ſheep. With a firm, though humble confidence, do I purpoſe to go forth ; not in my own ſtrength, but in the ſtrength of the Lord God ; and may he proſper the work of my hands !” This was in the year 1753, when the pious author was hardly 23 years of age ; and he had not been many months in orders, when one of the moſt celebrated preachers in the metropolis pronounced, that “ George Horne was, without exception, the beſt preacher in England.”

In the year 1756, he was again involved in controverſy. A pamphlet had been publiſhed at Oxford, ſuppoſed by Mr Kennicott, who afterwards gained ſuch fame as a collector of Hebrew manuſcripts, entitled *A Word to the Hutchinſonians*, in which Mr Horne was perſonally ſtruck at. To this work our author replied in a ſmall tract, called *An Apology for certain Gentlemen in the Univerſity of Oxford, Aſperſed in a late Anonymous Pamphlet* ; and whatever may be thought of the queſtion at iſſue, all men muſt admire the temper with which the apologiſt conducted himſelf under very great provocation.

But it was not about Hutchinſonianiſm alone that theſe two illuſtrious men were doomed to differ. Mr Horne took a decided part againſt Mr Kennicott's propoſal for collating the text of the Hebrew bible, with ſuch manuſcripts as could be found, for the purpoſe of *reforming the text*, and preparing it for a new tranſlation into the Engliſh language ; and in the year 1760, he publiſhed *A View of Mr Kennicott's Method of Correcting the Hebrew Text, with three Queries formed thereon, and humbly ſubmitted to the Chriſtian world.* That his alarm was on this occaſion too great, experience has ſhewn ; but that it was not groundleſs, is evident from the *View*, in which the reader will find above 20 inſtances from Mr Kennicott's diſſertations (ſee KENNICOTT, *Encycl.*), to ſhew what an inundation of licentious criticiſm was breaking in upon the ſacred text. Indeed there is reaſon to believe, that this tract, together with another on the ſame ſide of the queſtion by Dr Rutherford of Cambridge, contributed to repreſs the collector's raſhneſs, and to make the Bible of Dr Kennicott the valuable work which we find it. Be this as it may, ſuch was the moderation of the Drs Kennicott and Horne, that though their acquaintance commenced in hoſtility, they at length contracted for each other a friendſhip, which laſted to the end of their lives, and ſtill ſubſiſts between their families.

In what year Mr Horne was admitted to the degree of D. D. and when he was choſen preſident of his college, Mr Jones has not informed us ; but, if our memory does not deceive us, he had obtained both theſe preferments when, in the year 1772, he gave to the public a ſmall work, 8vo, entitled *Conſiderations on the Life and Death of St John the Baptiſt.* This tract was the ſubſtance of a courſe of ſermons, which he had many years before, in conformity to an eſtabliſhed cuſtom at Magdalen College, preached before the univerſity of Oxford. Mr Jones, ſpeaking of it, ſays, that “ he is perſuaded there was no other man of his time, whoſe fancy as a writer was bright enough, whoſe ſkill as an interpreter was deep enough, and whoſe heart as a moraliſt was *pure* enough, to have made him the author of that little work.” By moſt readers this ſtrain of panegyric will be thought extravagant, and of courſe it will defeat its own purpoſe ; but the work is certainly a work of merit.

In the year 1776, when the author was vice-chancellor, was publiſhed, in two volumes 4to, Dr Horne's Commentary on the Pſalms. It is a work of which very different opinions have been formed, though it was the reſult of the labour of twenty years. That it will always be a favourite companion of the devout Chriſtian, we are as much inclined to believe as Mr Jones ; but we cannot, without belying our own judgment, ſay that it appears to us calculated to produce much general good in an age like the preſent. Granting it to be true, which we believe will not be granted without ſome exceptions, that Clarke, and Hoadley, and Hare, and Middleton, and Warburton, and SHERLOCK, and SOUTH, and WILLIAM LAW, and Edmund Law, had turned the public attention, of which they had got the entire command, too much to the *letter* of the Bible to the neglect of the *ſpirit* of it ; ſhould not Dr Horne, after the example of St Paul, have let in the light gradually upon ſuch weak organs as thoſe of the public thus diſeaſed, rather than pour it upon them at once in a flood of ſplendor. The apoſtle “ fed his Corinthian converts with milk and not with meat” when he found them unable to bear the latter food ; and there is reaſon to ſuſpect that the carnal followers of Warburton, and Sherlock, and South, were unable to bear, at once, ſuch ſtrong meat, as that which makes the fifteenth pſalm a portrait of our Saviour. Indeed, we think it not improbable that the mind of Sherlock would have recoiled with horror from the very conception of the *poſſibility* of Jeſus Chriſt “ ſwearing to his neighbour and diſappointing him,” though that conception muſt have paſſed through a mind which was certainly as pure as his. The commentary, however, though truth thus compels us to ſay that, in our opinion, it is far from perfect, is certainly a work of great learning, great genius, and fervent piety, and ſuch as the devout Chriſtian will peruſe again and again with much advantage.

Dr Horne's next work was of a different kind, and, we think, of a ſuperior order. In the year 1776 was publiſhed a letter of Dr Adam Smith's, giving an account of the death of Mr David Hume. The object of the author was to ſhew that Mr Hume, notwithſtanding his ſceptical principles, had died with the utmoſt compoſure, and that in his life, as well as at his death, he had conducted himſelf as became one of the wiſeſt and beſt men that ever exiſted. The letter is very much laboured, and yet does no honour either to the author or his friend. It could not repreſent Mr Hume as ſupporting himſelf under the gradual decay of nature with the hopes of a happy immortality ; but it might have repreſented him as taking refuge, with other infidels, in the eternal ſleep of death. This, though but a gloomy proſpect, would not have been childiſh; but the hero of the tale is exhibited as talking like a ſchool-boy of his conferences with Charon, and his reluctance to go into the Stygian ferry-boat, and as conſoling himſelf with the thought of leaving all his friends, and his brother's family in particular, in great proſperity!!! The abſurdities of this letter did not eſcape the watchful and penetrating eye of Dr Horne; and as he could not miſtake its object, he held it up to the contempt and ſcorn of the religious world in *A Letter to Adam Smith, L. L. D. on the Life, Death, and Philoſophy of his Friend David Hume, Eſq; by one of the People called Chriſtians.* The reaſoning of this little tract is clear and concluſive, while its keen, though good humoured wit is inimitable; and it was, ſome years afterwards, followed by a ſeries of *Letters on Infidelity*, compoſed on the ſame plan, and with much of the ſame ſpirit. This ſmall volume, to the ſecond edition of which the letter to Dr Smith was prefixed, is better calculated than almoſt any other with which we are acquainted, to guard the minds of youth againſt the inſidious ſtrokes of infidel ridicule, the only dangerous weapon which infidelity has to wield.

When the letters on infidelity were publiſhed, their author had for ſome time been Dean of Canterbury, where he was beloved by the chapter and almoſt adored by the citizens. He was a very frequent preacher in the cathedral and metropolitical church, where the writer of this ſhort ſketch has liſtened to him with delight, and ſeen thouſands of people of very various deſcriptions hang with rapture on his lips. As a preacher indeed he excelled; and notwithſtanding the ſhortneſs of his ſight, which deprived him of ſome of the graces of a pulpit orator, ſuch were the excellence of his matter, the ſimple elegance of his ſtyle, and the ſweetneſs of his voice, that, when at the primary viſitation of the preſent archbiſhop, he preached his admirable ſermon *on the Duty of Contending for the Faith*, the attention of more than 2000 people was ſo completely fixed, that the ſmalleſt noiſe was not to be heard through the whole crowded choir. Of the importance of preaching, and of the proper mode of performing that duty, he had very juſt notions; and though he never had himſelf a parochial cure of ſouls, it was the deſire and pleaſure of his life to make himſelf uſeful in the pulpit wherever he was, whether in town or in the moſt obſcure corner of the country. Four or five volumes of his ſermons have been publiſhed ſince his death.

In the year 1787 he publiſhed, under the name of an undergraduate of the univerſity of Oxford, *a letter to Dr Prieſtley*, in which he made that oracle of Socinianiſm almoſt as ridiculous as, in the letter to Dr Smith, he had formerly made the hero of modern ſcepticiſm.

The merits of Dr Horne, which had made him preſident of Magdalen College, a king's chaplain, and dean of Canterbury, raiſed him, we think, in the year 1790, to the ſee of Norwich; and he had ſoon an opportunity of ſhewing that he had not loſt ſight of his ſpiritual character in the ſplendour of the peer of parliament. The Scotch Epiſcopalians had for ſome time been ſoliciting the legiſlature to repeal certain penal laws of uncommon ſeverity, under which they had groaned for upwards of forty years; but they found it a work of no little difficulty to make the equity of their claim generally underſtood*. In removing this difficulty no man was more aſſiſting to them than the Dean of Canterbury, to whom their religious and political principles were well known; and he continued his aſſiſtance after he was biſhop of Norwich. Indeed the whole bench ſhewed, on this occaſion, a zeal for the intereſts of true religion every way becoming their character of Chriſtian biſhops; and after Dr Horne was removed to a better world, the Scotch Epiſcopalians found among his ſurviving brethren friends as zealous and active as he.

Dr Horne, though a very handſome man, was not naturally of a ſtrong conſtitution; and from the diſadvantage of being uncommonly near-ſighted, he had not been able to increaſe its ſtrength by the practice of any athletic exerciſe. The only amuſement in which he took delight was agreeable converſation; and his life was therefore what is called ſedentary. The conſequence of this was, that the infirmities of age came faſt upon him; and when the deſign was formed of making him a biſhop, he felt himſelf little inclined to undertake the charge of ſo weighty an office. He was, however, prevailed upon to accept of the ſee of Norwich; but he enjoyed his new dignity for a very ſhort period, if he can with truth be ſaid to have *enjoyed* it at all. His health declined rapidly; and, in the autumn of 1791, he ſuffered, while on the road from Norwich to Bath, a paralytic ſtroke, the effects of which he never recovered. He lingered a month or two, with ſuch apparent changes in the ſtate of his health as ſometimes gave deluſive hopes to his family, till the 17th of January 1792, when he died in the 62d year of his age, with thoſe hopes which can be excited only by the conſciouſneſs of a well ſpent life, and by a firm truſt in the promiſes of the goſpel.

In this ſhort ſketch of the life of biſhop Horne we have taken the liberty to expreſs our diſſent from ſome of his opinions, and to ſtate the reaſons on which that diſſent reſts. By himſelf we know that this part of our conduct would have been applauded; but it is poſſible that by ſome of his friends it may be deemed diſreſpectful to his memory. To theſe gentlemen we beg leave to obſerve, that if Johnſon made the praiſe of *Kyrl*, Pope's Man of Roſs, really more ſolid by making it more credible, it will be difficult to perſuade us that we have done any injury to Dr Horne's fame by avoiding the extravagant panegyric of thoſe who ſeem to have conſidered him as a man exempted from error. He was firſt induced to favour the Hutchinſonians becauſe he thought he perceived danger to religion in the Newtonian doctrines of attraction and repulſion; and we very readily admit that many Newtonians, not underſtanding the doctrines of their maſter, have expreſſed themſelves in ſuch a manner as could not render a religious man partial to their ſyſtem. But from the dangers of miſtake, no ſyſtem, whether religious or philoſophical, was ever free; and the atheiſtical purpoſes which the agency of ethers and celeſtial fluids has lately been made to ſerve, muſt induce every man of piety to pauſe before he admit ſuch agency. Dr Horne lived to witneſs ſome of its pernicious effects; and we have reaſon to believe that they made a due impreſſion on his mind; but he ſpent his latter years, as indeed he had ſpent the greater part of his life, in nobler purſuits than the ſtudy of human ſcience; he ſpent them in the proper employments of a Chriſtian, a clergyman, and a biſhop. His faith was founded on a rock; and it was that genuine faith which worketh by love; for though his preferments

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* See Scotch Episcopalians in this *Supplement*.

were rich, his charity kept pace with them; and it has been proved that, notwithſtanding his proper economy, he hoarded not one ſhilling of his annual income. This was an elevation of character above all literary, above all philoſophical fame. The author of this article had the honour to be known to Dr Horne, to enjoy, if he miſtook not, a ſhare in his friendſhip, and to correſpond with him regularly for many years; and there is not one of his rational admirers who more fully admits the truth of the character given of him by Dr Thurlow late biſhop of Durham when ſucceeding him in the office of proctor in the Univerſity. "As to the laſt proctor (ſaid he) I ſhall ſpeak of him but in few words, for the truth of which I can appeal to all that are here preſent. If ever virtue itſelf was viſible and dwelt upon earth, it was in the perſon who this day lays down his office."

Soon after he was advanced to the preſidentſhip of Magdalen college, this great and good man married the only daughter of Philip Burton, Eſq; a gentleman of conſiderable fortune. By this lady he had three daughters, of whom the eldeſt was married to a clergyman a ſhort time before the death of her father, and the two younger were, in 1796, reſiding with Mrs Horne in Hertfordſhire.

HOROGRAPHY, the art of making or conſtructing dials; called alſo dialing, horologiography, gnomonica, ſciatherica, photoſciatherica, &c.

HOROPTER, in optics, is a right line drawn through the point where the two optic axes meet, parallel to that which joins the centres of the two eyes, or the two pupils.

HORSE-Shoe, in fortification, is a work ſometimes of a round, ſometimes of an oval figure, incloſed with a parapet, raiſed in the ditch of a marſhy place, or in low grounds; ſometimes alſo to cover a gate; or to ſerve as a lodgment for ſoldiers, to prevent ſurpriſes, or relieve an over-tedious defence.

HOVEN is a word of the ſame import with *raiſed, ſwelled, tumefied*. It is particularly applied to black cattle and ſheep, when from eating too voraciouſly of clover, or any other ſucculent food, they become ſwollen. Such cattle are, in the language of the farmer, called

Hoven-Cattle; and the beaſt, whether bullock or ſheep, which is hoven, when left without relief, dies in half an hour. The cauſe of the diſeaſe is the extra quantity of air taken down with that kind of food, which, in its paſſage from the paunch upwards, forces the broad leaves of the clover before it, till they cloſe up the paſſage at the entrance of the paunch, and prevent the wind from going upwards in its regular courſe. The uſual method of relief is to ſtab the animal in the paunch; an operation which is always dangerous, and has often proved fatal. It was therefore, with good reaſon, that the Society for the Encouragement of Arts, Manufactures, and Commerce, voted a bounty of fifty guineas to Mr Richard Eagar of Graſſham farm, near Guildford, for making public a very ſimple method practiſed by him for the cure of hoven-cattle. It is this; "let the grazier or farmer have always ready ſmooth knobs of wood, of different ſizes, fixed to the end of a flexible cane, which for oxen ſhould be at leaſt ſix feet long, and for ſheep three feet. When a beaſt is hoven, let one perſon take hold of him by the noſtril and one horn; let another hold his tongue faſt in one hand, putting the cane down his throat with the other. Be careful not to let the animal get the knob of the cane between his grinders: obſerve alſo to put the cane far enough down; the whole length will not injure. You will find the obſtacle at the entrance of the paunch: puſh the cane hard, and when you perceive a ſmell to come from the paunch, and the animal's body to ſink, the cure is performed, and Nature will act for itſelf."

This method, we doubt not, will prove ſucceſsful; but might not the purpoſe be as well, if not better, effected, by uſing, inſtead of the cane and knob, a piece of thick ſtiff rope, which, in many places of Scotland, is employed to force down turnips or potatoes when they ſtick in the throat of a bullock?

HOUGHTON (——) is a man to whom the ſcience of geography is ſo much indebted, that we are almoſt aſhamed to confeſs that we know not his Chriſtian name, the place where he was born, or the age at which he died. He had been a captain in the 69th regiment, and in the year 1779 had acted under General Rooke as fort-major in the iſland of Goree. Hearing, ſome time in the year 1789, or perhaps earlier, that the African aſſociation wiſhed to penetrate to the Niger by the way of Gambia, he expreſſed his willingneſs to undertake the execution of their plan. For this taſk he was peculiarly fitted. A natural intrepidity of character which ſeemed inacceſſible to fear, and an eaſy flow of conſtitutional good humour, which even the rougheſt accidents of life were not able to ſubdue, formed him for exploring the country of relentleſs ſavages; whilſt the darkneſs of his complexion was ſuch, that he ſcarcely differed in appearance from the Moors of Barbary, whoſe dreſs in travelling he intended to aſſume.

His inſtructions from the aſſociation were, to aſcertain the courſe, and, if poſſible, the riſe and termination of the Niger; and after viſiting the cities of Tombuctoo and Houssa (ſee theſe articles in this *Supplement*), to return by the way of the deſart, or by any other route which the circumſtances of his ſituation at the time might recommend to his choice.

Having left England on the 16th of October 1790, he arrived at the entrance of the Gambia on the 10th of November, and was kindly received by the king of Barra, who remembered the viſit which the major had formerly paid him from the iſland of Goree; and who now, in return for a ſmall preſent of the value of 20s. cheerfully tendered protection and aſſiſtance as far as his dominion or influence extended.

Proceedings of the African Aſſociation.

An offer from the maſter of an Engliſh veſſel employed in the trade of the river, enabled the Major, and the interpreter he had engaged on the coaſt, to proceed to Junkiconda; where he purchaſed from the natives a horſe and five aſſes, and prepared to paſs with the merchandiſe which conſtituted his travelling fund, to Medina, the capital of the ſmall kingdom of Woolli.

Fortunately for him, a few words, accidentally dropped by a negro woman in the Mandingo language, of which he had haſtily acquired a ſuperficial knowledge, excited ſuſpicions of danger; and gave him intimation of a conſpiracy which the negro miſtreſſes of the traders, who feared that the Major's expedition portended the ruin of their commerce, had formed againſt his life. Afraid, therefore, of travelling by the cuſtomary route, he availed himſelf of the opportunity which the dry ſea-

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ſon and the tide of ebb afforded of ſwimming his horſe and his aſſes acroſs the ſtream; and having by thoſe means avoided the parties who were ſent for his deſtruction, he proceeded with much difficulty on the ſouthern ſide of the river, to that diſtrict of Cantor which is oppoſite to the kingdom of Woolli. There he repaſſed the Gambia, and ſet a meſſenger to inform the king of his arrival, and to requeſt a guard for his protection.

An eſcort, commanded by the king's ſon, was immediately diſpatched; and the Major, whoſe intended preſent had been announced, was kindly received, and hoſpitably entertained at Medina.

The town is ſituated at the diſtance of about 900 miles by water from the entrance of the Gambia; and the country adjacent abounds in corn and cattle, and, generally ſpeaking, in all things that are requiſite for the ſupport, or eſſential to the comfort of life. Two different ſects of religion diſtinguiſh rather than divide the people; the one is compoſed of the profeſſors of the Mahomedan faith, who are called Buſhreens; the other, and, it is ſaid, the more numerous, conſiſts of thoſe who, denying the miſſion of the prophet, avow themſelves deiſts, and from their cuſtom of drinking with freedom the liquors of which he prohibited the uſe, are denominated Sonikees or drinking men.

In a letter from Major Houghton to his wife, which a ſeaman preſerved from the wreck of a veſſel in which the diſpatches to the ſociety were loſt, the Major indulged the reflections that naturally aroſe from his paſt and preſent ſituations. A bilious fever had attacked him ſoon after his arrival in the Gambia; but his health was now unimpaired—a conſpiracy had aſſailed his life; but the danger was paſſed—the journey from Junkiconda had expoſed him to innumerable hardſhips; but he was now in poſſeſſion of every gratification which the kindneſs of the king or the hoſpitality of the people could enable him to enjoy. Delighted with the healthineſs of the country, the abundance of the game, the ſecurity with which he made his excurſions on horſeback, and, above all, with the advantages that would attend the erection of a fort on the ſalubrious and beautiful hill of Fatetenda, where the Engliſh once had a factory, he expreſſes his earneſt hope that his wife will hereafter accompany him to a place in which an income of ten pounds a-year will ſupport them in affluence; and that ſhe will participate with him in the pleaſure of rapidly acquiring that vaſt wealth which he imagines its commerce will afford.

While, in this manner, he indulged the dream of future proſperity, and with ſtill more ample ſatisfaction contemplated the eclat of the diſcoveries for which he was preparing, but in the purſuit of which he was retarded by the abſence of the native merchant, for whoſe company he had engaged, he found himſelf ſuddenly involved in unexpected and irreſiſtible misfortune. A fire, the progreſs of which was accelerated by the bamboo roofs of the buildings, conſumed with ſuch rapidity the houſe in which he lived, and with it the greateſt part of Medina, that ſeveral of the articles of merchandize, to which he truſted for the expences of his journey, were deſtroyed; and to add to his affliction, his faithleſs interpreter, who had made an ineffectual attempt on his goods, diſappeared with his horſe and three of his aſſes; a trade gun which he had purchaſed on the river ſoon afterwards burſt in his hands, and wounded him in the face and arm: and though the hoſpitable kindneſs of the people of the neighbouring town of Barraconda, who cheerfully opened their houſes to more than a thouſand families, whoſe tenements the flames had conſumed, was anxiouſly exerted for his relief; yet the loſs of his goods, and the conſequent diminution of his travelling fund, were evils which no kindneſs could remove.

It was in this ſituation that, wearied with the fruitleſs hope of the return of the native trader, with whom he had contracted for his journey, he reſolved to avail himſelf of the company of another ſlave merchant, who was lately arrived from the ſouth, and was now on his way to his farm on the frontier of the kingdom of Bambouk. Accordingly, on the evening of the 8th of May, he proceeded by moon light and on foot, with his two aſſes, which the ſervants of the ſlave merchant offered to drive with their own, and which carried the wreck of his fortune; and journeying by a north-eaſt courſe, arrived on the fifth day at the uninhabited frontier which ſeparates the kingdoms of Woolli and Bondou.

He had now paſſed the former limit of European diſcovery; and while he remarked with pleaſure the numerous and extenſive population of this unviſited country, he obſerved, that the long black hair and copper complexion of the inhabitants announced their Arab original. They are a branch of that numerous tribe which, under the appellation of Foolies, have overſpread a conſiderable part of Senegambia; and their religious diſtinctions are ſimilar to thoſe which prevail in the kingdom of Woolli.

A journey of 150 miles, which was often interrupted by the engagements of his companion who traded in every town, conducted him to the banks of the Falemé, the ſouth-weſtern boundary of the kingdom of Bambouk. Its ſtream was exhauſted by the advanced ſtate of the dry ſeaſon, and its bed exhibited an appearance of ſlate intermixed with gravel.

Bambouk is inhabited by a nation, whoſe woolly hair and ſable complexions beſpeak them of the negro race, but whoſe character ſeems to be varied in proportion as the country riſes from the plains of its weſtern diviſion to the highlands of the eaſt. Diſtinguiſhed into ſects, like the people of Woolli and Bondou, by the different tenets of Mahomedans and Deiſts, they are equally at peace with each other, and mutually tolerate the reſpective opinions they condemn.

Agriculture and paſturage, as in the negro ſtates on the coaſt of the Atlantic, are their chief occupations; but the progreſs which they have made in the manufacturing arts, is ſuch as enables them to ſmelt their iron ore, and to furniſh the ſeveral inſtruments of huſbandry and war. Cloth of cotton, on the other hand, which in this part of Africa ſeems to be the univerſal wear, they appear to weave by a difficult and laborious proceſs; and to theſe two circumſtances it is probably owing, that with them the meaſure of value is not, as on the coaſt, a bar of iron, but a piece of cloth.

The common vegetable food of the inhabitants appears to conſiſt of rice; their animal, of beef or mutton. A liquor, prepared from fomented honey, ſupplies the want of wine, and furniſhes the means of thoſe feſtive entertainments that conſtitute the luxury of the court of Bambouk.

On the Major's arrival at the banks of the river Falemé, he found that the war which had lately ſubſiſted between the kings of Bondou and Bambouk was terminated by the ceſſion to the former of the conqueſts he had made in the low land part of the dominions of the latter; and that the king of Bondou had taken up his reſidence in the territory which he had thus obtained.

The Major haſtened to pay his reſpects to the victorious prince, and to offer a ſimilar preſent to that which the kings of Barra and Woolli had cheerfully accepted; but to his great diſappointment an ungracious reception, a ſullen permiſſion to leave the preſent, and a ſtern command to repair to the frontier town from which he came, were followed by an intimation that he ſhould hear again from the king. Accordingly, on the next day, the king's ſon, accompanied by an armed attendance, entered the houſe in which the Major had taken up his temporary dwelling, and demanded a ſight of all the articles he had brought. From theſe the prince ſelected whatever commodities were beſt calculated to gratify his avarice, or pleaſe his eye; and, to the Major's great diſappointment, took from him the blue coat in which he hoped to make his appearance on the day of his introduction to the Sultan of Tombuctoo. Happily, however, a variety of articles were ſucceſsfully concealed, and others of inferior value were not conſidered as ſufficiently attractive.

The Major now waited with impatience for the performance of the promiſe which the ſlave merchant, with whom he had travelled from the Gambia, had made of proceeding with him to Tombuctoo; but as the merchant was obliged to ſpend a few days at his rice farm on the banks of the Falemé, the Major accepted an invitation to the hoſpitality of his roof. There he obſerved, with extreme regret, that the apprehenſion of a ſcarcity of grain had alarmed his friend; and that, dreading the conſequences of leaving his family in ſo perilous a ſeaſon to the chances of the market, he had determined on collecting, before his departure, a ſufficient ſupply for their ſupport. This argument for delay was too forcible to be oppoſed; and therefore the Major reſolved to employ the interval in viſiting the king of Bambouk, who reſided in the town of Ferbanna, on the eaſtern ſide of the Serra Coles, or river of Gold. Unfortunately, however, by a miſtake of his guide, he loſt his way in one of the vaſt woods of the country; and as the rainy ſeaſon, which commenced with the new moon on the 4th of July, and was introduced with a weſterly wind, was now ſet in, the ground on which he paſſed the night was deluged with rain, while all the ſky exhibited that continued blaze of lightning, which in thoſe latitudes often accompanies the tornado. Diſtreſſed by the fever, which began to aſſail him, the Major continued his route at the break of day, and waded with difficulty through the river Serra Coles, which was ſwelled by the floods, and on the banks of which the alligators were baſking in the temporary ſun-ſhine.

Scarcely had he reached Ferbanna when his fever roſe to a height that rendered him delirious; but the ſtrength of his conſtitution, and the kindneſs of the negro family to which his guide had conducted him, ſurmounted the dangerous diſeaſe; and in the friendly reception which was given him by the king of Bambouk he ſoon forgot the hardſhips of his journey. The king informed him, that the loſſes he had lately ſuſtained in the conteſt with the armies of Bondou, aroſe from his having exhauſted his ammunition; for, as the French traders, who formerly ſupplied his troops, had abandoned the fort of St Joſeph, and, either from the dryneſs of the laſt ſeaſon, or from other cauſes, had deſerted the navigation of the upper part of the Senegal, he had no means of repleniſhing his ſtores; whereas his enemy, the king of Bondou, continued to receive from the Britiſh, through the channel of his agents on the Gambia, a conſtant and adequate ſupply.

Major Houghton availed himſelf of the opportunity which this converſation afforded, to ſuggeſt to the king the advantage of encouraging the Britiſh to open a trade by the way of his dominions to the populous cities on the banks of the Niger.

Such was the ſtate of the negociation, when all buſineſs was ſuſpended by the arrival of the annual preſents of Mead, which the people of Bambouk, at that ſeaſon of the year, are accuſtomed to ſend to their king; and which are always followed by an intemperate feſtival of ſeveral ſucceſſive days.

In the interim, the Major received, and gladly accepted, the propoſal of an old and reſpectable merchant of Bambouk; who offered to conduct him on horſeback to Tombuctoo, and to attend him back to the Gambia. A premium of L. 125, to be paid on the Major's return to the Britiſh factory at Junkiconda, was fixed by agreement as the merchant's future reward. It was further determined that the Major ſhould be furniſhed with a horſe in exchange for his two aſſes; and ſhould convert into gold duſt, as the moſt portable fund, the ſcanty remains of the goods he had brought from Great Britain.

This plan was much approved by the king, to whom the merchant was perſonally known; and who gave to the Major at parting, as a mark of his eſteem, and a pledge of his future friendſhip, a preſent of a purſe of gold. With an account of theſe preparations the Major cloſed his laſt diſpatch, of the 24th July 1791; and the African aſſociation entertained for ſome time ſanguine hopes of his reaching Tombuctoo. Alas! theſe hopes were blaſted. Mr Park, who ſucceeded him in the arduous taſk of exploring that ſavage country, learned, that having reached JARRA (See that article in this *Supplement*), he there met with ſome Moors who were travelling to Tiſheet (a place by the ſalt pits in the Great Deſart, ten days journey to the northward) to purchaſe ſalt; and that the Major, at the expence of ſome tobacco and a muſket, engaged them to convey him hither. It is impoſſible (ſays Mr Park) to form any other opinion on this determination, than that the Moors intentionally deceived him with a view to rob, and leave him in the Deſart. At the end of two days he ſuſpected their treachery, and inſiſted on returning to Jarra. Finding him perſiſt in this determination, the Moors robbed him of every thing which he poſſeſſed, and went off with their camels. Being thus deſerted, he returned to a watering place, in poſſeſſion of the Moors, called Farra; and being by theſe unfeeling wretches refuſed food, which he had not taſted for ſome days, he ſunk at laſt under his misfortunes. Whether he actually died of hunger, or was murdered outright by the ſavage Mahometans, Mr Park could not learn;

but he was ſhewn at a diſtance the ſpot in the woods to which his body was dragged, and where it was left a prey to corruption.

Thus periſhed, in the prime of life, Major Houghton, a man whoſe travels enlarged the limits of European diſcovery, and whoſe accounts of the places which he viſited were ſtrongly confirmed by the intelligence which the Britiſh conſul at Tunis collected from the Barbary merchants.

HOUSSA, the capital of an African empire, on the banks of the Niger, is a city which has excited much curioſity among men of ſcience, ſince it was firſt mentioned to a committee of the African Aſſociation about the year 1790. The perſon from whom they received their information was an Arab, of the name of Shabeni; who ſaid that the population of Houſſa, where he had reſided two years, was equalled only (ſo far as his knowledge extended) by that of London and Cairo: and, in his rude unlettered way, he deſcribed the government as monarchical, yet not unlimited; its juſtice as ſevere, but directed by written laws; and the rights of landed property as guarded by the inſtitutions of certain hereditary officers, whoſe functions appear to be ſimilar to thoſe of the Canongoes of Hindoſtan (ſee CANONGOES in this *Suppl.*); and whoſe important and complicated duties imply an unuſual degree of civilization and refinement. For the probity of the merchants of Houſſa, the Arab expreſſed the higheſt reſpect; but remarked, with indignation, that the women were admitted to ſociety, and that the honour of the huſband was often inſecure. Of their written alphabet, he knew no more than that it is perfectly different from the Arabic and the Hebrew characters; but he repreſented the art of writing as common in Houſſa. And when he deſcribed the manner in which their pottery is made, he gave, unknowingly to himſelf, a repreſentation of the ancient Grecian wheel. In paſſing to Houſſa from Tombuctoo, in which laſt city he had reſided ſeven years, he found the banks of the Niger more numerouſly peopled than thoſe of the Nile, from Alexandria to Cairo; and his mind was obviouſly impreſſed with higher ideas of the wealth and grandeur of the empire of Houſſa, than of thoſe of any kingdom which he had ſeen, England alone excepted.

The exiſtence of the city of Houſſa, and of the empire thus deſcribed by Shabeni, was ſtrongly confirmed by letters which the committee received from his Majeſty's conſuls at Tunis and Morocco; and it has been put beyond all poſſibility of doubt by Mr Park, who received from various perſons ſuch concurring accounts of it, as could not be the offspring of deliberate falſehood. From a well-informed ſhereeff, who had viſited Houſſa, and lived ſome years at Tombuctoo, he learned that the former of theſe cities was the largeſt that the ſhereeff had ever ſeen; and by comparing this man's account of its population with that of various other cities, of which Mr Park had ſeen one or two, we can hardly eſtimate the inhabitants of Houſſa at a leſs number than 100,000. Many merchants, with whom our traveller converſed, repreſented Houſſa as larger, and more populous, than Tombuctoo, and the trade, police, and government, as nearly the ſame in both. In that caſe, the king of Houſſa and chief officers of ſtate muſt be Moors, and zealots for the Mahometan religion; but they cannot be ſo intolerant as the ſovereign of Tombuctoo and his miniſters; for in Houſſa, Mr Park was told that the Negroes are in greater proportion to the Moors than in Tombuctoo, and that they have likewiſe ſome ſhare in the government. According to accounts derived from Barbary merchants, the people of Houſſa have the art of tempering their iron with more than European ſkill; and their files, in particular, are much ſuperior to thoſe of Great Britain and France. The conſuls at Tunis and Morocco aſſured the committee of the African Aſſociation, that at both theſe courts the eunuchs of the ſeraglio are brought from Houſſa.

To thoſe who may ſtill entertain doubts of ſo much refinement being to be found in the interior parts of a country, conſidered as peculiarly ſavage, we ſhall only obſerve, in the words of the committee of aſſociation, that it is by no means "impoſſible that the Carthaginians, who do not appear to have periſhed with their cities, may have retired to the ſouthern parts of Africa; and though loſt to the Deſart, may have carried with them to the new regions which they occupy ſome portion of thoſe arts and ſciences, and of that commercial knowledge, for which the inhabitants of Carthage were once ſo eminently famed. In Major Rennel's laſt map of North Africa, Houſſa is placed in 16° and about 20′ N. Lat. and 4° 30′ E. Long.

HOUZOUANAS, are a wandering people, who inhabit that part of Africa, which, in a direction from eaſt to weſt, extends from Caffraria to the country of the Greater Nimiquas (See NIMIQUAS in this *Suppl.*) According to the map prefixed to Vaillant's new travels, the diſtrict occupied by the Houzouanas lies between 16° and 29° eaſt longitude. Of its breadth from ſouth to north we are ignorant, but it begins at the 23d parallel, and ſtretches northward probably a great way.

M. Vaillant is inclined to believe, that the Houzouanas are the original ſtem of the various nations, inhabiting at preſent the ſouthern part of Africa, and that from them all the tribes of the eaſtern and weſtern Hottentots are deſcended. The people themſelves know nothing of their origin; but to the queſtions that are put to them on the ſubject, they always reply, that they inhabit the country which was inhabited by their anceſtors. At the Cape M. Vaillant received the following account of them, which, though he does not warrant its authenticity, has much the appearance of being authentic.

When the Europeans firſt eſtabliſhed themſelves at the Cape, the Houzouanas inhabited the country of Camdebo, the ſnowy mountains, and the diſtrict that ſeparates theſe mountains from Caffraria. Become neighbours to the colony, in conſequence of its extending itſelf towards them, they at firſt lived on peaceable terms with the planters; and, as they diſplayed more intelligence and greater activity than the Hottentots, they were even employed in preference to aſſiſt in cultivating the land and in forming the ſettlement. This good underſtanding and harmony were, however, ſoon interrupted by that multitude of lawleſs banditti ſent from Holland to people the country.

Thoſe worthleſs profligates wiſhed to enjoy the fruits of the land without the trouble of tilling it. Educated, beſides, with all the prejudices of the whites, they imagined that men of a different colour were born only to be their ſlaves. They accordingly ſubjected them to bondage, condemned them to the moſt laborious ſervices, and repaid thoſe ſervices with harſh and ſevere treatment. The Houzouanas, incenſed at ſuch arbitrary and tyrannical conduct, refuſed any longer to work for them, and retired to the defiles of their mountains. The planters took up arms and purſued them; they maſſacred them without pity, and ſeized on their cattle and their country. Thoſe who eſcaped their atrocities betook themſelves to flight, and removed to the land which they now occupy; but, on quitting their former poſſeſſions, they ſwore, in their own name and that of their poſterity, to exterminate thoſe European monſters, to be revenged againſt whom they had ſo many incitements. And thus, if tradition be true, was a peaceful and induſtrious nation rendered warlike, vindictive, and ferocious.

This hatred has been perpetuated from generation to generation, though the Houzouanas of the preſent day are ignorant of the original cauſe of it. Bred up with an invincible averſion to the planters, they know only that they are animated to plunder and deſtroy them; but it is only by a vague ſentiment of deteſtation, with the ſource of which they are unacquainted; and which, though it renders them cruel towards the planters, does not prevent them from being good, kind, and humane, towards each other.

The Houzouanas, being known only by their incurſions and plundering, are in the colonies often confounded with the Boſhmen, and diſtinguiſhed by the ſame appellation. Sometimes, however, from their tawny colour, they are called Chineſe Hottentots; and, by means of this double denomination, ill-informed travellers may eaſily be led into an error, of which the conſequence muſt be, that their narratives will be replete with abſurdity and falſehoods.

Their real name, and the only one which they give themſelves, is that of Houzouana; and they have nothing in common with the Boſhmen, who are not a diſtinct people, but a mere collection of fugitives and free-booters. The Houzouanas form no alliances but among themſelves. Being almoſt always at war with the ſurrounding nations, they never mix with them; and, if they conſent at any time to admit a ſtranger into their hordes, it is only after a long acquaintance, a ſort of apprenticeſhip, during which he has given proofs of his fidelity, and eſtabliſhed his courage. Such indeed are their courage and predatory habits, that they are the dread of all the ſurrounding tribes; and the Hottentots who accompanied M. Vaillant trembled at the very thought of entering the Houzouana territories. Nay, after they had lived many days among them, and had experienced their fidelity, they continued under the daily apprehenſion of being maſſacred by them. Yet one of their own countrymen, who had lived long among the Houzouanas, gave ſuch a character of that people as ſhould have baniſhed thoſe idle fears.

" The Houzouanas (ſaid he), are by no means what you ſuppoſe them to be, murderers by profeſſion. If they ſometimes ſhed blood, it is not from a thirſt of carnage, but to make juſt repriſals that they take up arms. Attacked and perſecuted by ſurrounding nations, they have found themſelves reduced to the neceſſity of flying to inacceſſible places among the barren mountains, where no other people could exiſt.

" If they find antelopes and damans to kill; if the nymphs of ants are abundant; or if their good fortune brings them plenty of locuſts—they remain within the precincts of their rocks; but if the proviſions neceſſary to ſubſiſtence fail, the nations in their neighbourhood muſt ſuffer. From the ſummits of their mountains, they ſurvey at a diſtance the countries around; and if they obſerve cattle, they make an incurſion to carry them off, or ſlaughter them upon the ſpot, according to circumſtances; but though they rob, they never kill, except to defend their lives, or by way of retaliation to revenge an ancient injury.

" It happens ſometimes, however, that after very fatiguing expeditions they return without booty; either becauſe the objects of their attack have diſappeared, or becauſe they have been repulſed and beaten. In ſuch caſes, the women, exaſperated by hunger and the lamentation of their children crying for food, become almoſt furious with paſſion. Reproaches, inſult, and threats, are employed; they wiſh to ſeparate from ſuch daſtardly men, to quit huſbands deſtitute of courage, and to ſeek others who will be more anxious to procure proviſion for them and their children. In ſhort, having exhauſted whatever rage and deſpair could ſuggeſt, they pull off their ſmall apron of modeſty, and beat their huſbands about the head with it till their arms are weary of the exerciſe.

" Of all the affronts which they can offer, this is the moſt inſulting. Unable to withſtand it, the men in their turn become furious. They put on their war-cap, a ſort of helmet made with the ſkin that covers the neck of the hyæna, the long hair of which forms a creſt that floats over the head, and ſetting out like madmen, never return till they have ſucceeded in carrying off ſome cattle.

" When they come back, their wives go to meet them, and extol their courage amidſt the fondeſt careſſes. In a word, nothing is then thought of but mirth and jollity; and, till ſimilar ſcenes are recalled by ſimilar wants, paſt evils are forgotten."

Such was the character given of this formidable people to M. Vaillant at his firſt interview with them; and during the long excurſions which he made in their company, they did not belie it in a ſingle inſtance. In many reſpects they appeared to reſemble the Arabs, who, being alſo wanderers, and like them brave and addicted to rapine, adhere with unalterable fidelity to their engagements, and defend, even to the laſt drop of their blood, the traveller who civilly purchaſes their ſervices, and puts himſelf under their protection. In our author's opinion, if it be at all practicable to traverſe from ſouth to north the whole of Africa, it could only be under the conduct of the Houzouanas; and he really thinks that fifty men of their temperate, brave, and indefatigable nation, would be ſufficient to protect an enterpriſing European through that long and hazardous journey.

Yet theſe people, ſo ſuperior both in body and mind to the other natives of South Africa, are but of low ſtature; and a perſon five feet four inches in height is accounted among them very tall; but in their little bodies, perfectly well proportioned, are united, with ſurpriſing

priſing ſtrength and agility, a certain air of aſſurance, boldneſs, and haughtineſs, which awes the beholder, and with which our author was greatly pleaſed. Of all the ſavage races, he ſaw none that appeared to be endowed with ſo active a mind, and ſo hardy a conſtitution.

Their head, though it exhibits the principal characteriſtics of that of the Hottentot, is, however, rounder towards the chin. They are alſo not ſo black in complexion; but have the lead colour of the Malays, diſtinguiſhed at the Cape by the name of *bouguinée*. Their hair, more woolly, is ſo ſhort, that he imagined at firſt their heads to have been ſhaved. The noſe too is ſtill flatter than that of the Hottentots; or, rather, they ſeem altogether deſtitute of a noſe; what they have conſiſting only of two broad noſtrils which project at moſt but five or ſix lines. From this confirmation of the noſe, a Houzouana, when ſeen in profile, is the reverſe of handſome, and conſiderably reſembles an ape. When beheld in front, he preſents, on the firſt view, an extraordinary appearance, as half the face ſeems to be forehead. The features, however, are ſo expreſſive, and the eyes ſo large and lively, that, notwithſtanding this ſingularity of look, the countenance is tolerably agreeable.

As the heat of the climate in which he lives renders clothing unneceſſary, he continues during the whole year almoſt entirely naked, having no other covering than a very ſmall jackal ſkin faſtened round his loins by two thongs, the extremities of which hang down to his knees. Hardened by this conſtant habit of nakedneſs, he becomes ſo inſenſible to the variations of the atmoſphere, that when he removes from the burning ſands of the level country to the ſnow and hoar-froſt of his mountains, he ſeems indifferent to and not even to feel the cold.

His hut in nowiſe reſembles that of the Hottentot. It appears as if cut vertically through the middle; ſo that the hut of a Hottentot would make two of thoſe of the Houzouanas. During their emigrations, they leave them ſtanding, in order that, if any other horde of the ſame nation paſs that way, they may make uſe of them. When on a journey, they have nothing to repoſe on but a mat ſuſpended from two ſticks, and placed in an inclined poſition. They often even ſleep on the bare ground. A projecting rock is then ſufficient to ſhelter them; for every thing is ſuited to a people whoſe conſtitutions are proof againſt the ſevereſt fatigue. If, however, they ſtop anywhere to ſojourn for a while, and find materials proper for conſtructing huts, they then form a kraal; but they abandon it on their departure, as is the caſe with all the huts which they erect.

This cuſtom of labouring for others of their tribe announces a ſocial character and a benevolent diſpoſition. They are indeed not only affectionate huſbands and good fathers, but excellent companions. When they inhabit a kraal, there is no ſuch thing among them as private property; whatever they poſſeſs is in common. If two hordes of the ſame nation meet, the reception is on both ſides friendly; they afford each other mutual protection, and confer reciprocal obligations. In ſhort, they treat one another as brethren, though perhaps they are perfect ſtrangers, and have never ſeen each other before.

Active and nimble by nature, the Houzouanas conſider it as amuſement to climb mountains, and the moſt elevated peaks; and they conducted M. Vaillant, his ſervants and cattle, over precipices, and through defiles, which he and his Hottentots would have deemed abſolutely impaſſable. The only arms of this people are bows and arrows, in the uſe of which they are very expert. The arrows, which are uncommonly ſhort, are carried on the ſhoulder in a quiver, about 18 inches in length, and four in diameter, made of the bark of the aloe, and covered with the ſkin of a large ſpecies of lizard, which theſe wanderers find in all their rivers, particularly on the banks of Orange and Fiſh River.

Nocturnal fires are a peculiar language underſtood and employed by almoſt all ſavage nations. None, however, have carried this art ſo far as the Houzouanas, becauſe none have ſo much need of underſtanding and bringing it to perfection. If it be neceſſary to announce a defeat or a victory, an arrival or departure, a ſucceſsful plundering expedition, or the want of aſſiſtance, in a word, any intelligence whatever, they are able, either by the number of their fires or the manner in which they arrange them, to make it known in an inſtant. They are even ſo ſagacious as to vary their fires from time to time, leſt their enemies ſhould become acquainted with their ſignals, and treacherouſly employ them in their turn to ſurpriſe them.

Our author ſays, that he is unacquainted with the principles of theſe ſignals, invented with ſo much ingenuity. He did not requeſt information; becauſe he very rationally inferred that his requeſt would not have been granted; but he obſerved, that three fires kindled at the diſtance of twenty paces from each other, ſo as to form an equilateral triangle, were the ſignal for rallying.

Among the phyſical qualities which, in M. Vaillant's opinion, prove that the Houzouanas are a diſtinct nation, he mentions the enormous natural rump of the women, as a deformity which diſtinguiſhes them from every other people, ſavage or poliſhed, which he had ever known. “I have ſeveral times (ſays he) had occaſion to remark, that, among the female Hottentots in general, as they advance in age, the inferior part of the back ſwells out, and acquires a ſize which it greatly exceeds the proportion it bore in infancy with the other parts of the body. The Houzouana women, having in their figure ſome reſemblance to the Hottentots, and appearing therefore to be of the ſame race, one might be induced to believe that their projection behind is only the Hottentot rump more ſwelled and extended. I obſerved, however, that among the former this ſingularity was an excreſcence of ſlow growth, and in ſome meaſure an infirmity of old age; whereas among the latter it is a natural deformity, an original characteriſtic of their race. The Houzouana mothers wear on their reins, like our miners, a ſkin which covers this protuberance of the poſteriors; but which, being thin and pliable, yields to the quivering of the fleſh, and becomes agitated in the ſame manner. When on a journey, or when they have children too young to follow them, they place them upon their rump. I ſaw one of theſe women run in this manner with a child, about three years of age, that ſtood erect on its feet at her back, like a footboy behind a carriage.”

If one half of what our traveller ſays of the activity and enterpriſing ſpirit of this ſingular people be true, might not the African Aſſociation ſend a ſecond Houghton, or ſecond Park, to make diſcoveries in that unexplored country, under the protection of the Houzouanas? We do not indeed think that it would be poſſible to traverſe the whole extent of Africa from ſouth to north, but Vaillant penetrated farther in that direction than any one had done before him; and it appears that with his intrepid Houzouanas he might have penetrated much farther.

HUNGARY-WATER, is ſpirit of wine diſtilled upon roſemary, and which therefore contains its oily and ſtrong-ſcented eſſence (ſee PHARMACY, nº 365. *Encycl.*) To be really good, ſays Profeſſor Beckmann, the ſpirit of wine ought to be very ſtrong, and the roſemary freſh; and if that be the caſe, the leaves are as proper as the flowers, which, according to the preſcription of ſome, ſhould only be taken. It is likewiſe neceſſary that the ſpirit of wine be diſtilled ſeveral times upon the roſemary; but that proceſs is too troubleſome and expenſive to admit of this water being diſpoſed of at the low price it is uſually ſold for; and it is certain that the greater part of it is nothing elſe than common brandy united with the eſſence of roſemary in the ſimpleſt manner. In general, it is only mixed with a few drops of the oil. For a long time paſt, this article has been brought to us principally from France, where it is prepared, particularly at Beaucaire, Montpelier, and other places in Languedoc, in which that plant grows in great abundance.

Hiſt. of Inventions.

The name *Hungary water* ſeems to ſignify, that this water, ſo celebrated for its medicinal virtues, is an Hungarian invention; and we read in many books, that the receipt for preparing it was given to a queen of Hungary by a hermit; or, as others ſay, by an angel, who appeared to her in a garden, all entrance to which was ſhut, in the form of a hermit or a youth. Some call the queen St Iſabella; but thoſe who pretend to be beſt acquainted with the circumſtance affirm, that Elizabeth, wife of Charles Robert king of Hungary, and daughter of Uladiſlaus II. king of Poland, who died in 1380 or 1381, was the inventreſs. By often waſhing with this ſpirit of roſemary, when in the 70th year of her age, ſhe was cured, as we are told, of the gout and an univerſal lameneſs; ſo that ſhe not only lived to paſs 80, but became ſo lively and beautiful, that ſhe was courted by the king of Poland, who was then a widower, and who wiſhed to make her his ſecond wife.

The Profeſſor juſtly conſiders this ſtory as a ridiculous fable (A). "It appears to me (ſays he) moſt probable, that the French name *l'eau de la reine d'Hongrie*, was choſen by thoſe who, in latter times, prepared ſpirit of roſemary for ſale, in order to give greater conſequence and credit to their commodity; as various medicines, ſome years ago, were extolled in the gazettes under the title of Pompadour, though the celebrated lady, from whoſe name they derived their importance, certainly neither ever ſaw them nor uſed them."

HUNTER (John), the celebrated ſurgeon, was the youngeſt child of John Hunter of Kilbride, in the county of Lanark. He was born on the 14th of July 1728, at Long Calderwood, a ſmall eſtate belonging to the family; and loſing his father when he was about ten years of age, he was perhaps too much indulged by his mother. One conſequence of this was, that at the grammar-ſchool he made no progreſs in learning; and he may be ſaid to have been almoſt totally illiterate when, in September 1748, he arrived in London. His brother, Dr William Hunter, of whom an account is given in the *Encyclopædia*, was then the moſt celebrated teacher of anatomy, and John had expreſſed a deſire to aſſiſt him in his reſearches. The Doctor, who was very deſirous to ſerve him, and anxious to form ſome opinion of his talents for anatomy, gave him an arm to diſſect for the muſcles, with the neceſſary directions how it was to be done; and he found the performance ſuch as greatly exceeded his expectation.

His firſt eſſay in anatomy having thus gained him ſome credit, Mr Hunter was now employed in a diſſection of a more difficult nature; this was an arm in which all the arteries were injected, and theſe, as well as the muſcles, were to be expoſed and preſerved. The manner in which this was performed, gave Dr Hunter ſo much ſatiſfaction, that he did not ſcruple to ſay that his brother would become a good anatomiſt, and that he ſhould not want for employment. From this period we may conſider Mr Hunter as having ſeriouſly engaged in anatomy; and under the inſtructions of Dr Hunter, and his aſſiſtant Mr Symonds, he had every opportunity of improvement, as all the diſſections at this time carried on in London were confined to that ſchool.

(A) It was firſt publiſhed to the world in 1659 in a poſthumous work of John Prevot, who ſays, that in the beginning of a very old breviary, he ſaw a remedy for the gout, written by the queen's own hand, in the following words:

"I Elizabeth, queen of Hungary, being very infirm and much troubled with the gout in the 72d year of my age, uſed for a year this receipt, given to me by an ancient hermit, whom I never ſaw before nor ſince; and was not only cured, but recovered my ſtrength, and appeared to all ſo remarkably beautiful, that the king of Poland aſked me in marriage, he being a widower and I a widow. I, however, refuſed him for the love of my Lord Jeſus Chriſt, from one of whoſe angels, I believe, I received the remedy. The receipt is as follows:

> "℞. Take of aqua vitæ, four times diſtilled, three parts, and of the tops and flowers of roſemary two parts: put theſe together in a cloſe veſſel, let them ſtand in a gentle heat 50 hours, and then diſtil them. Take one dram of this in the morning once every week, either in your food or drink, and let your face and the diſeaſed limb be waſhed with it every morning.

"It renovates the ſtrength, brightens the ſpirits, purifies the marrow and nerves, reſtores and preſerves the ſight, and prolongs life." Thus far from the Breviary. Then follows a confirmation which Prevot gives from his own experience.

In the ſummer 1749, Mr Cheſelden, at the requeſt of Dr Hunter, permitted him to attend at Chelſea Hoſpital; and he there learned the firſt rudiments of ſurgery.

The following winter he was ſo far advanced in the knowledge of human anatomy, as to inſtruct the pupils in diſſection, to whom Dr Hunter had very little time to pay attention. This office, therefore, fell almoſt entirely upon him, and was his conſtant employment during the winter ſeaſon.

In the ſummer months of 1750, Mr Hunter attended the hoſpital at Chelſea; in 1751, he became a pupil at St Bartholomew's, and in the winter was preſent at operations occaſionally, whenever any thing extraordinary occurred. The following ſummer he went to Scotland; and in 1753 entered, it is difficult to conceive for what reaſon, as a gentleman commoner at St Mary-hall, Oxford. In 1754 he became a ſurgeon's pupil at St George's hoſpital, where he continued during the ſummer months; and in 1756 was appointed houſe-ſurgeon.

In the winter 1755, Dr Hunter admitted him to a partnerſhip in his lectures, and a certain portion of the courſe was allotted to him; beſides which, he gave lectures when the Doctor was called away to attend his patients. Making anatomical preparations was at this time a new art, and very little known; every preparation, therefore, that was ſkilfully made, became an object of admiration; many were wanting for the uſe of the lectures; and the Doctor being himſelf an enthuſiaſt for the art, left no means untried to infuſe into his brother a love for his favourite purſuits. How well he ſucceeded, the collection afterwards made by Mr Hunter will ſufficiently evince.

Anatomy ſeems to have been a purſuit for which Mr Hunter's mind was peculiarly fitted, and he applied to it with an ardour and perſeverance of which there is hardly an example. His labours were ſo uſeful to his brother's collection, and ſo gratifying to his diſpoſition, that although in many other reſpects they did not agree, this ſimple tie kept them together for many years.

Mr Hunter worked for ten years on human anatomy; during which period he made himſelf maſter of what was already known, as well as made ſome addition to that knowledge. He traced the ramifications of the olfactory nerves upon the membranes of the noſe, and diſcovered the courſe of ſome of the branches of the fifth pair of nerves. In the gravid uterus, he traced the arteries of the uterus to their termination in the placenta. He was alſo the firſt who diſcovered the exiſtence of the lymphatic veſſels in birds.

Many parts of the human body being ſo complex, that their ſtructure could not be underſtood, nor their uſes aſcertained, Mr Hunter was led to examine ſimilar parts in other animals, in which the ſtructure was more ſimple, and more within the reach of inveſtigation; this carried him into a wide field, and laid the foundation of his collection in comparative anatomy.

In this new line of purſuit, this active inquirer began with the more common animals, and preſerved ſuch parts as appeared by their analogy, or in ſome other way, to elucidate the human economy. It was not his intention to make diſſections of particular animals, but to inſtitute an inquiry into the various organizations by which the functions of life are performed, that he might thereby acquire ſome knowledge of general principles.

So eagerly did Mr Hunter attach himſelf to comparative anatomy, that he ſought by every means in his power the opportunities of proſecuting it with advantage. He applied to the keeper of wild beaſts in the Tower for the bodies of thoſe which died there; and he made ſimilar applications to the men who ſhowed wild beaſts. He purchaſed all rare animals which came in his way; and theſe, with ſuch others as were preſented to him by his friends, he entruſted to the ſhowmen to keep till they died, the better to encourage them to aſſiſt him in his labours.

His health was ſo much impaired by exceſſive attention to his purſuits, that in the year 1760 he was adviſed to go abroad, having complaints in his breaſt which threatened to be conſumptive. In October of that year, Mr Adair, inſpector-general of hoſpitals, appointed him a ſurgeon on the ſtaff; and in the following ſpring he went with the army to Belliſle, leaving Mr Hewſon to aſſiſt his brother during his abſence.

Mr Hunter ſerved, while the war continued, as ſenior ſurgeon on the ſtaff, both in Belliſle and Portugal, till the year 1763; and in that period acquired his knowledge of gun-ſhot wounds. On his return to England he ſettled in London; where, not finding the emoluments from his half-pay and private practice ſufficient to ſupport him, he taught practical anatomy and operative ſurgery for ſeveral winters. He returned alſo, with unabated ardour, to comparative anatomy; and as his experiments could not be carried on in a large town, he purchaſed for that purpoſe, about two miles from London, a piece of ground near Brompton, at a place called Earl's Court, on which he built a houſe. In the courſe of his inquiries, this excellent anatomiſt aſcertained the changes which animal and vegetable ſubſtances undergo in the ſtomach when acted on by the gaſtric juice; he diſcovered, by means of feeding young animals with madder (which tinges growing bones red), the mode in which a bone retains its ſhape during its growth; and explained the proceſs of exfoliation, by which a dead piece of bone is ſeparated from the living.

His fondneſs for animals made him keep ſeveral of different kinds in his houſe, which, by attention, he rendered familiar with him, and amuſed himſelf by obſerving their peculiar habits and inſtincts; but this familiarity was attended with conſiderable riſk, and ſometimes led him into ſituations of danger, of which the following is a remarkable inſtance:

Two leopards, which were kept chained in an outhouſe, had broken from their confinement, and got into the yard among ſome dogs, which they immediately attacked; the howling this produced alarmed the whole neighbourhood; Mr Hunter ran into the yard to ſee what was the matter, and found one of them getting up the wall to make his eſcape, the other ſurrounded by the dogs; he immediately laid hold of them both, and carried them back to their den; but as ſoon as they were ſecured, and he had time to reflect upon the riſk of his own ſituation, he was ſo much agitated, that he was in danger of fainting.

On the fifth of February 1767, he was choſen a fellow of the Royal Society. His deſire for improvement in thoſe branches of knowledge which might aſſiſt in his reſearches, led him at this time to propoſe to Dr George Fordyce and Mr Cumming, an eminent mechanic, that they ſhould adjourn from the meetings of the Royal Society to ſome coffee-houſe, and diſcuſs ſuch ſubjects as were connected with ſcience. This plan was no ſooner eſtabliſhed, than they found their numbers increaſed; they were joined by Sir Joſeph Banks, Dr Solander, Dr Maſkelyne, Sir George Shuckburgh, Sir Harry Engleſield, Sir Charles Blagden, Dr Noothe, Mr Ramſden, Mr Watt of Birmingham, and many others. At theſe meetings diſcoveries and improvements in different branches of philoſophy were the objects of their conſideration; and the works of the members were read over and criticiſed before they were given to the public. It was in this year that, by an exertion in dancing, after the muſcles of the leg were fatigued, he broke his tendo achillis. This accident, and the confinement in conſequence of it, led him to pay attention to the ſubject of broken tendons, and to make a ſeries of experiments to aſcertain the mode of their union.

In the year 1768 Mr Hunter became a member of the corporation of ſurgeons; and in the year following, through his brother's intereſt, he was elected one of the ſurgeon's of St George's hoſpital. In May 1771, his Treatiſe on the Natural Hiſtory of the Teeth was publiſhed; and in July of the ſame year he married Miſs Home, the eldeſt daughter of Mr Home, ſurgeon to Burgoyne's regiment of light horſe. The expence of his purſuits had been ſo great, that it was not till ſeveral years after his firſt engagement with this lady that his affairs could be ſufficiently arranged to admit of his marrying.

Though after his marriage his private practice and profeſſional character advanced rapidly, and though his family began to increaſe, he ſtill devoted much of his time to the forming of his collection, which, as it daily became larger, was alſo attended with greater expence. The whole ſuit of the beſt rooms in his houſe were occupied by his preparations; and he dedicated his mornings, from ſunriſe to eight o'clock (the hour for breakfaſt), entirely to his purſuits. To theſe he added ſuch parts of the day as were not engaged in attending his patients.

The knowledge he derived from his favourite ſtudies he conſtantly applied to the improvement of the art of ſurgery, and omitted no opportunity of examining morbid bodies; from which he made a collection of facts which are invaluable, as they tend to explain the real cauſes of ſymptoms, which, during life, could not be exactly aſcertained, the judgment of the practitioner being too frequently miſled by theoretical opinions, and deluſive ſenſations of the patients.

In the practice of ſurgery, where caſes occurred in which the operations proved inadequate to their intention, he always inveſtigated, with uncommon care, the cauſes of that want of ſucceſs; and in this way detected many fallacies, as well as made ſome important diſcoveries, in the healing art. He detected the cauſe of failure, common to all the operations in uſe for the radical cure of the hydrocele, and was enabled to propoſe a mode of operating, in which that event can with certainty be avoided. He aſcertained, by experiments and obſervations, that expoſure to atmoſpherical air ſimply, can neither produce nor increaſe inflammation. He diſcovered in the blood ſo many phenomena connected with life, and not to be referred to any other cauſe, that he conſidered it as alive in its fluid ſtate. He improved the operation for the fiſtula lachrymalis, by removing a circular portion of the os unguis inſtead of breaking it down with the point of a trochar. He alſo diſcovered that the gaſtric juice had a power when the ſtomach was dead of diſſolving it; and gave to the Royal Society a paper on this ſubject, which is publiſhed in the Philoſophical Tranſactions.

In the winter 1773, he formed a plan of giving a courſe of lectures on the theory and principles of ſurgery, with a view of laying before the public his own opinions upon that ſubject. For two winters he read his lectures *gratis* to the pupils of St George's Hoſpital; and in 1775, gave a courſe for money upon the ſame terms as the other teachers in the different branches of medicine and ſurgery. But giving lectures was always particularly unpleaſant to him; ſo that the deſire of ſubmitting his opinions to the world, and learning their general eſtimation, were ſcarcely ſufficient to overcome his natural diſlike to ſpeaking in public. He never gave the firſt lecture of his courſe without taking 30 drops of laudanum to take off the effects of his uneaſineſs.

Comparative anatomy may be conſidered as the purſuit in which Mr Hunter was conſtantly employed. No opportunity eſcaped him. In the year 1773, at the requeſt of his friend Mr Walſh, he diſſected the torpedo, and laid before the Royal Society an account of its electrical organs. A young elephant, which had been preſented to the Queen by Sir Robert Barker, died, and the body was given to Dr Hunter, which afforded Mr Hunter an opportunity of examining the ſtructure of that animal by aſſiſting his brother in the diſſection; ſince that time two other elephants died in the Queen's menagerie, both of which came under Mr Hunter's examination. In 1774, he publiſhed in the Philoſophical Tranſactions an account of certain receptacles of air in birds, which communicate with the lungs, and are lodged both among the fleſhy parts and hollow bones of theſe animals; and a paper on the Gillaroo trout, commonly called in Ireland the *Gizzard-trout*.

In 1775, ſeveral animals of that ſpecies, called the *gymnotus electricus of Surinam*, were brought alive to this country, and by their electrical properties excited very much the public attention. Mr Walſh, deſirous of purſuing his inveſtigations of animal electricity, made a number of experiments on the living animals; and to give his friend Mr Hunter an opportunity of examining them, purchaſed thoſe that died. An anatomical account of their electrical organs was drawn up by Mr Hunter, and publiſhed in the Philoſophical Tranſactions. In the ſame volume there is a paper of his, containing experiments on animals and vegetables reſpecting their power of producing heat.

In the courſe of his purſuits, Mr Hunter met with many parts of animals where natural appearances could not be preſerved, and others, in which the minuter veſſels could not be diſtinctly ſeen when kept in ſpirits; it was therefore neceſſary to have them drawn, either at the moment, or before they were put into bottles.

The expence of employing profeſſed draughtſmen, the difficulty of procuring them, and the diſadvantage which they laboured under in being ignorant of the ſubject they were to repreſent, made him deſirous of having an able perſon in his houſe entirely for that purpoſe.

With this view he engaged an ingenious young artiſt to live with him for ten years; his time to be wholly employed as a draughtſman, and in making anatomical preparations. This gentleman, whoſe name was Bell, ſoon became a very good practical anatomiſt, and from that knowledge was enabled to give a ſpirited and accurate reſemblance of the ſubjects he drew, ſuch as is rarely to be met with in repreſentations of anatomical ſubjects. By his labours Mr Hunter's collection is enriched with a conſiderable number of very valuable drawings, and a great variety of curious and delicate anatomical preparations.

In January 1776, Mr Hunter was appointed ſurgeon extraordinary to his Majeſty; and in the ſpring he gave to the Royal Society a paper on the beſt mode of recovering drowned perſons.

In the autumn he was taken extremely ill; and the nature of his complaints made his friends, as well as himſelf, conſider his life to be in danger. When he reflected upon his own ſituation, that all his fortune had been expended in his purſuits, and that his family had no proviſion but what ſhould ariſe from the ſale of his collection, he became very ſolicitous to give it its full value, by leaving it in a ſtate of arrangement. This he accompliſhed with the aſſiſtance of Mr Bell and his brother-in-law Mr Home.

In 1778, he publiſhed the ſecond part of his Treatiſe on the Teeth, in which their diſeaſes, and the mode of treatment are conſidered. This rendered his work upon that ſubject complete. He publiſhed alſo in the Philoſophical Tranſactions a paper on the Heat of Animals and Vegetables. In 1779, he publiſhed his account of the Free Martin in the Philoſophical Tranſactions; and in 1780, he laid before the Royal Society an account of a woman who had the ſmall pox during pregnancy, where the diſeaſe ſeemed to have been communicated to the fœtus.

In 1781, he was elected a fellow of the Royal Society of Sciences and Belles Lettres at Gottenburg. And in 1782, he gave the Royal Society a paper on the Organ of Hearing in Fiſh. Beſides the papers which he preſented to that learned body, he read ſix Croonion lectures upon the ſubject of Muſcular Action, for the years 1776, 1778, 1779, 1780, 1781, and 1782. In theſe lectures he collected all his obſervations, upon muſcles, reſpecting their powers and effects, and the ſtimuli by which they are affected; and to theſe he added Comparative Obſervations upon the moving Powers of Plants.

Theſe lectures were not publiſhed in the Philoſophical Tranſactions, for they were withdrawn as ſoon as read, not being conſidered by the author as complete diſſertations, but rather as materials for ſome future publication.

It is much to be regretted (ſays Mr Home) that Mr Hunter was ſo tardy in giving his obſervations to the public; but ſuch was his turn for inveſtigation, and ſo extenſive the ſcale upon which he inſtituted his inquiries, that he always found ſomething more to be accompliſhed, and was unwilling to publiſh any thing which appeared to himſelf unfiniſhed. His obſervations on the Muſcular Action of the Blood-veſſels were laid before the Royal Society in 1780, and yet he delayed publiſhing them till his Obſervations on the Blood and Inflammation were arranged; and they make part of the volume which was publiſhed after his death.

In 1783, he was choſen into the Royal Society of Medicine and the Royal Academy of Surgery in Paris; and the ſame year the leaſe of the houſe which he occupied in Jermyn-ſtreet having expired, he purchaſed the leaſe of a large houſe on the eaſt-ſide of Leiceſter-ſquare, and the whole lot of ground adjoining to Caſtle-ſtreet, on which there was another houſe. In the middle ſpace between the two houſes, he erected, at the expence of L. 3000, a building for his collection; though, unfortunately for his family, the leaſe did not extend beyond 24 years.

In the building formed for the collection there was a room fifty-two feet long by twenty-eight feet wide, lighted from the top, and having a gallery all round, for containing his preparations. Under this were two apartments; one for his lectures, and the other, with no particular deſtination at firſt, but afterwards made uſe of for weekly meetings of medical friends during the winter. To this building the houſe in Caſtle-ſtreet was entirely ſubſervient; and the rooms in it were uſed for the different branches of human and comparative anatomy.

About this period Mr Hunter may be conſidered as at the height of his chirurgical career; his mind and body were both in their full vigour. His hands were capable of performing whatever was ſuggeſted by his mind; and his judgment was matured by former experience. Some inſtances of his extraordinary ſkill may very properly be mentioned.

He removed a tumor from the ſide of the head and neck of a patient at St George's Hoſpital, as large as the head to which it was attached; and by bringing the cut edges of the ſkin together, the whole was nearly healed by the firſt intention.

He diſſected out a tumor on the neck, which one of the beſt operating ſurgeons in this country had declared, rather too ſtrongly, that no one but a fool or a madman would attempt; and the patient got perfectly well.

He diſcovered a new mode of performing the operation for the popliteal aneuriſm, by taking up the femoral artery on the anterior part of the thigh, without doing any thing to the tumor in the ham. The ſafety and efficacy of this mode have been confirmed by many ſubſequent trials; and it muſt be allowed to ſtand very high among the modern improvements in ſurgery.

If we conſider Mr Hunter at this period of his life, it will afford us a ſtrong picture of the turn of his mind, of his deſire to acquire knowledge, and his unremitting aſſiduity in proſecuting whatever was the object of his attention.

He was engaged in a very extenſive private practice; he was ſurgeon to St George's Hoſpital; he was giving a very long courſe of lectures in the winter; he was carrying on his inquiries in comparative anatomy; had a ſchool of practical human anatomy in his houſe; and was always employed in ſome experiments reſpecting the animal economy.

He was always ſolicious for ſome improvement in

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medical education; and, with the aſſiſtance of Dr Fordyce, inſtituted a medical ſociety, which he allowed to meet in his lecture rooms, and of which he was choſen one of the patrons. This ſociety, called the *Lyceum Medicum Londinenſe*, under his auſpices and thoſe of Dr Fordyce, has acquired conſiderable reputation, both from the numbers and merits of its members.

In the year 1786, in conſequence of the death of Mr Middleton, Mr Hunter was appointed deputy ſurgeon-general to the army. He now publiſhed his work upon the Venereal Diſeaſe, which had been long expected by the public; and, if we may judge from the rapid ſale of the firſt edition, theſe expectations have not been diſappointed. He alſo publiſhed a work entitled, Obſervations on certain Parts of the Animal Economy. In this work he has collected ſeveral of his papers inſerted in the Philoſophical Tranſactions, which related to that ſubject, having permiſſion from the preſident and council of the Royal Society to reprint them; there are alſo Obſervations upon ſome other parts of the Animal Economy, which had not before been publiſhed. This work met with a very ready ſale.

In the year 1787, he gave a paper to the Royal Society, containing an Experiment to determine the Effect of extirpating one Ovarium on the Number of Young; a paper in which the wolf, jackall, and dog, are proved to be of the ſame ſpecies; and a third upon the Anatomy of the Whale Tribe. Theſe papers procured him the honour of receiving Sir John Copley's annual gold medal, given as a mark of diſtinguiſhed abilities.

His collection, which had been the great object of his life, both as a purſuit and an amuſement, was now brought into a ſtate of arrangement; and gave him at length the ſatisfaction of ſhewing to the public a ſeries of anatomical facts formed into a ſyſtem, by which the economy of animal life was illuſtrated. He ſhewed it to his friends and acquaintances twice a-year, in October to medical gentlemen, and in May to noblemen and gentlemen, who were only in town during the ſpring. This cuſtom he continued to his death.

Upon the death of Mr Adair, which happened in the year 1792, Mr Hunter was appointed inſpector-general of hoſpitals, and ſurgeon-general to the army. He was alſo elected a member of the Royal College of Surgeons in Ireland. In the year 1791, he was ſo much engaged in the duties of his office, as ſurgeon-general to the army, and his private practice, that he had little time to beſtow upon his ſcientifical objects; but his leiſure time, ſmall as it was, he wholly devoted to them.

In 1792, he was elected an honorary member of the Chirurgo-Phyſical Society of Edinburgh, and was choſen one of the vice-preſidents of the Veterinary College, then firſt eſtabliſhed in London. He publiſhed in the Tranſactions of the Society for the Improvement of medical and chirurgical Knowledge, of which ſociety he was one of the original members and a zealous promoter, three papers on the following ſubjects: Upon the Treatment of Inflamed Veins, on Introſuſception, and on a Mode of conveying Food into the Stomach in Caſes of Paralyſis of the Œſophagus.

He finiſhed his Obſervations on the Economy of Bees, and preſented them to the Royal Society. Theſe obſervations were made at Earl's Court, and had engaged his attention for many years; every inquiry into the economy of theſe inſects had been attended by almoſt unſurmountable difficulties; but theſe proved to him only an incitement, and the contrivances he made uſe of to bring the different operations of theſe indefatigable animals to view were almoſt without end.

Earl's Court to Mr Hunter was a retirement from the fatigues of his profeſſion; but in no reſpect a retreat from his labours; there, on the contrary, they were carried on with leſs interruption, and with an unwearied perſeverance. From the year 1772 till his death, he made it his cuſtom to ſleep there during the autumn months, coming to town only during the hours of buſineſs in the forenoon, and returning to dinner.

It was there he carried on his experiments on digeſtion, on exfoliation, on the tranſplanting of teeth into the combs of cocks, and all his other inveſtigations on the animal economy, as well in health as in diſeaſe. The common bee was not alone the ſubject of his obſervation, but the waſp, hornet, and the leſs known kinds of bees, were alſo objects of his attention. It was there he made the ſeries of preparations of the external and internal changes of the ſilk worm; alſo a ſeries of the incubation of the egg, with a very valuable ſet of drawings of the whole ſeries. The growth of vegetables was alſo a favourite ſubject of inquiry, and one on which he was always engaged in making experiments.

The collection of comparative anatomy which Mr Hunter has left, and which may be conſidered as the great object of his life, muſt be allowed to be a proof of talents, aſſiduity, and labour, which cannot be contemplated without ſurpriſe and admiration. It remains an unequivocal teſt of his perſeverance and abilities, and an honour to the country in whoſe ſchools he was educated, and by the patronage of which he was enabled on ſo extenſive a ſcale to carry on his purſuits. In this collection we find an attempt to expoſe to view the gradations of Nature, from the moſt ſimple ſtate in which life is found to exiſt, up to the moſt perfect and moſt complex of the animal creation—man himſelf.

By the powers of his art, this collector has been enabled ſo to expoſe, and preſerve in ſpirits or in a dried ſtate, the different parts of animal bodies intended for ſimilar uſes, that the various links of the chain of perfection are readily followed and may be clearly underſtood.

This collection of anatomical facts is arranged according to the ſubjects they are intended to illuſtrate, which are placed in the following order: *Firſt*, Parts conſtructed for motion. *Secondly*, Parts eſſential to animals reſpecting their own internal economy. *Thirdly*, Parts ſuperadded for purpoſes connected with external objects. *Fourthly*, Parts for the propagation of the ſpecies and maintenance or ſupport of the young.

Mr Hunter was a very healthy man for the firſt forty years of his life; and, if we except an inflammation of his lungs in the year 1759, occaſioned moſt probably by his attention to anatomical purſuits, he had no complaint of any conſequence during that period. In the ſpring of 1769, in his forty-firſt year, he had a regular fit of the gout, which returned the three following ſprings, but not the fourth; and in the ſpring of 1773, having met with ſomething which very forcibly affected his mind, he was attacked at ten o'clock in the forenoon with a pain in the ſtomach, attended with all the ſymptoms of *angina pectoris*. In the life of him prefixed to his *Treatiſe on the Blood, Inflammation, and Gun-Shot Wounds*,

Wounds, the reader will find one of the moſt complete hiſtories of that diſeaſe upon record. Suffice it, in this place, to ſay, that for twenty years he was ſubject to frequent and ſevere attacks of it, which however did not, till a ſhort time before his death, either impair his judgment or render him incapable of performing operations in ſurgery. "In autumn 1790 (ſays Mr Home), and in the ſpring and autumn 1791, he had more ſevere attacks than during the other periods of the year, but of not more than a few hours duration: in the beginning of October 1792, one, at which I was preſent, was ſo violent that I thought he would have died. On October the 16th, 1793, when in his uſual ſtate of health, he went to St George's Hoſpital, and meeting with ſome things which irritated his mind, and not being perfectly maſter of the circumſtances, he withheld his ſentiments; in which ſtate of reſtraint he went into the next room, and turning round to Dr Robertſon, one of the phyſicians of the hoſpital, he gave a deep groan and dropt down dead; being then in his 65th year, the ſame age at which his brother Dr Hunter had died."

It is a curious circumſtance, that the firſt attack of theſe complaints was produced by an affection of the mind, and every future return of any conſequence aroſe from the ſame cauſe; and although bodily exerciſe, or diſtention of the ſtomach, brought on ſlighter affections, it ſtill required the mind to be affected to render them ſevere; and as his mind was irritated by trifles, theſe produced the moſt violent effects on the diſeaſe. His coachman being beyond his time, or a ſervant not attending to his directions, brought on the ſpaſms, while a real misfortune produced no effect.

Mr Hunter was of a ſhort ſtature, uncommonly ſtrong and active, very compactly made, and capable of great bodily exertion. His countenance was animated, open, and in the latter part of his life deeply impreſſed with thoughtfulneſs. When his print was ſhewn to Lavater, he ſaid, "That man thinks for himſelf." In his youth he was cheerful in his diſpoſition, and entered into youthful follies like others of the ſame age; but wine never agreed with his ſtomach; ſo that after ſome time he left it off altogether, and for the laſt twenty years drank nothing but water.

His temper was very warm and impatient, readily provoked, and, when irritated, not eaſily ſoothed. His diſpoſition was candid, and free from reſerve, even to a fault. He hated deceit; and as he was above every kind of artifice, he deteſted it in others, and too openly avowed his ſentiments. His mind was uncommonly active; it was naturally formed for inveſtigation, and that turn diſplayed itſelf on the moſt trivial occaſions, and always with mathematical exactneſs. What is curious, it fatigued him to be long in a mixed company which did not admit of connected converſation; more particularly during the laſt ten years of his life.

He required leſs relaxation than moſt other men; ſeldom ſleeping more than four hours in the night, but almoſt always nearly an hour after dinner; this, probably, aroſe from the natural turn of his mind being ſo much adapted to his own occupations, that they were in reality his amuſement, and therefore did not fatigue.

In private practice he was liberal, ſcrupulouſly honeſt in ſaying what was really his opinion of the caſe, and ready upon all occaſions to acknowledge his ignorance, whenever there was any thing which he did not underſtand.

In converſation, he ſpoke too freely, and ſometimes harſhly, of his contemporaries; but if he did not do juſtice to their undoubted merits, it aroſe not from envy, but from his thorough conviction that ſurgery was as yet in its infancy, and he himſelf a novice in his own art; and his anxiety to have it carried to perfection, made him think meanly and ill of every one whoſe exertions in that reſpect did not equal his own.

HUNTERS, in fortification, denote pieces of timber, about ſix inches ſquare, placed at the lower end of the platform, next to the parapet, to prevent the wheels of the gun-carriages from damaging the parapet.

HYDROGRAPHICAL Charts or Maps, more uſually called ſea-charts, are projections of ſome part of the ſea, or coaſt, for the uſe of navigation. In theſe are laid down all the rhumbs or points of the compaſs, the meridians, parallels, &c. with the coaſts, capes, iſlands, rocks, ſhoals, ſhallows, &c. in their proper places, and proportions.

HYDROMETER, is an inſtrument, of which ſo much has been ſaid in the *Encycl.* under that title, and in the article *Specific Gravity*, that we certainly ſhould not again introduce it in this place, but to guard our readers againſt error, when ſtudying the works of the French chemiſts. Theſe gentlemen, who are ſo ſtrongly attached to every thing which is new, as to believe that their anceſtors have for ages been wandering in the mazes of ignorance, refer very frequently to the *peſe-liqueur* of Baumé; and as that inſtrument has never been generally uſed in this country, it becomes our duty to deſcribe its conſtruction.

Inſtead of adopting the ſimpler method of immediate numerical reference to the denſity of water expreſſed by unity, as is done in all modern tables of ſpecific gravity, he had recourſe to a proceſs ſimilar to that of graduating the ſtems of thermometers from two fixed points. The firſt of theſe points was obtained by immerſing his inſtrument, which is the common areometer, conſiſting of a ball, ſtem, and counterpoiſe, in pure water. At that point of the ſtem which was interſected by the ſurface of the fluid, he marked *zero*, or the commencement of his graduations. In the next place, he provided a number of ſolutions of pure dry common ſalt in water: theſe ſolutions contained reſpectively one, two, three, four, &c. pounds of the ſalt; and in each ſolution the quantity of water was ſuch, as to make up the weight equal to one hundred pounds in the whole; ſo that in the ſolution containing one pound of ſalt, there were ninety-nine pounds of water; in the ſolution containing two pounds of ſalt, there were ninety-eight pounds of water, and ſo of the reſt. The inſtrument was then plunged in the firſt ſolution, in which of courſe it floated with a larger portion of the ſtem above the fluid, than when pure water was uſed. The fluid, by the interſection of its ſurface upon the ſtem, indicated the place for making his firſt degree; the ſame operation repeated, with the fluid containing two pounds of ſalt, indicated the mark for the ſecond degree; the ſolution of three pounds afforded the third degree; and in this manner his enumeration was carried as far as fifteen degrees. The firſt fifteen degrees afterwards, applied with the compaſſes repeatedly along the ſtem, ſerving to extend the graduation as far as eighty degrees, if required.

This inſtrument, which is applicable to the admeaſurement of denſities exceeding that of pure water, is commonly diſtinguiſhed by the name of the *Hydrometer for ſalts*.

The hydrometer for ſpirits is conſtructed upon the ſame principle; but in this the counterpoiſe is ſo adjuſted, that moſt part of the ſtem riſes above the fluid when immerſed in pure water, and the graduations to expreſs inferior denſities are continued upwards. A ſolution of ten parts by weight of ſalt in ninety parts of pure water, affords the firſt point, or zero, upon the ſtem; and the mark indicated by pure water is called the tenth degree; whence, by equal diviſions, the remaining degrees are continued upwards upon the ſtem as far as the fiftieth degree.

Theſe experiments, in both caſes, are made at the tenth degree of Reaumur, which anſwers very nearly to fifty-five of Fahrenheit.

HYDRUS, or WATER SERPENT, one of the new ſouthern conſtellations, including only ten ſtars.

HYGROMETER, is an inſtrument of ſo much importance to the meteorologiſt, that it becomes us to give ſome account of every improvement of it which has fallen under our notice. In the *Encyclopædia*, the principles upon which hygrometers are conſtructed have been clearly ſtated, and the defects of each kind of hygrometer pointed out.

Inſtead of hairs or cat-gut, of which hygrometers of the firſt kind are commonly made, Caſſebois, a Benedictine monk at Mentz, propoſed to make ſuch hygrometers of the gut of a ſilk-worm. When that inſect is ready to ſpin, there are found in it two veſſels proceeding from the head to the ſtomach, to which they adhere, and then bend towards the back, where they form a great many folds. The part of theſe veſſels next the ſtomach is of a cylindric form, and about a line in diameter. Theſe veſſels contain a gummy ſort of matter from which the worm ſpins its ſilk; and, though they are exceedingly tender, means have been deviſed to extract them from the inſect, and to prepare them for the above purpoſe. When the worm is about to ſpin, it is thrown into vinegar, and ſuffered to remain there twenty-four hours; during which time the vinegar is abſorbed into the body of the inſect, and coagulates its juices. The worm being then opened, both the veſſels, which have now acquired ſtrength, are extracted; and, on account of their pliability, are capable of conſiderable extenſion. That they may not, however, become too weak, they are ſtretched only to the length of about fifteen or twenty inches. It is obvious that they muſt be kept ſufficiently extended till they are completely dry. Before they attain to that ſtate, they muſt be freed, by means of the nail of the finger, from a ſlimy ſubſtance which adheres to them. Such a thread will ſuſtain a weight of ſix pounds without breaking, and may be uſed for an hygrometer in the ſame manner as cat-gut; but we confeſs that we do not clearly perceive its ſuperiority.

To an improvement of the hygrometer conſtructed on the third principle, ſtated in the *Encyclopædia*, M. Hochheimer was led in the following manner:

Mr Lowitz found at Dmitriewſk in Aſtracan, on the banks of the Wolga, a thin bluiſh kind of ſlate which attracted moiſture remarkably ſoon, but again ſuffered it as ſoon to eſcape. A plate of this ſlate weighed, when brought to a red heat, 175 grains, and, when ſaturated with water, 247: it had therefore imbibed, between complete dryneſs and the point of complete moiſture, 72 grains of water. Lowitz ſuſpended a round thin plate of this ſlate at the end of a very delicate balance, faſtened within a wooden frame, and ſuſpended at the other arm a chain of ſilver wire, the end of which was made faſt to a ſliding nut that moved up and down in a ſmall groove on the edge of one ſide of the frame. He determined, by trial, the poſition of the nut when the balance was in equilibrio and when it had ten degrees of over-weight, and divided the ſpace between theſe two points into ten equal parts, adding ſuch a number more of theſe parts as might be neceſſary. When the ſtone was ſuſpended from the one arm of the balance, and at the other a weight equal to 175 grains, or the weight of the ſtone when perfectly dry, the nut in the groove ſhewed the exceſs of weight in grains when it and the chain were ſo adjuſted that the balance ſtood in equilibrio. A particular apparatus on the ſame principles as a vernier, applied to the nut, ſhewed the exceſs of weight to ten parts of a grain. Lowitz remarked that this hygrometer in continued wet weather gave a moiſture of more than 55 grains, and in a continued heat of 113 degrees of Fahrenheit only 1½ degree of moiſture.

The hygrometer thus invented by Lowitz was, however, attended with this fault, that it never threw off the moiſture in the ſame degree as the atmoſphere became drier. It was alſo ſometimes very deceitful, and announced moiſture when it ought to have indicated that dryneſs had again begun to take place in the atmoſphere. To avoid theſe inconveniences, M. Hochheimer propoſes the following method:

1. Take a ſquare bar of ſteel about two lines in thickneſs, and from ten to twelve inches in length, and form it into a kind of balance, one arm of which ends in a ſcrew. On this ſcrew let there be ſcrewed a leaden bullet of a proper weight, inſtead of the common weights that are ſuſpended. 2. Take a glaſs plate about ten inches long, and ſeven inches in breadth, deſtroy its poliſh on both ſides, free it from all moiſture by rubbing it over with warm aſhes, ſuſpend it at the other end of the balance, and bring the balance into equilibrium by ſcrewing up or down the leaden bullet. 3. Mark now the place to which the leaden bullet is brought by the ſcrew, as accurately as poſſible, for the point of the greateſt dryneſs. 4. Then take away the glaſs plate from the balance, dip it completely in water, give it a ſhake that the drops may run off from it, and wipe them carefully from the edge. 5. Apply the glaſs-plate thus moiſtened again to the balance, and bring the latter into equilibrium by ſcrewing the leaden bullet. Mark then the place at which the bullet ſtands as the higheſt degree of moiſture. 6. This apparatus is to be ſuſpended in a ſmall box of well dried wood, ſufficiently large to ſuffer the glaſs-plate to move up and down. An opening muſt be made in the lid, exactly of ſuch a ſize as to allow the tongue of the balance to move freely. Parallel to the tongue apply a graduated circle, divided into a number of degrees at pleaſure from the higheſt point of dryneſs to the higheſt degree of moiſture. The box muſt be pierced with ſmall holes on all the four ſides, to give a free paſſage to the air; and to prevent moiſture from penetrating into

into the wood by rain, when it may be requiſite to expoſe it at a window, it muſt either be lackered or painted. To ſave it at all times from rain, it may be covered, however, with a ſort of roof fitted to it in the moſt convenient manner. But all theſe external appendages may be improved or altered as may be found neceſſary.

HYPERBOLA Deficient, is a curve having only one aſymptote, though two hyperbolic legs running out infinitely by the ſide of the aſymptote, but contrary ways.

HYPOTRACHELION, in Architecture, is uſed for a little frize in the Tuſcan and Doric capital, between the aſtragal and annulets; called alſo the colerin and gorgerin. The word is applied by ſome authors in a more general ſenſe, to the neck of any column, or that part of its capital below the aſtragal.

I.

JACOBINS, in the language of the preſent day, is the name aſſumed, at the beginning of the French revolution, by a party in Paris, which was outrageouſly democratical, and fanatically impious. This party, which conſiſted of members of the National Aſſembly, and of others maintaining the ſame opinions and purſuing the ſame objects, formed itſelf into a club, and held its meetings in the hall belonging to the Jacobin friars, where meaſures were ſecretly concerted for exciting inſurrections, and over-awing at once the legiſlature and the king. The name of *Jacobin*, though it was derived from the hall where the club firſt met, has ſince been extended to all who are enemies to monarchy, ariſtocracy, and the Chriſtian religion; and who would have every man to be his own prieſt and his own lawgiver. Hence it is, that we have Jacobins in Great Britain and Ireland, as well as in France.

Of the proceedings of the French Jacobins, ſome account has been given in the *Encyclopædia*, under the title Revolution; and the ſubject will be reſumed in this *Supplement* under the ſame title. The purpoſe of the preſent article is to trace the principles of the ſect from their ſource; for theſe principles are not of yeſterday.

"At its very firſt appearance (ſays the Abbé Barruel), this ſect counted 300,000 adepts; and it was ſupported by two millions of men, ſcattered through France, armed with torches and pikes, and all the firebrands of the revolution." Such a wide ſpread conſpiracy could not be formed in an inſtant; and indeed this able writer has completely proved, that this ſect, with all its conſpiracies, is in itſelf no other than "the coalition of a triple ſect, of a triple conſpiracy, in which, long before the revolution, the overthrow of the altar, the ruin of the throne, and the diſſolution of all civil ſociety, had been debated and determined."

It is known to every ſcholar, that there have been in all ages and countries men of letters and pretenders to letters, who have endeavoured to ſignalize themſelves individually by writing againſt the religion of their country; but it was reſerved for the philoſophiſts (A) of France to enter into a combination for the expreſs purpoſe of eradicating from the human heart every religious ſentiment. The man to whom this idea firſt ocurred was Voltaire; who, daring to be jealous of his God, and being weary, as he ſaid himſelf, of hearing people repeat that twelve men were ſufficient to eſtabliſh Chriſtianity, reſolved to prove that one might be ſufficient to overthrow it. Full of this project, he ſwore, before the year 1730, to dedicate his life to its accompliſhment; and for ſome time he flattered himſelf that he ſhould enjoy alone the glory of deſtroying the Chriſtian religion. He found, however, that aſſociates would be neceſſary; and from the numerous tribe of his admirers and diſciples, he choſe D'Alembert and Diderot as the moſt proper perſons to co-operate with him in his deſigns. How admirably they were qualified to act the part aſſigned them, may be conceived from the life of Diderot in this *Supplement*. But Voltaire was not ſatisfied with their aid alone.

He contrived to embark in the ſame cauſe Frederic II. of Pruſſia, who wiſhed to be thought a philoſopher, and who of courſe deemed it expedient to talk and write againſt a religion which he had never ſtudied, and into the evidence of which he had probably never deigned to inquire. This royal adept was one of the moſt zealous of Voltaire's coadjutors, till he diſcovered that the philoſophiſts were waging war with the throne as well as with the altar. This indeed was not originally Voltaire's intention. He was vain; he loved to be careſſed by the great; and, in one word, he was, from natural diſpoſition, an ariſtocrate and admirer of royalty: But when he found that almoſt every ſovereign but Frederic, diſapproved of his impious projects as ſoon *as he perceived their iſſue*, he determined to oppoſe all the governments on earth, rather than forfeit the glory, with which he had flattered himſelf, of vanquiſhing Chriſt and his apoſtles in the field of controverſy.

He now ſet himſelf, with D'Alembert and Diderot, to excite univerſal diſcontent with the eſtabliſhed order of things. This was an employment entirely ſuited to their diſpoſition; for not being in any ſenſe *great* themſelves (B), they wiſhed to pull all men down to their own level. How effectually they contrived to convert the *Encyclopedie* into an engine to ſerve their purpoſes, has been ſhewn already; but it was not their only nor their moſt powerful engine; they formed ſecret ſocie-

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(A) This term was invented by Abbé Barruel, and we have adopted it, as denoting ſomething very different from the meaning of the word *philoſopher*.

(B) We do not by this mean to inſinuate that D'Alembert was not a man of ſcience. He was perhaps the only man of ſcience in that gang; but he was a maſter of no ſcience but mathematics; and his birth being ob-

Jacobins.

ties, aſſumed new names, and employed an enigmatical language. Thus, Frederic is called *Luc*: D'Alembert, *Protagoras*, and ſometimes *Bertrand*; Voltaire, *Raton*; and Diderot, *Platon*, or its anagram *Tonpla*; while the general term for the conſpirators is *Cacouac*. In their ſecret meetings they profeſſed to celebrate the myſteries of *Mythra*; and their great object, as they profeſſed to one another, was to confound the *wretch*, meaning J— C—. Voltaire propoſed to eſtabliſh a colony of philoſophiſts at Cleves, who. protected by the king of Pruſſia, might publiſh their opinions without dread or danger; and Frederic was diſpoſed to take them under his protection, till he diſcovered that their opinions were anarchical, as well as impious, when he threw them off, and even wrote againſt them.

They contrived, however, to engage the miniſters of the court of France in their favour, by pretending to have nothing in view but the enlargement of ſcience, in works which ſpoke indeed reſpectfully of revelation, while every diſcovery which they brought forward was meant to undermine its very foundation. When the throne was to be attacked, and even when barefaced atheiſm was to be promulgated, a number of impious and licentious pamphlets were diſperſed, for ſome time none knew how, from a ſecret ſociety formed at the Hotel d'Holbach at Paris. Theſe were ſold for trifles, or diſtributed *gratis* to ſchoolmaſters, and others who were likely to circulate their contents. D'Alembert, Diderot, and Condorcet, who was now aſſociated with the other conſpirators, flattered the ambition of every man among the great, and eſpecially of the Duke d'Orleans, the richeſt ſubject in Europe, and a prince of the blood of France. The firſt and the laſt of theſe three adepts had, by their mathematical knowledge, got ſuch an aſcendancy in the Royal Academy of Sciences, that they could admit or exclude candidates as they knew them to be friendly or inimical to the projects of the conſpirators; and they had contrived, by matchleſs addreſs and unwearied perſeverance, to fill almoſt all the ſeminaries of education with men of their own principles.

Thus was the public mind in France completely corrupted, when the maſon lodges, over which the infamous Orleans preſided, were viſited by a delegation from the German illuminati; and nothing more was neceſſary to produce the ſect of *Jacobins*, by whoſe intrigues and influence, France, as M. Barruel expreſſes himſelf, has become a prey to every crime. It was by the machinations of this ſect that its ſoil was ſtained with the blood of its pontiffs and prieſts, its rich men and nobles; with the blood of every claſs of its citizens, without regard to rank, age, or ſex. Theſe diſciples of Voltaire were the men who, after having made the unfortunate Louis, his queen, and ſiſter, drink, to the very dregs, the cup of outrage and ignominy during a long confinement, ſolemnly murdered them on a ſcaffold, proudly menacing all the ſovereigns of the earth with a ſimilar fate. Yet think not, indignant reader, that the ways of Providence are unequal. The nations of Europe were ripe for chaſtiſement; and that chaſtiſement theſe villains were employed to inflict: but their own puniſhment did not linger. Voltaire died in agonies of deſponding remorſe, which can be exceeded only by the torments of the damned. There is reaſon to believe that the end of D'Alembert and Diderot very much reſembled that of their leader; while the more hardened adept, Condorcet, became his own executioner; and the other chiefs of the rebellion have regularly inflicted vengeance on each other, every alteration of the French conſtitution (and theſe alterations have been many) being followed by the execution of thoſe by whom the government was previouſly adminiſtered.

Jaghire || Jago.

JAGHIRE, aſſignment made in Bengal by an Imperial grant upon the revenue of any diſtrict, to defray civil or military charges, penſions, gratuities, &c.

JAGHIREDER, the holder of a Jaghire.

St JAGO, the largeſt and moſt populous of the Cape de Verde Iſlands, of which ſome account has been given in the *Encyclopædia*, is repreſented by Sir George Staunton as liable to long and exceſſive droughts, for which no philoſophical cauſe can be aſſigned. When the embaſſy to China touched at it in the latter end of 1792, it was in a ſtate of abſolute famine. Little or no rain had fallen for about three years before. The rivers were almoſt all entirely dry. The ſurface of the earth was, in general, naked of any herbage. The greateſt part of the cattle had periſhed, not leſs through drought than want of food. Of the inhabitants many had migrated, and many were famiſhed to death. Nor was this calamity peculiar to St Jago. All the iſlands of Cape de Verde were ſaid to have experienced the ſame long drought, and to be conſequently in a ſtate of ſimilar deſolation. Yet the frequent ſhowers which were obſerved by the firſt navigators who touched at St Jago, induced them to give to the iſland the name of *Pluvialis*; and no change had been obſerved in the ſteady current of wind, blowing from the eaſt, which is common to tropical climates.

"What were the uncommon circumſtances (ſays Sir George) that took place in the atmoſphere of that part of Africa to which the Cape de Verde iſlands lie contiguous, or in the vaſt expanſe of continent extending to the eaſt behind it, and from which this direful effect muſt have proceeded, as they happened where no man of ſcience exiſted to obſerve or to record them, will therefore remain unknown; nor is theory bold enough to ſupply the place of obſervation. Whatever was the cauſe which thus arreſted the bountiful hand of Nature, by drawing away the ſources of fertility, it was obſervable, that ſome few trees and plants perſevered to flouriſh with a luxuriance, indicating that they ſtill could extract from the arid earth whatever portion of humidity it was neceſſary to derive from thence for the purpoſe of vegetable life, though it was denied to others."

Beſide the trees of the palm kind, which are often found verdant amidſt burning ſands, nothing, for example, could be more rich in flavour, or abound more with milky, though corroſive juice, than the aſclepias gigantea (ſee Asclepias, *Encycl.*), growing plentifully, about ſeveral feet high, without culture, indeed, but undiſturbed, it being of no avail to cut it down in favour of plants that would be uſeful, but required the aid of more moiſture from the atmoſphere. The jatropha

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ſcure, if not ſpurious, and abſtract mathematics not furniſhing ready acceſs to the great, his ideas, when compared with Voltaire's, were grovelling, and (as M. Barruel ſays) he was afraid to be ſeen.

pha curcas, or phyſic nut tree, which the French Weſt Indians, with ſome propriety, call *bois immortel*, and plant, on that account, in the boundaries of their eſtates, appeared as if its perpetuity was not to be affected by any drought. Some indigo plants were ſtill cultivated with ſucceſs in ſhaded vales, together with a few cotton ſhrubs. Throughout the country ſome of thoſe ſpecies of the mimoſa, or ſenſitive plant, which grow into the ſize of trees, were moſt common, and did not appear to languiſh. In particular ſpots the annona, or ſugar apple tree, was in perfect verdure. The boraſſus, or great fan palm, lifted, in a few places, its lofty head and ſpreading leaves with undiminiſhed beauty. In a bottom, about a mile and a half behind the town of Praya, was ſtill growing, in a healthy ſtate, what may be called for ſize a phenomenon in vegetation, a tree known to botaniſts by the name of adanſonia, and in Engliſh called *monkey bread tree*. The natives of St Jago call it *kaliſera*; others, baobab. Its trunk meaſured at the baſe no leſs than 56 feet in girth; but it ſoon divided into two great branches, one riſing perpendicularly, and meaſuring 42 feet in circumference; that of the other was about 26. By it ſtood another of the ſame ſpecies, whoſe ſingle trunk, of 38 feet girth, attracted little notice from the vicinity of its huge companion.

But the annual produce of agriculture was ſcarcely to be found. The plains and fields, formerly productive of corn, ſugar-canes, or plaintains, nouriſhed by regular falls of rain, now bore little ſemblance of vegetation. Yet in the ſmall number of plants which ſurvived the drought, were ſome which, from the ſpecimens ſent to Europe, were found to have been hitherto unknown. Vegetation quickly, indeed, revived wherever, through the ſoil, any moiſture could be conveyed.

Sir George repreſents Praya, the reſidence of the Portugueſe Viceroy, as a hamlet rather than a town. It conſiſts of about 100 very ſmall dwellings, one ſtory high, ſcattered on each ſide of the plain, which extended near a mile in length, and about the third of a mile in breadth; and fell off, all around, to the neighbouring valleys and to the ſea. Not being commanded by any neighbouring eminence, it was a ſituation capable of defence; the fort, however, or battery, was almoſt in ruins; and the few guns mounted on it were moſtly honey-combed, and placed on carriages which ſcarcely held together.

A party belonging to the embaſſy croſſed the country to the ruins of St Jago, the former capital of the iſland, ſituated in the bottom of a vale, through which ran a ſtream, then both ſmall and ſluggiſh. On each ſide of that ſtream are the remains of dwellings of conſiderable ſolidity and ſize; and the fragments of glaſs luſtres, ſtill hanging from the ceilings of ſome of the principal apartments, denote the elegance or riches that were once diſplayed in this now deſerted place. Not above half a dozen families remain in it at preſent; the reſt abandoned it, or periſhed. Here was ſtill, however, an attempt at a ſlight manufactory of ſtripped cotton ſlips, the ſame as are made in the other parts of the iſland, for the uſe of the Africans on the main, who pay for them in ſlaves, elephants teeth, and that gum which is generally called arabic.

Amidſt the ruins of St Jago, the party found a Portugueſe, to whom one of them was recommended, and who received them with the moſt cordial hoſpitality in his houſe, and treated them with every ſpecies of tropical fruits from his garden, lying on each ſide the river.

He had been a navigator; and informed them that the iſle of Brava, one of the Cape de Verde's, was a fitter and ſafer place for ſhips to call at for water and proviſions than the iſland of St Jago; that it had three harbours: one called Puerto Furno on the eaſt ſide of the iſland, from which veſſels muſt warp, or be towed out by boats; the Puerto Fajendago to the weſt; and the Puerto Ferreo to the ſouth, which was the beſt for large ſhips, and into which runs a ſmall river. In another of the Cape de Verde iſlands, called San Vicente, he obſerved that there was alſo a large harbour on the north end, but that freſh water was at ſome diſtance from it: and there was likewiſe a good port at Bonaviſta. This information of the harbours in the iſle of Brava was confirmed by accounts given by others to Sir Eraſmus Gower, who recommends to make a trial of them.

JALOFFS, or YALOFFS, are an active, powerful, and warlike people, inhabiting great part of that tract of Africa which lies between the Senegal and the Mandingo ſtates on the Gambia (See MANDINGOES in this *Supplement*). Their noſes, ſays Mr Park, are not ſo much depreſſed, nor their lips ſo protuberant, as thoſe of the generality of Africans; and though their ſkin is of the deepeſt black, they are conſidered by the white traders as the moſt ſightly negroes in that part of the continent where they live. They are divided into ſeveral independent ſtates or kingdoms, which are frequently at war with their neighbours or with each other. In their manners, ſuperſtitions, and government, they have a greater reſemblance to the Mandingoes than to any other nation; but excel them in the manufacture of cotton cloth, ſpinning the wool to a finer thread, weaving it in a broader loom, and dyeing it of a better colour. They make very good ſoap, by boiling ground nuts in water, and then adding a ley of wood aſhes. They likewiſe manufacture excellent iron, which they carry to Bondou to barter for ſalt. Their language is ſaid to be copious and ſignificant, and is often learned by Europeans trading to Senegal. From the names of their numerals, as given by Mr Park, it would appear that their numeration proceeds by *fives*, as ours does by *tens*.

Our author relates the event of a religious war, which, as it diſplays a generoſity of character very uncommon among ſavages, will afford pleaſure to the minds of many of our readers. Almami Abdulkader, ſovereign of a Mahomedan kingdom called Foota Torra, ſent to Damel, a king of the Jaloffs, an imperious meſſage, commanding him and his ſubjects to embrace inſtantly the faith of the prophet. The ambaſſador having got admiſſion to the preſence of Damel, ordered ſome Buſhreens (*i. e.* Mahomedan negroes) who accompanied him, to preſent the emblems of his miſſion. Two knives were accordingly laid before the Jaloff prince, and the ambaſſador explained himſelf as follows:

"With this knife (ſaid he) Abdulkader will condeſcend to ſhave the head of Damel, if Damel will embrace the Mahomedan faith; and with this other knife Abdulkader will cut the throat of Damel, if Damel refuſes to embrace it: Take your choice."—Damel coolly told the ambaſſador that he had no choice to make:

he neither choſe to have his head ſhaved, nor his throat cut. And with this anſwer the ambaſſador was civilly diſmiſſed.

Abdulkader took his meaſures accordingly; and with a powerful army invaded Damel's country. The inhabitants of the towns and villages filled up their wells, deſtroyed their proviſions, carried off their effects, and abandoned their dwellings, as he approached. By this means he was led on from place to place, until he had advanced three days journey into the country of the Jaloffs. He had, indeed, met with no oppoſition; but his army had ſuffered ſo much from the ſcarcity of water, that ſeveral of his men died by the way. This induced him to direct his march towards a watering place in the woods, where his men, having quenched their thirſt, and being overcome with fatigue, lay down careleſsly to ſleep among the buſhes. In this ſituation they were attacked by Damel before day-break, and completely routed. Many of them were trampled to death as they lay aſleep by the Jaloffs horſes; others were killed in attempting to make their eſcape; and a ſtill greater number were taken priſoners. Among the latter was Abdulkader himſelf. This ambitious, or rather frantic prince, who, but a month before, had ſent the threatening meſſage to Damel, was now himſelf led into his preſence as a miſerable captive. The behaviour of Damel, on this occaſion, is never mentioned by the ſinging men* but in terms of the higheſt approbation; and it was, indeed, ſo extraordinary in an African prince, that the reader may find it difficult to give credit to the recital. When his royal priſoner was brought before him in irons, and thrown upon the ground, the magnanimous Damel, inſtead of ſetting his foot upon his neck, and ſtabbing him with his ſpear, according to the cuſtom in ſuch caſes, addreſſed him as follows: "Abdulkader, anſwer me this queſtion. If the chance of war had placed me in your ſituation, and you in mine, how would you have treated me?" "I would have thruſt my ſpear into your heart (returned Abdulkader with great firmneſs); and I know that a ſimilar fate awaits me." "Not ſo (ſaid Damel); my ſpear is indeed red with the blood of your ſubjects killed in battle, and I could now give it a deeper ſtain, by dipping it in your own; but this would not build up my towns, nor bring to life the thouſands who fell in the woods. I will not therefore kill you in cold blood, but I will retain you as my ſlave, until I perceive that your preſence in your own kingdom will be no longer dangerous to your neighbours; and then I will conſider of the proper way of diſpoſing of you." Abdulkader was accordingly retained, and worked as a ſlave for three months; at the end of which period, Damel liſtened to the ſolicitations of the inhabitants of Foota Torra, and reſtored to them their king. Strange as this ſtory may appear, Mr Park has no doubt of the truth of it. It was told to him at Malacotta by the negroes; it was afterwards related to him by the Europeans on the Gambia; by ſome of the French at Goree; and confirmed by nine ſlaves, who were taken priſoners along with Abdulkader by the watering place in the woods, and carried in the ſame ſhip with him to the Weſt Indies.—Such generoſity as this reflects honour on human nature.

JARRA, is a town of conſiderable extent in the Mooriſh kingdom of Ludamar in Africa. The houſes are built of clay and ſtone intermixed, a kind of wall very common in many parts of Scotland, where clay is made to ſupply the place of mortar. The greater part of the inhabitants of Jarra are Negroes from the borders of the ſouthern ſtates, who prefer, ſays Mr Park, a precarious protection under the Moors, which they purchaſe by a tribute, to the being continually expoſed to their predatory hoſtilities. The tribute which they pay is conſiderable; and they manifeſt the moſt unlimited obedience and ſubmiſſion to their Mooriſh ſuperiors: by whom they are, in return, treated with the utmoſt indignity and contempt. The Moors in this, and the other ſtates adjoining the country of the Negroes, reſemble in their perſons the Mulattoes of the Weſt Indies, and ſeem to be a mixed race between the Moors, properly ſo called, of the north, and the Negroes of the ſouth; poſſeſſing many of the worſt qualities of both nations. Jarra is ſituated in 15° 5′ N. Lat. and 6° 48′ E. Long.

IBIS. Under the generic name TANTALUS *(Encycl.)*, we have deſcribed, after Mr Bruce, a bird which he found in Abyſſinia, and concluded to be the ſacred ibis of ancient Egypt. M. Vaillant, during his laſt travels in Africa, found, in ſome lakes near the elephants river, a bird very different from Mr Bruce's, which he conſidered as belonging to the ſame ſpecies; and which he deſcribes thus: It is three feet in height. Its head and throat, which are extremely bare, are covered with a ſkin of the brighteſt red, terminated by a band of a beautiful orange, which ſeparates the naked part from that covered with feathers. The upper part of the wings, having broad ſtripes of a fine violet colour, agreeably ſhaded, is bordered by a white band of feathers, the thick and ſilky beards of which, ſeparated from each other, have a perfect reſemblance to a rich fringe. The quills of the wings and tail are of a greeniſh black, which, as it receives the light in a more or leſs oblique direction, aſſumes the appearance of violet or purple. The reſt of the plumage is of a beautiful white. The bill, which is long and ſomewhat crooked, is yellow; as are the feet. This bird belongs to the genus of the ibis, of which we are already acquainted with ſeveral ſpecies.

ICE-HOUSE. See that article, *Encyclopædia*. Profeſſor Beckmann, in the third volume of his Hiſtory of Inventions, has proved clearly that the ancients were well acquainted with what ſerved the purpoſe of ice-houſes.

"The art (ſays he) of preſerving ſnow for cooling liquors during the ſummer, in warm countries, was known in the earlieſt ages. This practice is mentioned by Solomon *, and proofs of it are ſo numerous in the works of the Greeks and the Romans, that it is unneceſſary for me to quote them, eſpecially as they have been collected by others. How the repoſitories for keeping it were conſtructed, we are not expreſsly told; but it is probable that the ſnow was preſerved in pits or trenches.

"When Alexander the Great beſieged the city of Petra, he cauſed 30 trenches to be dug, and filled with ſnow, which was covered with oak branches; and which kept in that manner for a long time. Plutarch ſays, that a covering of chaff and coarſe cloth is ſufficient; and at preſent a like method is purſued in Portugal. Where the ſnow has been collected in a deep gulph,

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* *The hiſtorians of the country.*

* *Proverbs*, xxv. 15.

ſome graſs or green ſods, covered with dung from the ſheep pens, is thrown over it; and under theſe it is ſo well preſerved, that the whole ſummer through it is ſent the diſtance of 60 Spaniſh miles to Liſbon.

"When the ancients, therefore, wiſhed to have cooling liquors, they either drank the melted ſnow, or put ſome of it in their wine, or they placed jars filled with wine in the ſnow, and ſuffered it to cool there as long as they thought proper. That ice was alſo preſerved for the like purpoſe, is probable from the teſtimony of various authors; but it appears not to have been uſed ſo much in warm countries as in the northern. Even at preſent ſnow is employed in Italy, Spain, and Portugal; but in Perſia ice. I have never any where found an account of Grecian or Roman ice-houſes. By the writers on agriculture they are not mentioned."

ICHNOGRAPHY, in architecture, is a tranſverſe or horizontal ſection of a building, exhibiting the plot of the whole edifice, and of the ſeveral rooms and apartments in any ſtory; together with the thickneſs of the walls and partitions; the dimenſions of the doors, windows, and chimneys; the projectures of the columns and piers, with every thing viſible in ſuch a ſection.

JEBB (John), was born in Southampton-ſtreet, Covent Garden, London, on the 16th of February 1736. He was the eldeſt ſon of the Rev. John Jebb, dean of Caſhel, in the kingdom of Ireland. He received the elements of his education in different ſchools, and was admitted, July 7. 1753, penſioner in the univerſity of Dublin, whence he removed, November the 9th 1754, to St Peter's college in Cambridge, where he was likewiſe a penſioner. In January 1757 he proceeded to the degree of B. A. and his place in the diſtribution of academical honours was, on that occaſion, ſecond wrangler, the late eminent mathematician Dr Waring being the firſt. In 1758 he obtained the ſecond prize of fifteen guineas, annually given by the univerſity to the authors of the beſt compoſitions in Latin proſe, being ſenior or middle bachelors of arts. Dr Roberts, afterwards provoſt of Eton college, obtained the firſt.

In the month of June 1760, Mr Jebb was admitted probationer fellow of St Peter's college, and proceeded to the degree of Maſter of Arts at the commencement in the ſame year; and on the firſt of July 1761, was confirmed fellow by Dr Mawſon, biſhop of Ely.

On the 6th of June 1762, he was ordained deacon at Bugden by Dr John Green, biſhop of Lincoln; and on the 25th of September, 1763, he was admitted by the ſame biſhop into prieſt's orders.

On the 22d of Auguſt, 1764, Mr Jebb was collated by Dr Matthias Mawſon, biſhop of Ely, to the ſmall vicarage of Gamlingay, near Potton, in Bedfordſhire, upon the recommendation of Dr Law, maſter of Peterhouſe. On the 17th of the following October, he was elected by the univerſity into the rectory of Ovington, near Watton, in Norfolk, after a competition with the Rev. Henry Turner, then fellow of St John's college, afterwards vicar of Burwell, in Cambridgeſhire. Upon caſting up the votes, there appeared to be for Mr Jebb 91, for Mr Turner 73; and accordingly he was inſtituted into the ſame the 15th of December following.

On the 29th of the ſame month, (December 1764). Mr Jebb married Anne, eldeſt daughter of the Rev. James Torkington, rector of Little Stukeley, in Huntingdonſhire, and of lady Dorothy Sherard, daughter of Philip, ſecond earl of Harborough.

Early in the year 1765, Mr Jebb, together with the Rev. Robert Thorpe, fellow of Peterhouſe, and the Rev. George Woolſton, fellow of Sidney college, publiſhed, in a ſmall quarto, a comment on thoſe parts of Sir Iſaac Newton's *Principia* which more immediately relate to the ſyſtem of the world. The title of the joint work of theſe able and judicious philoſophers was, "Excerpta quædam e Newtoni principiis philoſophiæ naturalis, cum notis variorum." A work, of which the univerſity of Cambridge continues to bear teſtimony to the excellence, by the general uſe of it in the courſe of academical education.

Mr Chappelow profeſſor of Arabic, dying on the 14th of January 1768, Mr Jebb offered himſelf a candidate for the vacant chair; but it was given to Dr Hallifax, afterwards biſhop of Glouceſter; a man of deſerved celebrity, of whom we regret that it was not in our power to give a biographical ſketch.

On July 10. 1769, Mr Jebb was inſtituted to the vicarage of Flixton, near Bungay, in Suffolk, on the preſentation of William Adair, Eſq. of Flixton-hall; and on the 4th of April 1770, was inſtituted to the united rectories of Homersfield and St Croſs, pariſhes contiguous to Flixton, upon the ſame preſentation: being alſo, in the ſummer of the ſame year, nominated chaplain to Robert earl of Harborough. In conſequence of the acceſſion of theſe preferments, though not conſiderable in themſelves, he reſigned, ſome time in the month of October 1771, the rectory of Ovington, which he had received from the univerſity; and Mr Sheepſhanks, fellow of St John's college, was elected in his place.

Dr Hallifax ſucceeding to the profeſſorſhip of civil law, in the month of October 1770, upon the death of Dr Ridlington, Mr Jebb once more ſolicited that of Arabic, which Dr Hallifax then vacated: but he had by this time diſplayed ſuch an innovating ſpirit in religion, that the univerſity gave the vacant profeſſorſhip to Mr Craven, a man reſpected even by Mr Jebb and his friends.

Early in the year 1771, a deſign was formed of applying to parliament for relief in the matter of ſubſcription to the liturgy, and thirty-nine articles of the Church of England; and in the proſecution of this deſign Mr Jebb took a very active part. He attended different meetings of the diſcontented clergy, held at the Feathers tavern, London, aſſiſted in the drawing up of their petition, and wrote their circular letter, which gave to the public an account of their aims. He buſied himſelf at the ſame time in making various attempts to bring about what he called a reformation of the univerſity of Cambridge: but finding them fruitleſs, he retired, on the 25th of June 1772, to Bungay, where he ſtudied French and Italian, and proceeded in a plan of ſome *political* or *conſtitutional lectures*.

He had by this time ceaſed to read the prayers of the church, though he ſtill continued to preach occaſionally; and the Archdeacon of Suffolk, holding, this year, his uſual viſitation of ſome neighbouring pariſhes in the church of Flixton, Mr Jebb preached ſuch a ſermon againſt ſubſcription, as drew upon himſelf a public rebuke from the Archdeacon, in the preſence of the clergy. "Much altercation, (ſays he) enſued;

and for ſome days I expected a ſummons to Norwich; but have heard no more of it. *I acted thus, with a view to call the attention of the Norwich clergy to our cauſe;* and have in part ſucceeded."

He acted much more honourably than this, when, in 1775, he reſigned all his preferments in the church; which ſurely he ought not to have retained one day after his conſcience would not permit him to read the prayers of the liturgy. He now reſolved to become a phyſician; and after attending St Bartholomew's hoſpital in London for ſix months, as the pupil of Dr William Pitcairn, he received, on the 18th of March 1777, a diploma of Doctor of Phyſic from the univerſity of St Andrews!! He did not, however, commence practice till the 5th of February 1778; and even then he continued to attend the lectures of Dr Hunter, Mr John Hunter, and Dr Higgins. On the 18th of February 1779 he was elected a fellow of the Royal Society.

Dr Jebb, at the breaking out of the American war, had ſhewn himſelf at Cambridge a warm partizan of the revolting colonies; and of courſe a keen advocate for what he called, and, we doubt not, thought, the civil liberties of mankind. He now ſignalized himſelf by "An addreſs to the Freeholders of Middleſex," aſſembled at Free maſon's tavern in Great Queen-ſtreet, on Monday, December the 20th 1779, for the purpoſe of eſtabliſhing meetings to maintain and ſupport the freedom of election. Upun this occaſion, he communicated to James Townſend, Eſq. chairman of that meeting, the above addreſs, under the ſignature of "Salus Publica;" preſuming, that if the ſentiments appeared to be founded in reaſon, they would not be the leſs regarded on account of their being ſuggeſted by an unknown individual."

This addreſs was immediately printed, and very ſoon paſſed through three editions, each being enlarged by the addition of freſh matter; and in 1782, followed the fourth edition corrected, which alſo bore our author's name in the title page.

About the end of February 1780, Dr Jebb was appointed by the committee of the county of Huntingdon, one of their deputies, to attend a meeting in London of repreſentatives from certain other petitioning counties, in order to concert meaſures for the more effectual reform of the preſent conſtitution of the houſe of commons. Soon afterwards he became one of the moſt active members of "the ſociety for conſtitutional information;" of which the object, according to their own account, was to diffuſe throghout the kingdom, as univerſally as poſſible, a knowledge of the great principles of conſtitutional freedom, particularly ſuch as reſpect the election and duration of the repreſentative body. "With this view (ſay they), conſtitutional tracts, intended for the extenſion of this knowledge, and to communicate it to perſons of all ranks, are printed and diſtributed gratis, at the expence of the ſociety. Eſſays, and extracts from various authors, calculated to promote the ſame deſign, are alſo publiſhed under the direction of the ſociety, in ſeveral of the newſpapers; and it is the wiſh of the ſociety to extend this knowledge throughout every part of the united kingdoms, and to convince men of all ranks, that it is their intereſt, as well as their duty, to ſupport a free conſtitution, and to maintain and aſſert thoſe common rights, which are eſſential to the dignity and to the happineſs of human nature." Could Dr Jebb have foreſeen all the miſchiefs which have flowed from this inſtitution; could he have foreſeen the wonderful ſpawn of factious ſocieties which have ſprung from it as from a parent ſtock, our veneration for genius and learning will not permit us to believe, that he would have neglected the ſtudies of his profeſſion for the ſake of taking the lead in party politics.

Dr Petit, one of the phyſicians of St Bartholomew's hoſpital, dying the 26th of May, Dr Jebb offered himſelf a candidate to ſucceed to that appointment. The election came on the 23d of June; when Dr Budd, his antagoniſt, ſucceeded by a great majority.

The oppoſition which was made to his election at St Bartholomew's, followed him in the winter, when he offered himſelf at St Thomas's hoſpital in the borough. Indeed he relinquiſhed his pretenſions there ſooner than in the former place; but for no other reaſon than becauſe he found that all his political principles were likely to be again objected to him, and to hazard his ſucceſs.

In the year 1783 he concurred with others in forming "the ſociety for promoting the knowledg of the ſcriptures," which met firſt on the 20th of September in that year, and whoſe meetings continued to be held, and, for ought we know to the contrary, are ſtill held at Eſſex-houſe. The ſketch of their plan was chiefly written by Dr Jebb; and their object was to propagate the doctrines of Unitarianiſm, for which he was as great a zealot as for civil liberty.

His health now began to decline; but during his confinement, he ſtudied the Saxon language, the Anglo Saxon laws, Engliſh hiſtory and antiquities, with a view to examine into our criminal code, and particular points of liberty. The vigour of his mind was ſtill equal to the furniſhing himſelf with this freſh ſtore of knowledge; he foreſaw the advantage of ſuch an acquiſition in the inveſtigation of the legal rights of Engliſhmen, and had deſigned to have employed it in the ſupport of ſome great conſtitutional queſtions, which he conſidered as eſſential to the freedom of his country.

But as the year began to dawn, it was very obſervable to many of his friends that, according to every appearance, and without ſome very great and ſingular effort of nature, his increaſed debility would defeat every exertion of the moſt judicious medical aſſiſtance, and terminate the remaining ſparks of human life.

In this enfeebled ſtate, his mind was active. His "Thoughts on Priſons" were printed and circulated in the county of Suffolk in 1785, by his much valued friend Mr Lofft; and there is ſufficient reaſon for concluding that this little tract had effect on the deliberations of the juſtices at Ipſwich and Bury, then engaged in erecting a new gaol for the diviſion of Ipſwich, and a new houſe of correction for that of Bury.

The good effects of this very excellent tract, it was apprehended, would be extended by a more general publication. In this hope Dr Jebb reviſed and corrected it with his dying hand: and his ſurviving friend publiſhed it ſoon after his death, adding thereto "an abſtract of felonies created by ſtatute and other articles relative to the penal law.

He continued to linger till May the 2d 1786, when, about 8 o'clock in the evening, he breathed his laſt,
leaving

Jefferſonia
Jerboa

Jerboa,
Jillifree.

leaving behind him, among men of different perſuaſions, very different characters. By the diſſenters he is ſeldom mentioned but as the *Great Jebb*; by churchmen, his abilities are univerſally allowed, whilſt regret is expreſſed that they were ſo often employed in ſupport of faction and hereſy. His moral character has never been aſperſed.

JEFFERSONIA, a new plant lately diſcovered in Georgia by Dr Brickel of Savannah, and ſo named by him in compliment to the vice preſident of the United States. In the *Monthly Magazine* for July 1798 we have the following deſcription of it;

JEFFERSONIA pentendria monogynia.

Calyx, below, compoſed of five ſhort oval imbricated leaves; *corolla*, monophyllous, funnel-ſhaped on the receptacle, ſub-pentangular, bearing the filaments near the baſe, its margin hypocrateriform, divided into five round ducts nearly equal; *ſtyle*, pitiform, ſhorter than the petal, but longer than the ſtamens; *ſtigma*, quadripid; *anthers*, erect, linear, ſagittated; *fruit*, two univalved, carinated, polyſpermous capſules, united at the baſe, opening on their tops and contiguous ſides, having flat ſeeds, with a marginal wing.

Only one ſpecies is as yet diſcovered, *Jefferſonia ſempervireus*. It is a ſhrub with round poliſhed twining ſtems, which climb up on buſhes and ſmall trees; the petioles ſhort, oppoſite; leaves oblong, narrow, entire, evergreen, acute; flowers axillary, yellow, having a ſweet odour. The woods are full of this delightful ſhrub, which is covered with bloſſoms for many months in the year.

JERBOA, ſee Mus, *Encycl*, where deſcriptions are given of the jaculus or common jerboa, and of the Arabian, Egyptian, and Siberian jerboas. A variety of this animal has lately been found in Canada by Major-general Davies, F. R. S. and L. S. who ſays it belongs to Schreber's genus of Dipus, and may be thus characteriſed: DIPUS CANADENSIS *palmis tetradactylis, plantis pentadactylis, caudâ annulatâ undique ſetoſâ, corpore longiore*. The truth, however, ſeems to be, that it is only a variety, if indeed a variety, of the Siberian jerboa. The beautiful figure indeed given by General Davies of the Canadian jerboa differs in ſome reſpects from our figure of the Sibericus. Its ears lie flat and farther down the neck; its belly is not ſo large; its toes are longer; and it has no bruſh at the end of the tale; but the habits of the two animals ſeem to be the ſame. This will be apparent from the following extracts of the General's letter to the Linnean Society:

"The firſt I was ſo fortunate to catch was taken in a large field near the falls of Montmorenci, and by its having ſtrayed too far from the ſkirts of the wood, allowed myſelf, with the aſſiſtance of three other gentlemen, to ſurround it, and after an hour's hard chaſe to get it unhurt, though not before it was thoroughly fatigued; which might in a great meaſure accelerate its death.

"During the time the animal remained in its uſual vigour, its agility was incredible for ſo ſmall a creature. It always took progreſſive leaps of from three to four, and ſometimes of five yards, although ſeldom above 12 or 14 inches from the ſurface of the graſs; but I have frequently obſerved others in ſhrubby places and in the woods, amongſt plants, where they chiefly reſide, leap conſiderably higher. When found in ſuch places, it is impoſſible to take them, from their wonderful agility, and their evading all purſuit by bounding into the thickeſt cover they can find."

That the Canadian, as well as the Siberian Jerboa, ſleeps through the winter, ſeems evident from a ſpecimen having been found, towards the end of May, incloſed in a ball of clay, about the ſize of a cricket ball, nearly an inch in thickneſs, perfectly ſmooth within, and about twenty inches under ground. It was given to the General; who proceeds thus:

"How long it had been under ground it is impoſſible to ſay; but as I never could obſerve theſe animals in any parts of the country after the beginning of September, I conceive they lay themſelves up ſome time in that month, or beginning of October, when the froſt becomes ſharp: nor did I ever ſee them again before the laſt week in May, or beginning of June. From their being enveloped in balls of clay, without any appearance of food, I conceive they ſleep during the winter, and remain for that term without ſuſtenance. As ſoon as I conveyed this ſpecimen to my houſe, I depoſited it, as it was, in a ſmall chip box, in ſome cotton, waiting with great anxiety for its waking; but that not taking place at the ſeaſon they generally appear, I kept it until I found it begin to ſmell: I then ſtuffed it, and preſerved it in its torpid poſition. I am led to believe, its not recovering from that ſtate aroſe from the heat of my room during the time it was in the box, a fire having been conſtantly burning in the ſtove, and which, in all probability, was too great for reſpiration. I am led to this conception from my experience of the ſnow bird of that country, which always expires in a few days (after being caught, although it feeds perfectly well) if expoſed to the heat of a room with a fire or ſtove; but being nouriſhed with ſnow, and kept in a cold room or paſſage, will live to the middle of ſummer."

JETTE, the border made round the ſtilts under a pier, in certain old bridges, being the ſame with ſtarling; conſiſting of a ſtrong framing of timber filled with ſtones, chalk, &c. to preſerve the foundations of the piers from injury.

JILLIFREE is a town on the northern bank of the river Gambia, oppoſite to James's iſland, where the Engliſh had formerly a ſmall fort. The kingdom of Barra, in which it is ſituated, produces great plenty of the neceſſaries of life; but the chief trade of the inhabitants is in ſalt, which they carry up the river in canoes; and, in return, bring down Indian corn, cotton cloths, elephants teeth, ſmall quantities of Gold duſt, &c. "The number of canoes and people conſtantly employed in this trade, make the king of Barra (ſays Mr Park) more formidable to Europeans than any other chieftain on the river, and have encouraged him to eſtabliſh thoſe exorbitant duties, which traders of all nations are obliged to pay at entry, amounting nearly to L. 20 on every veſſel, great and ſmall. Theſe duties, or cuſtoms, are generally collected in perſon by the alkaid or governor of Jillifree, who is attended by a numerous train of noiſy and troubleſome dependants, who, by their frequent intercourſe with the Engliſh, have acquired a ſmattering of our language, and beg for every thing which they fancy with ſuch earneſtneſs, that traders, in order to get quit of them, are frequently obliged to grant their requeſts. Lat. 13° 16′. Long. 16° 10′ weſt from Greenwich.

1 Object of the Illuminati.

ILLUMINATI is the name which was aſſumed by a ſecret ſociety or order, founded, on the firſt of May 1776, by Dr Adam Weiſhaupt profeſſor of canon law in the univerſity of Ingolſtadt. The real object of this order was, by clandeſtine arts, to overturn every government and every religion; to bring the ſciences of civil life into contempt; and to reduce mankind to that imaginary ſtate of Nature when they lived independent of each other on the ſpontaneous productions of the earth. Its avowed object, however, was very different. It profeſſed to diffuſe from ſecret ſocieties, as from ſo many centres, the light of ſcience over the world; to propagate the pureſt principles of virtue; and to re-inſtate mankind in the happineſs which they enjoyed during the golden age fabled by the poets. Such an object was well adapted to make a deep impreſſion on the ingenuous minds of youth; and to young men alone Weiſhaupt at firſt addreſſed himſelf.

It will naturally occur to the reader, that the means of attaining this glorious object ſhould have been made as public as poſſible; and that the veil of ſecrecy thrown over the proceedings of the order was calculated to excite ſuſpicion, and to keep even *young* men of virtue and ſagacity at a diſtance. In any other country than Germany ſecrecy might perhaps have had this effect; but various circumſtances conſpired there to make it operate with a powerful attraction.

Ever ſince free-maſonry had acquired ſuch reputation throughout Europe, a multitude of petty ſecret ſocieties had been formed in the univerſities of Germany, each having its lodge, its maſter, its myſteries, all modelled on thoſe founded by maſons coming from England and Scotland (A). Before the foundation of Weiſhaupt's order, theſe lodges, we believe, were in general harmleſs; or if they were productive of any evil, it was only by giving the youth of the univerſities a taſte for ſecrecy and miſticiſm. Of this Weiſhaupt availed himſelf; and as ſoon as he had conceived the outlines of his plan, and digeſted part of his ſyſtem, he initiated two of his own pupils, to whom he gave the names of AJAX and TIBERIUS, aſſuming that of SPARTACUS to himſelf. Theſe two diſciples ſoon vying with their maſter in impiety (for it will be ſeen by and bye that he was moſt impious), he judged them worthy of being admitted to his myſteries, and conferred on them the higheſt degree which he had as yet invented. He called them *Areopagites*, denominated this monſtrous aſſociation, THE ORDER OF ILLUMINATI, OR ILLUMINEES, and inſtalled himſelf GENERAL of the order.

When public report ſpread the news in Germany of this new order having been founded in the univerſity of Ingolſtadt by Weiſhaupt, it was generally ſuppoſed to be one of thoſe little college-lodges which could not intereſt the adepts after they had finiſhed their ſtudies. Many even thought that Weiſhaupt, who was at that time a ſworn enemy to the Jeſuits, had founded this lodge with no other view than to form a party for himſelf againſt theſe fathers, who after the ſuppreſſion of their order had been continued in their offices of public teachers at the univerſity of Ingolſtadt; and this opinion the illuminees were at pains to propagate. His character, too, was at this time ſuch as to remove every ſuſpicion from the public mind. A ſeeming aſſiduity in his duty, and a great ſhew of zeal and erudition in expounding the laws, eaſily miſled people to believe that his whole time and talents were engroſſed with the ſtudy of them; and if we are to credit his own account, Ingolſtadt had never witneſſed a profeſſor ſo well calculated to add new luſtre to its univerſity.

2 Art of the founder.

This ſeems, indeed, to have been the general opinion as well as his own; for, ſome time after the foundation of his order, he applied himſelf with ſuch diligence and apparent candour to the duties of his office, that he was choſen what Abbé Barruel's tranſlator calls SUPERIOR of the univerſity. This new dignity only added to his hypocriſy, and furniſhed him with freſh means of carrying on his dark deſigns. He converted his houſe into one of thoſe boarding houſes where young men, perpetually under the eye of their maſters, are ſuppoſed to be better preſerved than anywhere elſe from the dangers which threaten them at that age. He ſolicited fathers and mothers to entruſt their children to his care; and, counterbalancing in ſecret the leſſons which he was obliged to give in public, he ſent home his pupils well diſpoſed to continue the ſame career of ſeduction which he himſelf carried on at Ingolſtadt. Atrociouſly impious, we ſee him (ſays M. Barruel), in the firſt year of his illuminiſm, aping the God of Chriſtianity, and ordering *Ajax*, in the following terms, to propagate the doctrines of his new goſpel: "Did not Chriſt ſend his apoſtles to preach his goſpel to the univerſe? You that are my Peter, why ſhould you remain idle at home? Go then and preach."

Theſe preachers had yet received no particular deſignation; for when his firſt adepts were initiated, he was far from having completed the code of his order. He knew that years and experience were neceſſary to perfect that gradual ſyſtem of initiations and trials which, according to the plan he had conceived, his novices were to undergo; but he could not endure the idea of ſacrificing years to mere theoretic projects; and he flattered himſelf with the hopes of ſupplying the deficiencies of his incomplete code by proviſional regulations and private inſtructions, and of acquiring aſſociates who would receive his new goſpel implicitly, and cooperate with him in all his views.

3 The ſect divided into claſſes of

At length, however, the code was completed, and the ſect divided into two grand claſſes; and each of theſe again ſubdivided into leſſer degrees, proportionate to the progreſs of the adepts.

The

(A) Such, we are ſorry to ſay, is the caſe ſtill. In a letter, dated the 10th of May 1799, which we received from a gentleman of learning and honour then reſiding in Upper Saxony, is the following account of the univerſity of Jena: "This univerſity contains from two to three thouſand ſtudents, who are almoſt all republicans, and go about the country in republican uniforms. They are all formed into clubs or *ſecret ſocieties*; and the quarrel of one member of a club is taken up by all. The conſequence is, that the number of duels among the different clubs is inconceivable. The weapon is generally the ſabre, and the duel often ends in the death of one of the combatants." Yet gentlemen of Great Britain ſend their ſons to Germany to be educated!

Illuminati.

4
Preparation and

“ The *firſt* claſs is that of Preparation. It contains four degrees, *viz.* thoſe of *Novice*, of *Minerval*, of *Minor Illuminee*, or *Illuminatus Minor*, and of *Major Illuminee*, or *Illuminatus Major*. To this claſs belong likewiſe ſome intermediary degrees, borrowed from free-maſonry, as means of propagation. Of the maſonic degrees, the code of the illuminati admits the firſt three without *any alteration;* but it adapts more particularly to the views of the ſect the degree of *Scotch Knight*, and ſtyles it the degree of *Directing Illuminee*, or *Illuminatus dirigens*.

5
The Myſteries.

The *ſecond* claſs is that of the Mysteries, which are ſubdivided into the *leſſer* and *greater myſteries*. The leſſer comprehend the prieſthood, and adminiſtration of the ſect, or the degrees of *prieſts*, and of *regents* or *princes*.

In the *greater myſteries* are comprehended the two degrees of *Magus* or philoſopher, and of the *Man-king*. The *elect* of the latter compoſe *the council and degree of Areopagites*.

6
The recruiter,

“ In all theſe claſſes, and in every degree (ſays the Abbé Barruel), there is an office of the utmoſt conſequence, and which is common to all the brethren. It is that which is occupied by him who is known in the code by the appellation of *Recruiter*, or *Brother Inſinuator*. This (continues our author) is not a term of my invention: it is really to be found in the code, and is the denomination of that illuminee, whoſe employment is to entice members into the ſect.”

As the whole ſtrength of the order depended upon the vigilant and ſucceſsful exerciſe of this office, ſome brethren were carefully inſtructed for it, who might afterwards viſit the different towns, provinces, and kingdoms, in order to propagate the doctrines of illuminiſm. Weiſhaupt propoſed to ſelect as his apoſtles either weak men, who would implicitly obey his orders, or men of abilities, who would improve the office by artifices of their own. It was, however, a duty which every brother was obliged to exerciſe once or twice in his life, under the penalty of being for ever condemned to the lower degrees.

To ſtimulate the ardour of the brother inſinuator, he was appointed ſuperior over every novice whom he ſhould convert. To aſſiſt his judgment, he was inſtructed in three important points concerning the deſcription of men whom he ought to ſelect for converſion, the means which he ought to employ for enticing them to enter the order, and the arts which he ought to ſtudy to form their character.

7
To pry into the characters of all men.

To enable the recruiter to determine whom he ought to ſelect for converſion, he was to inſinuate himſelf into all companies; he was to pry into the character of all whom he ſhould meet with, whether friends, relations, ſtrangers, or enemies; he was to write down all his remarks regularly every day; to point out their ſtrong and weak ſides, their paſſions and prejudices, their intimacies, their intereſts, and their fortune. This journal was to be tranſmitted twice every month to the ſuperiors; by which means the order would learn who were friendly or hoſtile to their views, and who were the individuals to whom they ought to direct their arts of ſeduction (B).

Illuminati.

The perſons to be excluded were all ſuch as would expoſe the order to ſuſpicion or reproach. All indiſcreet talkers, all who were proved violent, and difficult to be managed, all addicted to drunkenneſs, and all Pagans, Jews, and Jeſuits, were to be rejected. As the patronage of princes would tend much to enrich and ſtrengthen the ſociety, it was agreed to admit them to the inferior degrees, but they were never to be initiated into the grand myſteries; they were never to riſe beyond the degree of Scotch knight.

8
Perſons proper for the order,

The perſons to be ſelected were young men of all ſtations, from eighteen to thirty; but particularly thoſe whoſe education was not completed, and conſequently whoſe habits were not formed. “ Seek me out (ſays Weiſhaupt in his directions to the inſinuator) the dexterous and daſhing youths. We muſt have adepts who are inſinuating, intriguing, full of reſource, bold and enterpriſing; they muſt alſo be flexible and tractable, obedient, docile, and ſociable ” In another place he ſays, “ Above all things pay attention to the figure, and ſelect the well made men and handſome young fellows. They are generally of engaging manners and nice feelings. When properly formed, they are the beſt adapted for negociations; for firſt appearances prepoſſeſs in their favour. It is true, they have not the depth that men of more gloomy countenances often have. *They are not the perſons to be entruſted with a revolt, or the care of ſtirring up the people;* but it is for that very reaſon we muſt know how to chooſe our agents. I am particularly fond of thoſe men whoſe very ſoul is painted in their eyes, whoſe foreheads are high, and whoſe countenances are open. Above all, examine well the eyes, for they are the very mirrors of the heart and ſoul. Obſerve the look, the gait, the voice. Every external appearance leads us to diſtinguiſh thoſe who are fit for our ſchool.”

9
To be ſeduced by whatever means;

Though young men were preferred, yet perſons of all ages were to be admitted if their character accorded with the principles of the order. The inſinuator was deſired to ſeek out thoſe who were diſtinguiſhed by their power, riches, or learning. “ Spare no pains (ſays Weiſhaupt), ſpare nothing in the acquiſition of ſuch adepts. If heaven refuſe its ſuccour, conjure hell.

Flectere ſi nequeas ſuperos, Acheronta moveta.”

Perſons were to be ſingled out from thoſe profeſſions which give men influence over others, or put them in the moſt favourable ſituation for diſſeminating any peculiar opinions. With this view, ſchoolmaſters, and ſuperintendants of eccleſiaſtic ſeminaries, were to be ſought after with much care. Bookſellers, poſt-maſters, and the ſecretaries of poſt-offices, were alſo to be ſelected. Thoſe profeſſions which accuſtomed men to ſpeak and argue, as that of counſellors and attorneys, and even phyſicians, were alſo to be courted. “ They are worth having (ſays Weiſhaupt), but they are ſometimes real devils, ſo difficult are they to be led; they are, however, worth having when they can be gained over.” Every exertion was to be made to gain the officers of a prince, whether preſiding over provinces or attending him in his councils. “ He that has done this, has done more than if he had engaged the prince himſelf.”

(B) As a ſpecimen of the journals kept by the inſinuators, and of the characters which the illuminees ſelected

There was alſo another deſcription of men of whom Weiſhaupt very wiſely judged that they would be admirably fitted for the diffuſſion of his doctrines. Theſe were the diſappointed and diſſatisfied. "Select thoſe in particular (ſays he) who have met with misfortunes, not from accidents, but from ſome injuſtice; that is to ſay, in other words, the diſcontented; for ſuch men are to be called into the boſom of illuminiſm as into their proper aſylum."

10 And their characters tranſmitted to the ſuperiors.

When the inſinuator has made choice of his victim, he is required to draw from his diary a view of his character, opinions, principles, and connections. This he is to tranſmit to the ſuperiors for their examination, and that they may compare it with the diaries which they have already received, perhaps from different inſinuators. When the choice of this inſinuator is approved, the ſuperiors determine which of the inſinuators will be beſt qualified to perform the taſk of ſeducing their candidate.

Two different methods were recommended; one of which was to be employed in enticing men who were ſomewhat advanced in life or diſtinguiſhed by ſcience; the other was to be uſed in ſeducing young men whoſe character was not formed.

11 Proper methods of ſeducing men of knowledge,

With men of knowledge, who had already imbibed the principles of modern philoſophiſm (for no true philoſophers were to be attempted), the inſinuator was to aſſume the character of a philoſopher well acquainted with the myſteries of ancient times. He was to deſcant upon the importance of the ſecret doctrines tranſmitted by tradition, to quote the gymnoſophiſts of India, the prieſts of Iſis in Egypt, and thoſe of Eleuſis, with the Pythagorean ſchool in Greece. He was to learn by heart certain paſſages from Iſocrates, Cicero, and Seneca, that he might have them ready upon all occaſions. He was to throw out hints, that theſe ſecret doctrines explained the difficult queſtions concerning the origin and order of the univerſe, the Providence of God, the nature of the ſoul, its immortality and future deſtination; he was to inſpire them with the belief that the knowledge of theſe things would render life more agreeable and pain more ſupportable, and would enlarge their ideas of the majeſty of God: he was then to declare that he had been initiated into theſe myſteries. If the candidate expreſſed any curioſity to be made acquainted with them, the inſinuator was firſt to aſcertain his opinions upon ſome leading points, by propoſing to him to write a diſſertation upon certain queſtions. Should the anſwers not pleaſe the inſinuator, he was to relinquiſh his prey; but ſhould they be ſatisfactory, the candidate was to be admitted to the firſt degree.

12 And young men,

When the ſelected victim was young, and had not imbibed any of thoſe opinions which correſponded with the principles of the ſect, a different method was to be followed. "Let your firſt care (ſays the legiſlator to his inſinuators) be to gain the affection, the confidence, and the eſteem of thoſe whom you are to entice into the order. Let your whole conduct be ſuch, that they ſhall ſurmiſe ſomething more in you than you wiſh to ſhew; hint that you belong to ſome ſecret and powerful ſociety; excite by degrees, and not at once, a wiſh in your candidate to belong to a ſimilar ſociety. Certain arguments and certain books, which the inſinuator muſt have, will greatly contribute to raiſe ſuch a wiſh; ſuch, for example, are thoſe which treat of the union and ſtrength of aſſociations."

Every inſinuator muſt be provided with books of this ſort. But that their ſucceſs might not depend ſolely upon books, Weiſhaupt gave to his diſciples a ſpecimen of the artifices which they might employ. The inſinuator might begin by obſerving, that a child in the cradle, abandoned to itſelf, is entirely helpleſs; and that it is by the aſſiſtance of others that it acquires ſtrength; and that princes owe their greatneſs and their power to the union of their ſubjects. Then the inſinuator might touch on the importance of knowing mankind, and the arts of governing them; that one man of parts might eaſily lead hundreds, even thouſands, if he but knew his advantages. He was next to dwell upon the defects of civil ſociety; to mention how little relief a man can obtain even from his beſt friends; and how very neceſſary it is for individuals to ſupport one another in theſe days: to add, that men would triumph even over heaven were they but united. He was to adduce as examples, the influence of the freemaſons and of the Jeſuits. He was to aſſert, that all the great events which take place in the world depend upon hidden cauſes, which theſe ſocieties powerfully influence. He was to awake in the breaſt of his pupil the deſire of reigning in ſecret; of prepa-
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for propagating their principles, we ſhall give the character of Zwack, denominated *Cato*, as it is deſcribed in the tablet of his inſinuator Ajax (Maſſenhauſen).

"Francis Xaverius Zwack was ſon of Philip Zwack, commiſſary of the *Chambre de Comptes*, and was born at Ratiſbon; at the time of his initiation (29th May 1776) he was twenty years of age, and had finiſhed his college education.

"He was then about five feet high; his perſon emaciated with debauchery; his conſtitution bordering on melancholy; his eyes of a dirty grey, weak and languiſhing; his complexion pale and ſallow; his health weak, and much hurt by frequent diſorders; his noſe long, crooked and hooked; his hair light brown; gait precipitate; his eyes always caſt towards the ground; under the noſe, and on each ſide of the mouth, a mole.

"His heart tender and philanthropic in an extaordinary degree; but ſtoic when in a melancholy mood; otherwiſe a true friend, circumſpect, reſerved, extremely ſecret; often ſpeaking advantageouſly of himſelf; envious of other people's perfections; voluptuous; endeavouring to improve himſelf; little calculated for numerous aſſemblies; choleric and violent, but eaſily appeaſed; willingly giving his private opinions when one has the precaution to praiſe him, though contradicting him; a lover of novelties. On religion and conſcience widely differing from the received ideas; and thinking preciſely as he ought, to become a good member of the order.

"His predominant paſſions are, pride, love of glory, probity; he is eaſily provoked; has an extraordinary propenſity for myſteries; a perpetual cuſtom of ſpeaking of himſelf and of his own perfections; he is alſo a perfect maſter in the arts of diſſimulation; a proper perſon to be received into the order, as applying himſelf particularly to the ſtudy of the human heart." Such is the character of the beloved diſciple of Weiſhaupt, the incomparable Cato, and a leader of the ſect of the illuminees!

ring in his cloſet a new conſtitution for the world; and of governing thoſe who think they govern others.

13 Into the noviciate.

After theſe, or other artifices of the ſame kind, have been employed, if the candidate be inſpired with an ardour to be initiated, and give ſatisfactory anſwers to the queſtions propoſed to him, he is immediately admitted a novice. But ſhould he reject all means of ſeduction, let him take heed to imſelf; "for the vengeance of ſecret ſocieties is not a common vengeance; it is the hidden fire of wrath. It is irreconcileable; and ſcarcely ever does it ceaſe the purſuit of its victims until it has ſeen them immolated."

14 Period of the noviciate.

The period of the noviciate varied according to the age of the new convert to illuminiſm. At firſt it continued three years for thoſe under 18 years of age, two years for thoſe between 18 and 24, and one year for thoſe who were near 30; but it was afterwards ſhortened,

The novice was not acquainted with any of the order except his inſinuator, under whoſe direction he remained during his noviciate. The firſt leſſons which he was taught reſpected the inviolable nature of the ſecrecy which every illuminee was obliged to obſerve. He was told that ſilence and ſecrecy were the very ſoul of the order; that ingenuouſneſs was a virtue only with reſpect to his ſuperiors; and that diſtruſt and reſerve were fundamental principles. He was enjoined never to ſpeak of any circumſtance relating to the order, concerning his own admiſſion, or the degree which he had received, not even before brethren, without the ſtrongeſt neceſſity; and was required to ſign a declaration to this purpoſe.

15 Dictionary, geography, calendar, and cypher of the order.

The novice was next taught the dictionary of the order, its geography, calendar, and cypher. To prevent the poſſibility of diſcovery, every illuminee received a new name, which was characteriſtic of his diſpoſitions, or of the ſervices which were expected of him. Thus Weiſhaupt, as we have obſerved, was called *Spartacus*, becauſe he pretended to wage war againſt thoſe oppreſſors who had reduced mankind to ſlavery; and Zwack, as we have ſeen, was named *Cato*, becauſe he had written a diſſertation in favour of ſuicide, and had once determined to commit that crime.

According to the new geography of the order, Bavaria was called *Achaia*; Munich was called *Athens*; Vienna was named *Rome*; Wurtzburg was denominated *Carthage*; and Ingolſtadt, the fountain of the order, was called *Epheſus*, and by the profound adepts *Eleuſis*. The novice had alſo to learn the Perſian calendar, which the order had adopted. Their era began A. D. 630. The months received new names: May was called *Adarpahaſcht*; June, *Chardad*; July, *Thermeh*; Auguſt, *Merdedmeh*; and ſo on. The cypher conſiſted of numbers which correſponded to the letters of the alphabet, in this order *a*, *b*, *c*, *d*, anſwering to the numbers 12, 11, 10, 9.

The novice had next to ſtudy *the ſtatutes of the illuminees*, which he was aſſured contained nothing injurious to the ſtate, to religion, or to good morals. He was next deſired to apply himſelf to acquire the morality of the order; which he was to do, not by reading the goſpels, but by peruſing Epictetus, Seneca, and Antoninus, and by ſtudying the works of the modern ſophiſts Weiland, Meiners, and Helvetius, &c. The ſtudy of man was alſo recommended as the moſt intereſting of all the ſciences. He was taught this ſtudy not merely as a ſcience, but as an art. A model of a journal was given him, and he was required to inſert in it obſervations upon the character of every perſon that he happened to meet with. To quicken his diligence, the inſinuator occaſionally examined his journal. In the mean time, the inſinuator was watching him as a centinel, and noting down regularly obſervations upon the defects and merits of his pupil, which he always ſent to his ſuperiors.

16 Novice obliged to draw his own character.

The great object of the inſinuator was to entangle the novice, and to bind him indiſſolubly to the order. With this view he required the novice to draw a faithful picture of himſelf, under the pretence that he would thus know himſelf better. He deſired him to write down his name, his age, his country, his reſidence, and his employment; to give a liſt of the books in his library; to ſtate his revenue; to enumerate his friends and enemies, and the cauſe of his enmities. He was alſo to give a ſimilar account of his father and mother, his brothers and ſiſters, and to be very careful in pointing out their paſſions and prejudices, their ſtrong and weak ſides.

In the mean time, the inſinuator was occupied in drawing up a new ſtatement of every thing he had been able to diſcover of the character and conduct of the novice. This ſtatement was tranſmitted to the ſuperiors, compared with the former. If the novice was approved, he was then admitted to the ſecond degree, upon his anſwering, in a ſatisfactory manner, 24 grand queſtions, which might enable the order to judge of his principles and the credit to which he was entitled, and would fix him down by ſtronger ties to the authority of the ſuperiors. The deteſtable principles of the illuminees now begin to appear, as will be evident from the following queſtions which we have ſelected:

17 Power of life and death claimed by the ſociety.

Have you ſeriouſly reflected on the importance of the ſtep you take, in binding yourſelf by engagements that are unknown to you? Should you ever diſcover in the order any thing wicked or unjuſt to be done, what part would you take? Do you, moreover, grant the power of life and death to our order or ſociety? Are you diſpoſed, upon all occaſions, to give the preference to men of our order over all other men? Do you ſubject yourſelf *to a blind obedience, without any reſtriction whatſoever?*

The novice having thus ſurrendered his conſcience, his will, and his life, to the devotion of the conſpirators, and thus ſubſcribed, with his own hand, and confirmed by his oath, a reſolution to become the moſt abject ſlave, was now deemed qualified to aſcend to the ſecond degree, called *Minerval*.

18 Admiſſion to the degree of Minerval.

In the dead hour of midnight he was conducted to a retired apartment, where two of the order were waiting to receive him. The ſuperior, or his delegate, appeared ſtanding in a ſevere and threatening poſture; he held a glimmering lamp in his hand, and a naked ſword lay before him. The novice was aſked, whether he ſtill perſiſted in his intention of adhering to the order? Upon anſwering in the affirmative, he was ordered into a dark room, there to meditate in ſilence on his reſolution. On his return, he was ſtrictly and repeatedly queſtioned if he was determined to give implicit obedience to all the laws of the order? The inſinuator became ſecurity for his pupil, and then requeſted for him the protection of the order, which the ſuperior granted with great ſolemnity, proteſting that nothing would be found there hurtful to religion, to morals, or to the ſtate. Having thus ſaid, the ſuperior takes up the naked ſword, and pointing it at the heart of the novice, threatens him with the fatal conſequences of betraying the ſecrets of the order. The novice again takes an oath, by which he binds himſelf, in the moſt unlimited manner, to ſerve the order with his life, honour, and eſtate, and to obſerve an inviolable obedience and fidelity to all his ſuperiors. He is then admitted a Minerval, and henceforth is allowed to attend the academy of the ſect.

19 Minerval academy; The Minerval academy was compoſed of 10, 12, or 15 Minervals, and placed under the direction of a major Illuminee. It met twice every month in an inner apartment, ſeparated from the other rooms of the manſion by an antichamber; the door of which was to be ſhut with care during the meeting, and ſtrongly ſecured by bolts. At the commencement of every meeting, the preſident read and commented upon ſome ſelect paſſages of the Bible, Seneca, Epictetus, Marcus Aurelius, or Confucius; evidently with a view of diminiſhing the reverence for the ſacred writings, by thus placing them on a level with the heathen moraliſts. Then each brother was aſked what books he had read ſince laſt meeting, what obſervations he had made, and what ſervices he had performed for promoting the ſucceſs of the order?

20 Its library. To each Minerval academy a library belonged. This was formed by the contributions of the brethren, by preſents of books, and by another method very extraordinary. All Illuminees acting as librarians, or keepers of archives, were admoniſhed to *ſteal* ſuch books or manuſcripts as might be uſeful to the order. At one time, ſending a liſt of the books which he wiſhed to be embezzled from the library of the Carmes, Weiſhaupt ſays, "All theſe would be of much greater uſe if they were in our hands. What do thoſe raſcals do with all theſe books?

Every brother at his admiſſion was required to declare to what art or ſcience he meant chiefly to apply; and it was expected that he ſhould afterwards every year give an account of the diſcoveries or improvements which he had made. All the other brethren who were occupied in the ſame ſtudies, were deſired to give him every poſſible aſſiſtance. Thus a kind of academy was formed, to which thoſe who could not ſerve it by their talents might give pecuniary contributions. That this academy might have the appearance of a literary ſociety, prizes were annually diſtributed; the beſt diſcourſe was publiſhed, and the profits ſent to the coffers of the order.

Every month the preſident was to take a review of the faults which he had obſerved in his pupils, and examine them concerning thoſe which they might have been conſcious of in themſelves; and it would be an unpardonable neglect, ſay the ſtatutes, ſhould any pupil pretend that, during the ſpace of a whole month, he had remarked nothing reprehenſible.

It is impoſſible to read theſe rules without admiring them. Were men but half as anxious, attentive, and careful, to render themſelves good citizens and good men, as theſe men were to render themſelves ſucceſsful conſpirators, what a bleſſed world ſhould we ſee!

21 Admiſſio to the degree of minor illuminee. The Minerval was rigorouſly ſcrutinized, whether he was ready to ſubmit to every torture, or even to commit ſuicide, rather than give any information againſt the order. Suicide was reckoned not only innocent, but honourable, and was alſo repreſented as a peculiar ſpecies of voluptuouſneſs. In order to diſcover the ſentiments of the Minervals upon this ſubject, they were required to write a diſſertation upon the character and death of Cato, or any ſimilar ſubject. They were alſo deſired to diſcuſs the favourite doctrine of Weiſhaupt, that *the end ſanctifies the means;* a principle of the moſt pernicious tendency, which would render calumny, aſſaſſination, ſedition, and treaſon, laudable and excellent. Next, they were called upon to compoſe a diſſertation, by which their opinions concerning kings and prieſts might be aſcertained. If they performed all theſe taſks with the ſpirit of an infidel, and the deſperate firmneſs of a conſpirator, they were then judged worthy of being promoted to the degree of minor illuminee.

22 Minor illuminees trained for the degree of

The minor illuminees held meetings ſimilar to thoſe of the Minerval academy. It was neceſſary that the preſident ſhould be one who was raiſed to the degree of prieſt, and initiated in the myſteries; but he was required to perſuade his pupils, that beyond the degree which he had attained there were no myſteries to be diſcloſed. The minor illuminees were to be ſo trained, that they might look upon themſelves as the founders of the order; that by this powerful motive they might be animated to diligence and exertion. With this view, hints were ſcattered rather than precepts enjoined. It was inſinuated, that the world was not ſo delightful as it ought; that the happineſs for which man was made is prevented by the misfortunes of ſome, and the crimes of others; that the wicked have power over the good; that partial inſurrection is uſeleſs; and that peace, contentment, and ſafety, might be eaſily obtained by means drawn from the greateſt degree of force of which human nature is capable. Such views, it is added, actuating a ſecret ſociety, would not only be innocent, but moſt worthy of the wiſe and well-diſpoſed.

Weiſhaupt had formed, with peculiar care, a code for this degree, which was intitled, *Inſtructions for forming uſeful Labourers in Illuminiſm.* Theſe inſtructions diſcover an aſtoniſhing knowledge of human nature, and are drawn up with a degree of ſyſtematic coolneſs which perhaps no conſpirator before him ever exhibited. He lays down rules, by which the character of almoſt any perſon may be aſcertained. He recommends to the minor illuminees, to attend to the conduct of any perſon entruſted to their care, at two periods; when he is tempted to be what he ought not to be, and when, removed from the influence of every external temptation, he follows the dictates of his inclination. They were to ſtudy the peculiar habits and ruling paſſions of each; to kindle his ardour by deſcanting on the dignity of the order, and the utility of its labours; to infuſe a ſpirit of obſervation, by aſking queſtions, and applauding the wiſdom of the anſwers; to correct the failings of their pupil, by ſpeaking of them as if they were not his, and thus making him judge in his own cauſe; to inſtruct and adviſe, not by tedious declamation, but by ſometimes dropping a few words to the purpoſe, when the mind ſhould be in a proper ſtate to receive them. Above all, they were directed to avail themſelves of thoſe moments when they obſerved a pupil diſcontented with the world. "It is then (ſays Weiſhaupt) you muſt preſs the ſwelling heart, ſtimulate the ſenſibility, and demonſtrate how neceſſary ſecret ſocieties are for the attainment of a better order of things."

23
Scotch novice.

Having paſſed with applauſe through the ſtates of probation already deſcribed, the minor illuminee is promoted to the rank of major illuminee, or Scotch novice. As major illuminee, he is encompaſſed with more rigid chains; and as Scotch novice, he is diſpatched as a miſſionary into maſonic lodges, to convert the brethren to illuminiſm.

The candidate for this degree is ſtrictly examined, in order to diſcover what opinions he now entertains concerning the object of the ſociety; the motives that prompted him to join it; whether he is diſpoſed ſtill to co-operate with the reſt of the brethren in accompliſhing the grand object; and whether he be a member of any other ſociety; and what are the duties which it requires.

24
Candidates for higher degrees ſubmit to new trials.

The fertile genius of Weiſhaupt is not exhauſted; he has ſtill in reſerve artifices more profound, and bonds more powerful; his reſources keep pace with the progreſs of his ſchemes. He now lays a ſnare for his pupils, from which he hopes none can eſcape, and therefore he flatters himſelf they are his for ever. He demands of every candidate for higher degrees, to write, as a proof of confidence, a minute and faithful account of his whole life, without any reſerve or diſſimulation. Reſerve or diſſimulation would indeed be vain; for the moſt ſecret circumſtances of his life are already well known to the adepts, by means of innumerable ſpies, who, by the appointment of the ſuperiors, have, unknown to him, been watching and ſcrutinizing all his actions and words, his temper, paſſions, and opinions.

Now is preſented to the candidate the code of the brother ſcrutator, called by the order the *noſce te ipſum* (know thyſelf). This is a catechiſm, containing from a thouſand to fifteen hundred queſtions, concerning his perſon, his health, his education, his opinions, his inclinations, his habits, his paſſions, his prejudices, and even his weakneſſes. Queſtions are alſo propoſed reſpecting his acquaintances, his relations, friends, and enemies. The candidate is required to enumerate his favourite colours, to deſcribe his language, the nature of his converſation, his gait and geſtures. Nothing, in ſhort, is omitted that can tend to diſtinguiſh his character as an individual, or as a member of ſociety. Upon many qualities in his character, thirty, forty, or ſometimes near a hundred queſtions are propoſed. The following ſpecimen will enable the reader to judge what aſtoniſhing care Weiſhaupt employed to diſcriminate characters.

Is his *gait* ſlow, quick, or firm? Are his ſteps long, ſhort, dragging, lazy, or ſkipping? Is his *language* regular, diſorderly, or interrupted? In ſpeaking, does he agitate his hands, his head, or his body with vivacity? Does he cloſe upon the perſon he is ſpeaking to? Does he hold him by the arm, clothes, or button-hole? Is he a great talker, or is he taciturn? If ſo, why? Is it through prudence, ignorance, reſpect, or ſloth? &c. Concerning his *education*, he is queſtioned to whom does he owe it? Has he always been under the eyes of his parents? How has he been brought up? Has he any eſteem for his maſters? Has he travelled, and in what countries?

By theſe queſtions his temper and diſpoſitions might be accurately known. His leading paſſions would be diſcovered by the following queries: "When he finds himſelf with different parties, which does he adopt; the ſtrongeſt or the weakeſt; the wittieſt or the moſt ſtupid? Or does he form a third? Is he conſtant and firm in ſpite of all obſtacles? How is he to be gained? by praiſe, by flattery, or low courtſhip; by women, money, or the entreaties of his friends? Does he love ſatire; and on what does he exerciſe that talent; on religion, hypocriſy, intolerance, government, miniſters, monks?" &c.

All theſe queſtions are to be anſwered and illuſtrated by facts. It is neceſſary to obſerve that the ſcrutators alſo give in written anſwers to all theſe queſtions. When the candidate has thus given a minute hiſtory of his life, and revealed all his ſecrets, his foibles, his errors, his vices, and his crimes, Weiſhaupt triumphantly exclaims, "Now I hold him; I defy him to hurt us; if he ſhould wiſh to betray us, we have alſo his ſecrets."

The adept is next introduced into a dark apartment, where he ſolemnly ſwears to keep ſecret whatever he may learn from the order. He then delivers up the hiſtory of his life, ſealed, when it is read to the lodge, and compared with the character drawn of him by the brother ſcrutators. A corner of the veil is now lifted up, ſtill, however, with extreme caution. Nothing appears palpable but the pureſt principles and moſt generous deſigns. At the ſame time many things are darkly ſuggeſted, which are incompatible with purity and generoſity; for while the utmoſt care is employed to deceive the underſtanding, nothing is neglected that can tend ſecretly to corrupt the heart. A number of queſtions are aſked; the evident intention of which is to make the adept diſcontented with the preſent moral government of the world, and to excite the deſire of attempting a great revolution. After anſwering theſe queſtions, the ſecretary opens the code of the lodge; and having informed the young illuminee that the object of the order is to diffuſe the pure truth, and to make virtue triumph, he proceeds to ſhow that this is to be accompliſhed by freeing men from their prejudices, and enlightening their underſtandings. "To attain this, (continues the ſecretary), we muſt trace the origin of all ſciences, we muſt reward oppreſſed talents, we muſt undertake the education of youth; and, forming an indiſſoluble league among the moſt powerful geniuſes, we muſt boldly, though with prudence, combate ſuperſtition, incredulity ,and folly; and at length form our people to true, juſt, and uniform principles on all ſubjects." The ſecretary adds, that in attempting to diveſt vice of its power, that the virtuous may be rewarded even in this world, the order is counteracted by *princes and prieſts, and the political conſtitutions of nations*; that, however, it was not intended to excite revolutions and oppoſe force by force, but merely to bind the hands of the protectors of diſorder, and to govern without appearing to command; that the powers of the earth muſt be encompaſſed with a legion of indefatigable men, all directing their labours towards the improvement of human nature. Were there but a certain number of ſuch men in every country, each might form two others. "Let theſe (ſays he) only be united, and nothing will be impoſſible to our order." All this is very ſpecious; it is well contrived to faſcinate the imagination of the young, and the heart of the

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the generous and benevolent, while, under all this pretended regard to virtue and to the happineſs of mankind, is concealed a moſt formidable conſpiracy againſt the peace of the world.

After this addreſs is delivered, the major illuminee is preſented with the codes of the inſinuator and ſcrutator; for he muſt now inſpect the pupils of the inſinuators, and muſt exerciſe the office of ſcrutator while preſiding over the Minerval academies.

25
The degree of Scotch knight.

The next degree, which is that of Scotch knight, is both intermediate and ſtationary. It is ſtationary for thoſe who are not ſufficiently imbued with the principles of the order, and intermediate for thoſe who have imbibed the true ſpirit of illuminiſm. The Scotch knights were appointed the directors of all the preparatory degrees, and to watch over the intereſts of the order within their diſtrict. They were to ſtudy plans for increaſing the revenues of the order, and to endeavour to promote to public offices of confidence, of power and wealth, as many of the adepts as poſſible; and to ſtrive to acquire an abſolute ſway in the maſonic lodges. They were to procure the management of the maſonic funds; and while they were to perſuade the brethren that theſe were expended according to their own orders, they were to employ them for promoting the views of the order. Thus one office of the Scotch knights was to embezzle the money that was entruſted to them, in order to diffuſe truth, and to make virtue triumph.

After paſſing with applauſe through this long and tedious probation, the adept is introduced to the claſs of the myſteries. He is not yet, however, made acquainted with the whole ſecrets of the ſociety; he muſt ſtill ſubmit to new trials; his curioſity muſt be farther excited, his imagination muſt be kept longer upon the ſtretch, and his principles of depravity be rendered more violent and inveterate before the vail be entirely withdrawn, which will diſcover to him Weiſhaupt and his infernal crew, plotting the deſtruction of the laws, ſciences, and religion of mankind. The degree of epopt or prieſt, to which the adept was next raiſed, opened to view, however, ſo great a part of the myſteries, that the reader will be fully prepared to expect the ſecrets which remain to be unfolded in the other degrees.

26
Preparations for the prieſthood.

Before being admitted to the degree of epopt, the adept was required to give a written anſwer to ten preliminary queſtions. The inſinuations againſt the eſtabliſhed order of the world, which had formerly been ſlightly mentioned, increaſe now to an indirect propoſal to attempt a complete revolution. The candidate is aſked, whether he thinks the world has arrived at that happy ſtate which was intended by nature? Whether civil aſſociations and religion attain the ends for which they were deſigned? Whether the ſciences are conducive to real happineſs? or whether they are not merely the offspring of the unnatural ſtate in which men live, and the crude inventions of crazy brains? It is then propoſed as a queſtion, whether there did not in antient times exiſt an order of things more ſimple and happy? What are the beſt means for reſtoring mankind to that ſtate of felicity? Should it be by public meaſures, by violent revolutions, *or by any means that would enſure ſucceſs?* Would it not be proper, with this view, to preach to mankind a religion more perfect, and a philoſophy more elevated? And, in the mean time, is it not adviſable to diſſeminate the truth in ſecret ſocieties?

Should the anſwers given to theſe queſtions accord with the ſentiments of the order, on the day fixed for the initiation, the candidate is blindfolded, and, along with his introducer, is put into a carriage, the windows of which are darkened. After many windings and turnings, which it would be impoſſible for the adept to trace back, he is conducted to the porch of the temple of the myſteries. His guide ſtrips him of the maſonic inſignia which he wore as a knight, removes the bandage from his eyes, and preſents him with a drawn ſword; and then having ſtrictly enjoined him not to advance a ſtep till he is called, leaves him to his meditations. At length he hears a voice exclaiming, "Come, enter, unhappy fugitive; the fathers wait for you; enter, and ſhut the door after you." He advances into the temple, where he ſees a throne with a rich canopy riſing above it, and before it, lying upon a table, a crown, a ſceptre, a ſword, ſome pieces of gold, and precious jewels, interlaid with chains. At the foot of the table, on a ſcarlet cuſhion, lie a white robe, a girdle, and the ſimple ornaments of the ſacerdotal order. The candidate is required to make his choice of the attributes of royalty, or of the white robe. If he chooſe the white robe, which he knows it is expected he ſhould do, the hierophant, or inſtructor, thus addreſſes him: "Health and happineſs to your great and noble ſoul. Such was the choice we expected from you. But ſtop; it is not permitted you to inveſt yourſelf with that robe, until you have heard to what we now deſtine you." The candidate is then ordered to ſit down; the book of the myſteries is opened, and the whole brethren liſten in ſilence to the voice of the hierophant.

27
Inſtructions previous to admiſſion.

The exordium is long and pompous; much artifice is concealed in it, and much eloquence diſplayed. It expatiates on the ſublime and generous views of the ſociety; evidently with the deſire of lulling aſleep the ſuſpicion of the candidate, of exciting him to admiration, and of inſpiring him with enthuſiaſm. The hierophant then proceeds to unveil the myſteries. He launches out into a ſplendid deſcription of the original ſtate of mankind; when health was their ordinary ſtate, when meat, and drink, and ſhelter, were their only wants. At that period (ſays he) men enjoyed the moſt ineſtimable bleſſings, *equality and liberty*; they enjoyed them to their utmoſt extent: but when the wandering life ceaſed, and property ſtarted into exiſtence; when arts and ſciences began to flouriſh; when a diſtinction of ranks and civil aſſociations were eſtabliſhed, "liberty was ruined in its foundation, and equality diſappeared. The world then ceaſed to be a great family, to be a ſingle empire; the great bond of nature was rent aſunder." Wants now increaſed, and the weak imprudently ſubmitted to the wiſe or the ſtrong, that they might be protected. As the ſubmiſſion of one perſon to another ariſes from wants, it ceaſes when the wants no longer exiſt. Thus the power of a father is at an end when the child has acquired his ſtrength. Every man, having attained to years of diſcretion, may govern himſelf; when a whole nation, therefore, is arrived at that period, there can exiſt no farther plea for keeping it in wardſhip.

Such a ſtate as that of civil ſociety, is then repreſented as incompatible with the practice of virtue. "With the diviſion of the globe, and of its ſtates, benevolence (ſays the hierophant) was reſtrained within certain limits, beyond which it could no longer be extended. Patriotiſm was deemed a virtue; and he was ſtyled a patriot who, partial towards his countrymen, and unjuſt to others, was blind to the merits of ſtrangers, and believed the very vices of his own country to be perfections. We really beheld (continues he) patriotiſm generating localiſm, the confined ſpirit of families, and even egoiſm. Diminiſh, reject that love of country, and mankind will once more learn to know and love each other as men. Partiality being caſt aſide, a union of hearts will once more appear, which will expand itſelf over the globe."

Theſe unphiloſophical declamations, enthuſiaſtically pronounced, at length make the proſylete exclaim, in uniſon with his maſter, "Are ſuch then the conſequences of the inſtitution of ſtates, and of civil ſociety? O folly! Oh people! that you did not foreſee the fate that awaited you; that you ſhould yourſelves have ſeconded your deſpots in degrading human nature to ſervitude, and even to the condition of the brute!"

Having wrought up the proſelyte to this pitch of frenzy, and enumerated all the evils which, according to Weiſhaupt, ariſe from political aſſociation, the hierophant comes to reveal the means by which the grievances of the human race may be redreſſed. "Providence (he ſays) has tranſmitted the means to us of ſecretly meditating, and at length operating, the ſalvation of human kind. Theſe means are the ſecret ſchools of philoſophy. Theſe ſchools have been in all ages the archives of nature, and *of the rights of man.* Theſe ſchools ſhall one day retrieve the fall of human nature, and PRINCES AND NATIONS SHALL DISAPPEAR FROM THE FACE OF THE EARTH; and that without any violence. Human nature ſhall form one great family, and the earth ſhall become the habitation of the man of reaſon. *Reaſon ſhall be the only book of laws, the ſole code of man.* This is one of our *grand myſteries.* Attend to the demonſtration of it; and learn how it has been tranſmitted down to us."

This pretended demonſtration makes part of the ſame ſophiſtical harangue; and conſiſts in panegyrics on the dignity of human nature; in a baſeleſs morality; and in a ſcandalous perverſion of the Chriſtian Scriptures, with a blaſphemous account of the miniſtry of the Saviour of the world.

"What ſtrange blindneſs (continues the hierophant) can have induced men to imagine, that human nature was always to be governed as it has hitherto been? Where is the being who has condemned men, the beſt, the wiſeſt, and the moſt enlightened men, to perpetual ſlavery? Why ſhould human nature be bereft of its moſt perfect attribute, that of governing itſelf? Why are thoſe perſons to be always led who are capable of conducting themſelves? Is it then impoſſible for mankind, or at leaſt the greater part of them, to come to majority? Are we then fallen ſo low as not even to feel our chains, as to hug them, and not cheriſh the flattering hope of being able to break them, and recover our liberty? No; let us own that it is not impoſſible to attain UNIVERSAL INDEPENDENCE."

28
The illuminees enemies to commerce.

The principal means which Weiſhaupt offers to his adepts for the conqueſt of this land of promiſe, is to diminiſh the wants of the people; and accordingly the code denounces eternal war with every ſpecies of commerce. Hence the hierophant proceeds to inform the candidate, that he who wiſhes to ſubject nations to his yoke, need but to create wants, which he alone can ſatiſfy. "Confer (ſays he) upon the *mercantile tribe* ſome rank or ſome authority in the government, and you will have created perhaps the moſt formidable, the moſt deſpotic of all powers. He, on the contrary, who wiſhes to render mankind free, teaches them how to refrain from the acquiſition of things which they cannot afford: he enlightens them, he infuſes into them bold and inflexible manners. If you cannot diffuſe, at the ſame inſtant, this degree of light among all men, at leaſt begin by enlightening yourſelf, and by rendering yourſelf better. The mode of diffuſing univerſal light is, not to proclaim it at once to the whole world, but to begin with yourſelf; then turn to your next neighbour: you too can enlighten a third and a fourth: let theſe in the ſame manner extend and multiply the number of the children of light, until *numbers and force ſhall throw power into your hands.* You will ſoon acquire ſufficient force to *bind the hands of your opponents, to ſubjugate them,* and to ſtifle wickedneſs in the embryo;" *i. e.* you will ſoon be able to ſtifle every principle of law, of government, of civil or political ſociety, whoſe very inſtitution, in the eyes of an illuminee, is the germ of all the vices and misfortunes of human nature.

29
Their morality;

The hierophant, continuing to inſiſt on the neceſſity of enlightening the people to operate the grand revolution, ſeems to be apprehenſive that the candidate may not yet clearly conceive the real plan of this revolution, which is in future to be the ſole object of all his inſtructions. Let your inſtructions and lights be univerſally diffuſed; ſo ſhall you render mutual ſecurity univerſal; *and ſecurity and inſtruction will enable us to live without prince or government.* The inſtruction which is to accompliſh this great end, is inſtruction in *morality,* and *morality alone;* for "*true morality* is nothing elſe than the art of teaching men to *ſhake off their wardſhip,* to attain the age of manhood; and thus to need neither princes nor governments. The morality which is to perform this miracle, is not a morality of vain ſubtleties. It is not that morality which, degrading man, renders him careleſs of the goods of this world, forbids him the enjoyment of the innocent pleaſures of life, and inſpires him with the hatred of his neighbour. *Above all,* it muſt *not* be that morality which, adding to the miſeries of the miſerable, throws them into a ſtate of puſillanimity and deſpair, *by the threats of hell and the fear of devils.* It muſt be a divine doctrine, ſuch as Jeſus taught to his diſciples, and of which he gave the real interpretation in his ſecret conferences."

30
And blaſphemies of Chriſt.

The impious hierophant then proceeds, with matchleſs blaſphemy, to repreſent the Redeemer of mankind as teaching, like the Grecian ſophiſts, an exoteric and an eſoteric doctrine. He deſcribes him as the grand maſter of the illuminees; and affirms, that the object of his *ſecret,* which is loſt to the world in general, has been preſerved in their myſteries. It was "to reinſtate mankind in their ORIGINAL EQUALITY and LIBERTY, and to prepare the means. This explains in

what

what ſenſe Chriſt was the *Saviour and Redeemer of the world*. The doctrine of original ſin, of the fall of man, and of his regeneration, can now be underſtood. The ſtate of pure nature, of fallen or corrupt nature, and the ſtate of grace, will no longer be a problem. Mankind, in quitting their ſtate of *original liberty*, *fell* from the ſtate of nature, and *loſt their dignity*. In their civil ſociety, under their governments, they no longer live in the ſtate of *pure* nature, but in that of *fallen* and *corrupt* nature. If the moderating of their paſſions, and the diminution of their wants, reinſtate them in their primitive dignity, that will really conſtitute their *redemption* and their *ſtate of grace*. It is to this point that morality, and the moſt perfect of all morality, that of Jeſus, leads mankind. When at length this doctrine ſhall prevail throughout the world, the reign of the good and of the elect ſhall be eſtabliſhed."

31 Preparatory rites to

This language (as M. Barruel obſerves) is ſurely not enigmatical; and the proſelyte who has heard it without ſhuddering, may flatter himſelf with being worthy of this Antichriſtian prieſthood. He is led back to the porch, where he is inveſted with a white tunic and broad ſcarlet belt of ſilk. The ſleeves of the tunic, which are wide, are tied in the middle and at the extremities with ribbons likewiſe of ſcarlet; and the candidate is recalled into the temple of myſteries. He is met by one of the brethren, who does not permit him to advance till he has declared "whether he perfectly underſtands the diſcourſe which has been read to him; whether he has any doubts concerning the doctrines taught in it; whether his heart is penetrated with the ſanctity of the principles of the order; whether he is ſenſible of the call, feels the ſtrength of mind, the fervent will, and all the diſintereſtedneſs requiſite to labour at the *grand undertaking*; whether he is ready to make a ſacrifice of *his will*, and to ſuffer himſelf to be *led* by the moſt *excellent ſuperiors of the order*."

32 Initiation to the prieſthood.

The rites of the preceding degree were in impious deriſion of the ſacrament of the Lord's ſupper; thoſe of the preſent are an atrocious mimicry of ſacerdotal ordination; at which, as every one knows, the Lord's ſupper is likewiſe celebrated. A curtain is drawn, and an altar appears with a crucifix upon it. On the altar is a bible; and the ritual of the order lies on a reading deſk, with a cenſer and a phial full of oil beſide it. The dean, or preſident, who acts the part of a biſhop, bleſſes the candidate, cuts hair from the crown of his head, anoints him, clothes him in the veſtments of the prieſthood, and pronounces prayers after the faſhion of the order. He preſents him with a cap, ſaying, "Cover thyſelf with this cap; it is more precious than the royal diadem." The mock communion is then diſtributed; and it conſiſts of milk and honey, which the dean gives to the proſelyte, ſaying, "This is that which nature gives to man. Reflect how happy he would ſtill have been, if the deſire of ſuperfluities had not, by depriving him of a taſte for ſuch ſimple food, multiplied his wants, and poiſoned the balm of life." The ceremonies are terminated by delivering to the epopt that part of the code which relates to his new degree.

33 Duties of the prieſt or epopt.

Among the inſtructions which it contains, the following are more particularly worthy of notice. The epopt, ſays the code, "will take care that the writings of the members of the order ſhall be cried up, and that the trumpet of fame ſhall be ſounded in their honour. He will alſo find means of *hindering the reviewers from caſting any ſuſpicions* on the writers of the ſect." He is likewiſe inſtructed to *bribe* the common people into the intereſts of the order, and to corrupt their minds, by getting poſſeſſion of ſchools and other ſeminaries of learning. But "if it be neceſſary for us to be maſters of the ordinary ſchools (ſays the impious legiſlator), of how much more importance will it be to gain over the *Eccleſiaſtic ſeminaries and their ſuperiors!* With them we gain over the chief part of the country; we acquire *the ſupport of the greateſt enemies to innovation*; and the grand point of all is, that through *the clergy* we become *maſters of the middle and lower claſſes of the people*."

34 Qualifications for the degree of regent.

From the degree of epopt or prieſt are choſen the *regents* or *prince-illuminees*. On making this choice, ſays the code, three things of the utmoſt conſequence are to be obſerved. "1*ſt*, The greateſt reſerve is neceſſary with reſpect to this degree: 2*dly*, Thoſe who are admitted into it, muſt be as much as poſſible *free men*, and *independent of princes*: 3*dly*, They muſt have clearly manifeſted their *hatred of the general conſtitution*, or the *actual ſtate* of mankind; and have ſhewn how evidently they wiſh for a *change in the government of the world*." If theſe requiſites be found in an epopt who aſpires to the degree of regent, ſix preliminary queſtions are put to him; of which the obvious meaning is to diſcover, whether he deems it lawful and proper to teach ſubjects to throw off the authority of their ſovereigns, or, in other words, to deſtroy every king, miniſter, law, magiſtrate, and public authority on earth.

35 Admiſſion to this degree.

When theſe queſtions are anſwered to the ſatisfaction of his examiner, he is informed, "that as, in future, he is to be entruſted with papers belonging to the order of far greater importance than any which he has yet had in his poſſeſſion, it is neceſſary that the order ſhould have farther ſecurities. He is therefore commanded to make his *will*, and inſert a clauſe with reſpect to any private papers which he may leave, in caſe of ſudden death. He is to get a formal or juridical receipt for that part of his will from his family, or from the public magiſtrate; and he is to take their promiſes in writing, that they are to fulfil his intentions." This precaution being taken, and the day fixed for his inauguration, he is admitted into an antechamber hung with black, where he ſees a ſkeleton, elevated two ſteps, with a crown and ſword lying at its feet. Having given up the written diſpoſitions, &c. reſpecting his papers, his hands are loaded with chains as if he were a ſlave, and he is left to his meditations. A dialogue then takes place between his introducer and the provincial, who is ſeated on a throne in a ſaloon adjoining. It is in a voice loud enough to be heard by the candidate, and conſiſts of various queſtions and anſwers; of which the following may ſerve for a ſpecimen:

Prov. Who has reduced him to this ſtate of ſlavery?

Anſ. by the Introd. SOCIETY, GOVERNMENTS, the SCIENCES, and falſe RELIGION.

Prov. And he wiſhes to caſt off this yoke, to become a ſeditious man and a rebel?

Anſ. No; he wiſhes to unite with us, to JOIN IN

OUR

OUR FIGHTS AGAINST THE CONSTITUTION OF GOVERNMENTS, the corruption of morals, and the profanation of religion. He wiſhes, through our means, to become POWERFUL, that he may attain the GRAND ULTIMATUM.

Prov. Is he ſuperior to *prejudices?* Does he prefer the *general intereſt of the univerſe* to that of *more limited aſſociations?*

Anſ. Such have been his promiſes.

Prov. Aſk him, whether the ſkeleton which is before him be that of a *king*, a *nobleman*, or a *beggar?*

Anſ. He cannot tell; all that he ſees is, that this ſkeleton was a man like us; and the character of *man* is all that he attends to.

After a great deal of inſidious mummery like this, the epopt is admitted to the degree of prince; but before his inveſtiture with the inſignia of that order, he is exhorted to be *free*, *i. e.* to be a man, and a man who knows how to *govern himſelf*; a man who knows his duty, and his *impreſcriptible rights;* a man who ſerves the *univerſe alone;* whoſe actions are ſolely directed to the *general benefit* of the world and of human nature. "Every thing elſe (ſays the provincial) is INJUSTICE." A long panegyric is then made on the happineſs which will be experienced by mankind, when *every father* of a family ſhall be *ſovereign* in his tranquil cot! when he that wiſhes to invade theſe *ſacred rights* ſhall not find an aſylum on the face of the earth! when idleneſs ſhall be no longer ſuffered; and when *the clod of uſeful ſciences ſhall be caſt ſide* (c)!

36 Sign of the degree. The *ſign* of this degree conſiſted in extending out the arms to a brother with the hands open; the *gripe* was to ſeize the brother by the two elbows, as it were to prevent him from falling; and the *word* was REDEMPTION! The epopt was inveſted with his principality by receiving a buckler, boots, a cloak, and a hat; and on receiving the boots, he was deſired to *fear no road* which might lead to the propagation or diſcovery of *happineſs*. Thus decorated, the prince illuminee received the *fraternal embrace,* and heard the inſtructions for his new degree.

One would think that the adept had now arrived at the very acmé of profaneneſs and treaſonable conſpiracy. He has been initiated in myſteries which burleſque Chriſtianity and its Divine Author, and at the ſame time vow vengeance againſt all government, all law, and all ſcience: yet Weiſhaupt, in a letter to Cato Zwack, his incomparable man, ſays, that he has compoſed four degrees above that of regent, or prince-illuminee; with reſpect even to the *loweſt* of which, his degree of prieſt will be found no more than child's play. "The ritual of theſe degrees, (ſays he), I never ſuffer to go out of my hands. It is of too ſerious an import; it is the key of the ancient and modern, the religious and political, hiſtory of the univerſe."

This caution of the chief conſpirator has deprived us of the power to give ſo particular an account of theſe degrees as we have done of the preceding; but the Abbé Barruel aſſures us that they were reduced to two, viz. that of MAGUS, and that of the MAN-KING; and that theſe two conſtituted the GREATER MYSTERIES. When the adept was admitted to the degree of *magus*, he was illuminized only in philoſophy and religion; when to that of *man-king*, new lights were given him reſpecting property, and every ſpecies of political aſſociation. The Abbé quotes a paſſage from *the Critical hiſtory of all the degrees of illuminiſm,* written by a man of honour, who had paſſed through them all, which will give the reader a ſufficient idea of the object of theſe laſt degrees.

37 Objects of the degrees of magus and man-king. "With reſpect to the two degrees of *magus* and of *man-king* (ſays this writer), there is no reception, that is to ſay, there are no ceremonies of initiation. Even the elect are not permitted to tranſcribe theſe degrees; they only hear them read, and that is the reaſon why I do not publiſh them in this work. The firſt is that of Magus, called alſo philoſopher. It contains the fundamental principles of Spinoziſm. Here every thing is *material;* God and the world are but one and the ſame thing: all religions are inconſiſtent, chimerical, and the invention of ambitious men."

That this is the doctrine of Spinoza, and that Spinoza was an atheiſt, is moſt certain; but though nothing can be *eſſentially* worſe than atheiſm, we are ſtrongly inclined to ſuſpect that, at the initiation of the Magus, expreſſions muſt have been uſed more *ſhocking at leaſt to the ear* than the philoſophic jargon of the apoſtate Jew. It is long ſince the philoſophy of Spinoza was in Germany recommended from the preſs (ſee SPINOZA, *Encycl.*); it is but very lately that a profeſſor in the univerſity of Jena publiſhed a book, in which he teaches that there is *no God*, and that we abſurdly give that title to *the relations of Nature* (D); and ſomething approaching ſo near to atheiſm had been communicated to the adept when he was admitted to the prieſthood, that we are perſuaded Weiſhaupt muſt have alluded to *language* at leaſt different from that in which Spinoza taught his dark doctrines, and that language, accompanied perhaps with impious and audacious geſtures, when he ſaid that, compared with his higher myſteries, his degree of prieſt was but child's play.

What gives ſome degree of probability to this conjecture, if it be nothing more, is the following fact related by the Abbé Barruel. During the French revolution (ſays that able and well-informed writer), a comedian appeared

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(C) This will naturally ſurpriſe our readers; but it could not ſurpriſe him to whom it was addreſſed; for when candidate for the prieſthood, he had been aſked, "Do the ſciences which men cultivate, furniſh them with real lights? Are they conducive to real happineſs? Are they not, on the contrary, the offspring of numberleſs wants, and of the unnatural ſtate in which men live? Are they not the crude inventions of crazy brains?" There were, however, to be academies for the cultivation of ſuch ſciences as ſuited the deſigns of the order. Each academy was to conſiſt of nine epopts, of whom ſeven were to preſide reſpectively over ſo many departments of ſcience, whilſt the other two were to officiate as ſecretaries. One of the departments included the occult ſciences, to which belonged the art of *raiſing the ſeals of the letters* of all who belonged not to the order, and of ſecuring their own letters againſt ſimilar practices!!

(D) We learned this from the letter already quoted in note (A).

38
Atheiſm and

appeared (E), dreſſed in the ſacerdotal robes of the illuminees, and perſonally defying Almighty God. "No! (ſaid the impious wretch) thou doſt not exiſt. If thou haſt power over the thunderbolts, graſp them; aim them at the man who dares ſet thee at defiance in the face of thy altars. But no! I blaſpheme thee, and I ſtill live. No! thou doſt not exiſt." It will be ſeen by and bye, that the chiefs of the revolution, and even numbers of their tools, were illuminized; and is it improbable that this blaſphemer, who was arrayed in the inſignia of the epopts, made uſe of the language and geſtures of the higher myſteries? Whether it be or not, M. Barruel has proved, even from the writings of Weiſhaupt himſelf, that the magi were at leaſt atheiſts of the ſchool of Spinoza.

"The ſecond degree of the grand myſteries, called the *Man-king*, teaches (according to the author of the Critical Hiſtory), that every inhabitant of the country or town, every father of a family, is ſovereign, as men formerly were in the times of the patriarchal life, to which mankind is once more to be carried back; that in conſequence all authority and all magiſtracy muſt be deſtroyed."

39
Savagiſm.

This may appear to be nothing more than what the adept has been already taught in the leſſer myſteries; and it is in fact nothing more than that to which he muſt have ſeen theſe myſteries tending; but the reader underſtands not the language of the illuminees, if he ſuppoſes that, by the patriarchal ſtate, they mean ſuch a ſtate as that of the patriarchs of the Old Teſtament. No! their patriarchal ſtate is the fancied ſavage ſtate of the atheiſtical philoſophers of Greece and Rome, when mankind had neither property nor fixed habitation. This is evident from one of the diſcourſes of the hierophant; in which he tells the adept, that it would have been happy for man "had he known how to preſerve himſelf in the primitive ſtate in which Nature had placed him! But ſoon the unhappy germ developed itſelf in his heart, and reſt and happineſs diſappeared. As families multiplied, the neceſſary means of ſubſiſtence began to fail. *The Nomade or roaming life ceaſed; property began; men choſe fixed habitations; agriculture brought them together;* LIBERTY WAS RUINED IN ITS FOUNDATIONS, AND EQUALITY DISAPPEARED."

To reſtore that liberty and equality, therefore, which is the ultimate object of the order, and conſtitutes the MAN-KING, all property muſt be aboliſhed, every houſe burnt, as well the cottage of the peaſant as the palace of the prince; and mankind muſt once more inhabit woods and caverns without clothes and without fire, and ſally out occaſionally to encounter their fellow-brutes, and to ſearch for food among the wild herbs of the deſart. According to Mochus the Phenician, and the Greek philoſophers of this hopeful ſchool, this was the original ſtate of man *; and to this ſtate it was the object of Weiſhaupt and his adepts to reduce man again. Hence we hear them laviſhing the moſt rapturous encomiums on the Goths and Vandals who over-ran the Roman empire, annihilated the arts, put a ſtop to agriculture, and burnt the towns and villages of civilized Europe! It was thus, according to the illuminees, that thoſe barbarians regenerated mankind: but the regeneration was not complete; for the Goths and Vandals could not preſerve themſelves from the contagion of civil life; and their fall from ſavagiſm to ſcience drew from Weiſhaupt's hierophants the moſt piteous lamentations!

40
The laſt ſecret of the order.

The laſt ſecret communicated to the moſt favoured adepts was the novelty of the order. Hitherto their zeal had been inflamed, and their reſpect demanded to an inſtitution pretended to be of the higheſt antiquity. The honour of inſtituting the myſteries had been ſucceſſively attributed to the children of the Patriarchs, to ancient philoſophers, even to Chriſt himſelf, and to the founders of the maſonic lodges (ſee MASONRY in this *Suppl.*). But now the time is come when the adept, initiated in the higher myſteries, is ſuppoſed to be ſufficiently enthuſiaſtic in his admiration of the order, to be entruſted with the hiſtory of its origin. Here then they inform him, that this ſecret ſociety, which has ſo artfully led him from myſtery to myſtery; which has, with ſuch perſevering induſtry, rooted from his heart every principle of religion, all love of his country, and affection for his family; all pretenſions to property, to the excluſive right to riches, or to the fruits of the earth;—this ſociety, which has taken ſo much pains to demonſtrate the tyranny and deſpotiſm of all laws human and divine, and of every government, whether monarchical, ariſtocratical, or republican; which has declared him free, and taught him that he has no ſovereign on earth or in heaven; no rights to reſpect in others, but thoſe of perfect equality, of ſavage liberty, and of the moſt abſolute independence; that this ſociety is not the offspring of an ignorant and ſuperſtitious antiquity, but of modern philoſophy; in one word, that the true father of illuminiſm is no other than Adam Weiſhaupt, known in the ſociety by the name of SPARTACUS! This *important* ſecret, however, remained a myſtery even to the greater part of the *magi* and the *man-kings*, being revealed only to the grand council of *areopagites*, and to a few other adepts of diſtinguiſhed merit.

41
Propoſal for a female order.

So zealouſly was the order bent upon propagating its execrable principles through the whole world, that ſome of the chiefs had planned an order of female adepts, in ſubſerviency to the deſigns of the men. "It will be of great ſervice, (ſays *Cato* Zwack), it will procure us both information and money, and will ſuit charmingly the taſte of ſome of our trueſt members, who are lovers of the ſex." An aſſeſſor of the Imperial chamber at Wetzlar, of the name of Dittfurt, but known among the illuminees by that of *Minos*, expreſſed even his deſpair of ever bringing men to the grand object of the order without the ſupport of female adepts; and he makes an offer of his own wife and his four daughters-in-law to be firſt initiated. This order was to be ſubdivided into two claſſes, each forming a ſeparate ſociety, and having different ſecrets. The firſt was to be compoſed of virtuous women; the ſecond of the wild, the giddy, and the voluptuous. The brethren were to conduct the firſt, by promoting the reading of good books; and to train the ſecond

* See Doig's *Letters on the Savage State.*

(E) He does not ſay where this appearance was made; but the circumſtances related lead us to ſuppoſe that it was in a church.

ſecond to the arts of *ſecretly gratifying their paſſions*. The wife of an adept named Ptolemy Magus was to preſide over one of the claſſes; which (ſays Minos) will become, under her management and his, a very pretty ſociety. "You muſt contrive pretty degrees, and dreſſes, and ornaments, and elegant and decent rituals. No man muſt be admitted. This will make them more keen, and they will go much farther than if we were preſent, or than if they thought that we knew of their proceedings. Leave them to the ſcope of their own fancies, and they will ſoon invent myſteries which will put us to the bluſh, and myſteries which we can never equal. They will be our great apoſtles. Reflect on the reſpect, nay, the awe and terror, inſpired by the female myſtics of antiquity. Ptolemy's wife muſt direct them, and ſhe will be inſtructed by Ptolemy; and my ſtep-daughters will conſult with me. We muſt always be at hand to prevent the introduction of any improper queſtion. We muſt prepare themes for their diſcuſſion: thus we ſhall confeſs them, and inſpire them with our ſentiments. No man, however, muſt come near them. This will fire their roving fancies, and we may expect rare myſteries!"

42
Rejected by Spartacus.

But notwithſtanding all the plans and zeal of this profligate wretch and others of the fraternity, it does not appear that the General *Spartacus* ever conſented to the eſtabliſhment of the ſiſterhood. He ſupplied, however, the want of ſuch an inſtitution, by ſecret inſtructions to the regents, on the means of making the influence of women over men ſubſervient to the order, without entruſting them with any of the ſecrets. "The fair ſex (ſays he) having the greateſt part of the world at their diſpoſal, no ſtudy is more worthy the adept than the *art of flattery*, in order to gain them. They are all more or leſs led by vanity, curioſity, pleaſure, or the love of novelty. It is on that ſide, therefore, they are to be attacked, and by that to be rendered ſubſervient to the order." That Weiſhaupt's ſagacity had not on this occaſion forſaken him, is very evident; ſince it has been proved that the German fair, who were the correſpondents of the illuminees, welcomed the French invaders of their native country *. Nay, ſo lately as the winter of 1798, our correſpondent in Saxony heard ſeveral of theſe illuminized ladies expreſs a wiſh that the French might invade and conquer England; for then, ſaid they, *tea and coffee would be cheaper!*

It is not enough for the founder of a ſect of conſpirators to have fixed the preciſe object of his plots. His accomplices muſt form but one body, animated by one ſpirit; its members muſt be moved by the ſame laws, under the inſpection and government of the ſame chiefs. A full account of the government of Weiſhaupt's order will be found in the valuable work of Abbé Barruel; our limits permit us to give only ſuch a general view of it as may put our readers on their guard againſt the ſecret machinations of theſe execrable villains, whoſe lodges are now recruiting, under different denominations, in every country in Europe.

43
Subordination of the illuminees.

Wherever illuminiſm has gained a footing, as the means of ſubordination, there is a general diviſion of command as well as of locality. The *candidates* and *novices* are each under the direction of his own inſinuator, who introduces him into the *Minerval lodges*; each *Minerval lodge* has a ſuperior from among the preparatory claſs, under the inſpection of the intermediary claſs. So many lodges conſtitute a diſtrict, under the direction of a ſuperior, whom the order calls *dean*. The dean is ſubjected to the *provincial*, who has the inſpection and command of all the lodges and deaneries of the province. Next in order comes the *national ſuperior*, who has full power over all within his nation, provincials, deans, lodges, &c. Then comes the ſupreme council of the order, or the *areopagites*, over which preſides the *general* of illuminiſm. Thus has the order formed within itſelf a ſupreme tribunal, to whoſe inquiſition all nations are to be ſubjected. The areopagites, conſiſting of twelve fathers of the order, with the general at their head, form the centre of communication with all the national ſuperiors on earth; each *national* is the centre of one particular nation; the *provincial*, of one province; the *dean*, of the lodges within his deanery; the *Minerval maſter*, of his academy; the *venerable*, of his maſonic lodge; and the *inſinuator* or *recruiter*, of his *novices* and *candidates*.

44
Their mode of correſpondence;

The higher degrees (ſays Weiſhaupt in one of his inſtructions to the regents) muſt always be hidden from the lower. The ſimple illuminee therefore correſponds with his immediate ſuperior, knowing perhaps no other member of the order; the latter, with his dean; and thus gradually aſcending to the national ſuperiors, who alone are acquainted with the reſidence of the areopagites, as they again are with the names and reſidence of the general. Any member, however, of the inferior degrees, may occaſionally correſpond with his unknown ſuperiors, by addreſſing his letters *Quibus licet*; and in theſe letters he may mention whatever he thinks conducive to the advancement of the order. If he be a novice, he may in theſe letters inform his ſuperiors how his inſtructor behaves to him, or may draw the character of any perſon whatever. When the letter of any adept contains ſecrets, or complaints which he chooſes to conceal from his immediate ſuperior, he directs it *Soli* or *Primo*; and then it can be opened only by the *provincial*, the *national ſuperior*, the *areopagites*, or the *general*, according to the rank of the writer, which is by ſome contrivance unknown to M. Barruel, indicated on the outſide of the letter. The *provincial* opens the letters of the *minor* and *major* illuminees which are directed *Soli*; the *Quibus licets* of the epopts; and the *Primos* of the novices; but he cannot open either the *Primo* of the minerval, the *Soli* of the Scotch knight, or the *Quibus licet* of the regent. He can only form a conjecture as to the perſons who open his own letters, and thoſe which he is not permitted to open himſelf.

45
And of giving importance to their order,

When it is conſidered, that by one of Weiſhaupt's ſtatutes, the provincial has in each chapter or diſtrict a confidential epopt, who is his *ſecret cenſor* or *ſpy*; that theſe ſpies are to inſinuate themſelves into all companies, and collect *anecdotes of ſecret hiſtory*; that the hiſtorian of the province is to inſert theſe anecdotes into a journal kept for that purpoſe; and that the provincials are obliged to forward the contents of theſe journals to the high ſuperiors of the order--ſome notion may be formed of the influence of the general and areopagites in every country into which illuminiſm has found its way. "The means of acquiring an aſcendency over men (ſays Weiſhaupt), are incalculable. Who could enumerate them all? They muſt vary with the diſpoſition of the times. At one period, it is a

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* Dr Robiſon's *Proofs of a Conſpiracy*.

taſte for the marvellous that is to be wrought upon. At another, the lure of ſecret ſocieties is to be held out. For this reaſon, it is very proper to make your inferiors believe, without telling them the real ſtate of the caſe, that all other ſecret ſocieties, particularly that of *Freemaſonry*, *are ſecretly directed by us*. Or elſe, and IT IS REALLY THE FACT IN SOME STATES, THAT POTENT MONARCHS ARE GOVERNED BY OUR ORDER. When any thing remarkable or important comes to paſs, hint that it *originated with our* order. Should any perſon by his merit acquire a great reputation, let it be generally underſtood that *he is one of us*.

46
By every means, good or bad.

“ If our order cannot eſtabliſh itſelf in any particular place, with all the forms and regular progreſs of our degrees, *ſome other form muſt be aſſumed*. Always have *the object* in view; that is the eſſential point. No matter what *the cloak* be, provided you ſucceed; *a cloak*, however, *is always neceſſary*, for in *ſecrecy our ſtrength lies*. The INFERIOR LODGES OF FREEMASONRY ARE THE MOST CONVENIENT CLOAKS for our GRAND OBJECT; becauſe the world is already familiariſed with the idea, that *nothing of importance*, or *worthy of their attention, can ſpring from maſonry*.” No artifice, however, is to be left untried. “ You may attend large and commercial towns during the times of fairs in different characters; as *a merchant*, *an officer*, *an abbé*. Everywhere you will perſonate an extraordinary man, having important buſineſs on your hands; but all this muſt be done with a great deal of *art and caution*, leſt you ſhould have the appearance of an adventurer. You may write your orders with a *chymical preparation of ink*, *which diſappears after a certain time*. Never loſe ſight of the *military ſchools*, of the *academies*, *printing preſſes*, *libraries*, *cathedral chapters*, or *any public eſtabliſhments* that can influence *education*, or *government*. Let our regents perpetually attend to the various means, and form plans, for MAKING US MASTERS *of all theſe eſtabliſhments*. When an author ſets forth principles true in themſelves, but which do not as yet ſuit *our general plan of education for the world*, or principles, the publication of which is premature; every effort muſt be made to *gain over the author*; but ſhould all our attempts fail, and we ſhould prove unable to entice him into the order, *let him be diſcredited by every poſſible means*”

Of their methods of diſcrediting authors, one has come to our knowledge, which muſt be intereſting to ſome of our readers. Dr Robiſon's work, entitled *Proofs of a Conſpiracy*, &c. which firſt unmaſked theſe hypocrites in this country, found its way into Germany, and was tranſlated into the German language, and expoſed to ſale at the Leipſic fairs. The illuminees, under the diſguiſe of *merchants* and *abbes*, attended, and bought up the whole impreſſion, which they committed to the flames. A ſecond edition was publiſhed, and it ſhared the ſame fate (F). This was a more compendious way of anſwering the learned author than that which has been adopted by the Jacobin journaliſts in London; but perhaps it may convince the readers of theſe journals, that the Doctor has not ſo far miſtaken the ſenſe of the writings of *Philo* and *Spartacus*, as their illuminiſed maſters wiſh them to believe.

When theſe arts of diſſeminating the diſorganiſing and impious principles of the order are duly conſidered, and when it is remembered that its emiſſaries dare not diſobey a ſingle injunction of the high ſuperiors, without expoſing themſelves to poiſon, or to the daggers of a thouſand unſeen aſſaſſins, no man can be ſurpriſed to learn that the illuminees contributed greatly to the French revolution. 47 Illuminiſm of France. The philoſophers of France had indeed prepared the public mind for embracing readily the doctrines of illuminiſm; and ſo early as 1782, *Philo* and *Spartacus* had formed the plan of illuminizing that nation; but they were afraid of the vivacity and caprice of the people, and extended not their attempts, at that time, beyond Straſbourg. Already, however, there exiſted ſome adepts in the very heart of the kingdom; and the Marquis de Mirabeau, when ambaſſador at the court of Berlin, was initiated at Brunſwick by a diſciple of Philo Knigge's. On his return to France he began to introduce the new myſteries among his maſonic brethren.

48
By means of free maſonry.

The ſtate of free maſonry was at that time peculiarly adapted to the views of the conſpirators. The French had engrafted on the old and innocent Britiſh maſonry a number of degrees, gradually riſing above each other, to the very myſteries of illuminiſm itſelf (ſee MASONRY in this *Suppl.*) Theſe were called the *philoſophical* degrees, and comprehended the *knights of the ſun*, the higher *Roſicrucians*, and the *knights Kadeſh*. At the head of all theſe ſocieties, whether ancient or modern, were three lodges at Paris, remarkable for the authority which they exerciſed over the reſt of the order, and Philip of Orleans was the grand-maſter. So early as the year 1787, France contained 282 towns, in which were to be found regular lodges, under the direction of that execrable wretch. He increaſed their number by introducing to the *maſonic* myſteries the loweſt of the rabble, as well as thoſe French guards whom he deſtined to the ſubſequent attack of the baſtile, and to the ſtorming of the palace of his near relation and royal maſter. In every country town and village lodges were opened for aſſembling the workmen and peaſantry, in hopes of heating their imaginations with the ſophiſticated ideas of equality and liberty, and the rights of man; and it was then that Mirabeau invited a deputation from the order of Weiſhaupt, which very quickly diffuſed the light of illuminiſm through the whole kingdom. Inſtead of *Spartacus* Weiſhaupt, *Cato* Zwack, and *Philo* Knigge, we find wielding the firebrands of revolution in the capital of France, *Philip of Orleans*, *Mirabeau*, *Syeyes*, and *Condorcet*. The day of general inſurrection was fixed by theſe miſcreants for the 14th of July 1789. At the ſame hour, and in all parts of France, the cries of *equality* and *liberty* reſounded from the lodges. The Jacobin clubs were formed; and hence ſprung the revolution, with all its horrors of atheiſm, murder, and maſſacre!

In ſupport of this account of the illuminees we have not loaded our margin with authorities; becauſe our detail has been taken wholly from the valuable works of

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(A) This information was communicated to us by a gentleman of character, who was at Leipſic when the two impreſſions of the book were thus diſpoſed of. The Abbé Barruel's work has no doubt been anſwered in the ſame way, though we cannot ſay ſo upon the ſame authority.

of Abbé Barruel and Dr Robiſon, to which we refer our readers for much curious information that our limits do not permit us to give. We cannot, however, conclude the article, without making ſome remarks on that ſpecious principle by which the conſpirators have deluded numbers, who abhor their impieties, and who would not go all their length even in rebellion; we mean the maxim, "that it is our duty to love all men with an equal degree of affection, and that any partial regard for our country, or our children, is unjuſt."

49 Reflections on the fundamental principles of illuminiſm;

That this maxim is falſe, every *Chriſtian* knows, becauſe he is enjoined to "do good indeed unto all men, but *more eſpecially* to them who are of the houſehold of faith;" becauſe he is told, that "if any man provide not for his *own*, and eſpecially for thoſe of his *own houſe*, he hath denied the faith, and is worſe than an infidel;" becauſe his divine maſter, immediately after reſolving all duty into the love of God and man, delivers a parable, to ſhew that we neither can nor ought to love all men *equally*; and becauſe the ſame Divine Perſon had one diſciple whom he loved more than the reſt. But we wiſh thoſe *philoſophers* who talk perpetually of *the mechaniſm* of the human mind, and at the ſame time affect to have no *partial* fondneſs for any individual, but to love all with the ſame degree of *rational* affection, to conſider well whether ſuch philanthropy be conſiſtent with what they call (very improperly indeed) *mechaniſm*. If this mechaniſm be (as one of them ſays it is) nothing more than *attraction* and *repulſion*, we know that it *cannot* extend with equal force over the whole world; becauſe the force of attraction and repulſion varies with the diſtance. If by this abſurd phraſe, they mean a ſet of *inſtinctive* propenſities, or feelings, we know that among ſavages, who are more governed by inſtinct than civilized men, philanthropy is a feeling or propenſity of a very limited range. If they believe all our paſſions to originate in ſelf love, then is it certain that our philanthropy muſt be progreſſive; embracing firſt, and with ſtrongeſt ardour, our relations, our friends, and our neighbours; then extending gradually through the ſociety to which we belong; then graſping our country; and laſt of all the whole human race. Perhaps they may ſay that reaſon teaches us to love all men equally, becauſe ſuch equal love would contribute moſt to the ſum of human happineſs. This ſome of them indeed have actually ſaid; but it is what no man of reflection can poſſibly believe. Would the ſum of human happineſs be increaſed, were a man to pay no greater attention to the education of his own children than to the education of the children of ſtrangers? were he to do nothing more for his aged and helpleſs parents than for any other old perſon whatever? or, were he to neglect the poor in his neighbourhood, that he might relieve thoſe at the diſtance of 1000 miles? Theſe queſtions are too abſurd to merit a ſerious anſwer.

When a man, therefore, boaſts of his univerſal benevolence, declaring himſelf ready, without fee or reward, to ſacrifice every thing dear to him for the benefit of ſtrangers whom he never ſaw; and when he condemns, in the cant phraſe of faction, that narrow policy which does not conſider the whole human race as one great family—we may ſafely conclude him to be either a conſummate hypocrite, who loves none but himſelf, or a philoſophical fanatic, who is at once a ſtranger to his duty and to the workings of his own heart.

50 Exemplified in the conduct of the illuminees.

If this concluſion require any farther proof, we have it in the conduct of Weiſhaupt and his areopagites. In the hand-writing of *Cato* his *incomparable man*, was found the deſcription of a ſtrong box, which, if forced open, would blow up and *deſtroy its contents*; ſeveral receipts for *procuring abortion*; a compoſition which *blinds or kills* when ſpurted in the face; *tea* for procuring abortion: *Herbæ quæ habent qualitatem delateream*; a method for filling a bed-chamber with *peſtilential vapours*; how to take off impreſſions of ſeals, ſo *as to uſe them afterwards as ſeals*; a receipt *ad excitandum furorem uterinum*; and a diſſertation on *ſuicide*. Would genuine philanthropiſts have occaſion for ſuch receipts as theſe? No! the order which uſed them was founded in the moſt conſummate villany, and by the moſt deteſtable hypocrite. The inceſtuous Weiſhaupt ſeduced the widow of his brother, and ſolicited poiſon and the dagger to murder the woman whom he had fondly preſſed in his arms. "Execrable hypocrite (ſays M. Barruel), he implored, he conjured both art and friendſhip, to deſtroy the innocent victim, the child, whoſe birth muſt betray the morals of his father. The ſcandal from which he ſhrinks, is not that of his crime: it is the ſcandal which, publiſhing the depravity of his heart, would deprive him of that authority by which, under the cloak of virtue, he plunged youth into vice and error. *I am on the eve,* (ſays he) *of loſing that reputation which gave me ſo great authority over our people: My ſiſter in-law is with child. I will hazard a deſperate blow, for I neither can nor will loſe my honour.*" Such is the benevolence of thoſe who, baniſhing from their minds all partial affection for their children and their country, profeſs themſelves to be members of one great family, the family of the world!

IMAGINARY Quantities, or *Impoſſible Quantities*, in algebra, are the even roots of negative quantities; which expreſſions are Imaginary, or impoſſible, or oppoſed to real quantities; as $\surd - aa$, or $^4\surd - a^4$, &c. For as every even power of any quantity whatever, whether poſitive or negative, is neceſſarily poſitive, or having the ſign +, becauſe + by +, or — by —, give equally +; hence it follows that every even power, as the ſquare for inſtance, which is negative, or having the ſign —, has no poſſible root; and therefore the even roots of ſuch powers or quantities are ſaid to be impoſſible or imaginary. The mixt expreſſions ariſing from imaginary quantities joined to real ones, are alſo imaginary; as $a - \surd - aa$, or $b + \surd - aa$.

Imaginary Roots of an equation, are thoſe roots or values of the unknown quantity, which contain ſome imaginary quantity. Thus the roots of the equation $xx + aa = 0$, are the two imaginary quantities $+ \surd - aa$ and $- \surd - aa$, or $+ a\surd - 1$ and $- a\surd - 1$.

IMPACT, the ſimple or ſingle action of one body upon another to put it in motion. Point of impact is the place or point where a body acts.

IMPERFECT Number, is that whoſe aliquot parts, taken all together, do not make a ſum that is equal to the number itſelf, but either exceed it, or fall ſhort of it; being an abundant number in the former caſe, and a defective number in the latter. Thus, 12 is an abundant imperfect number, becauſe the ſum of all its aliquot parts, 1, 2, 3, 4, 6, makes 16, which exceeds the

the number 12. And 10 is a defective imperfect number, becauſe its aliquot parts, 1, 2, 5, taken all together, make only 8, which is leſs than the number 10 itſelf?

IMPOST, in architecture, a capital or plinth, to a pillar, or pilaſter, or pier, that ſupports an arch, &c.

Doctrine of Impulſion.

IMPULSION, is the term employed in the language of mechanical philoſophy, for expreſſing a ſuppoſed peculiar exertion of the powers of body, by which a moving body changes the motion of another body by hitting or ſtriking it. The plaineſt caſe of this action is when a body in motion hits another body at reſt, and puts it in motion by the ſtroke. The body thus put in motion is ſaid to be IMPELLED by the other: and this way of producing motion is called IMPULSION, to diſtinguiſh it from PRESSION, THRUSTING, or PROTRUSION, by which we puſh a body from its place without ſtriking. The term has been gradually extended to every *change* of motion occaſioned by the colliſion of bodies.

1
Hiſtory of it.

When ſpeculative men began to collect into general claſſes, the obſervations made during the continual exertions of our own perſonal powers on external bodies, in order to gain the purpoſes we had in view, it could not be long before they remarked, that as we, by the ſtrength of our arm, can move a body, can ſtop or any how change its motion; ſo a body already in motion produces effects of the ſame kind in another body, by hitting it. Such obſervations were almoſt as early and as intereſting as the other; and the attention was very forcibly turned to the general facts which obtained in this way of producing motion; that is, to the expiſcation of the general laws of impulſion. We do not find, however, in what remains of the phyſical ſcience of the ancients, that they had proceeded far in this claſſification. While mechanics, or the ſcience of machines, had acquired ſome form, and had been the ſubject of ſucceſsful mathematical diſcuſſion, we do not find that any thing ſimilar had been done in the ſcience of impulſe. Yet the artillery of ancient times was very ingenious and powerful. But although Vegetius, and Ammianus Marcellinus, and Hero, deſcribe the mechaniſm of theſe engines with great care, and frequently with mathematical ſkill, we ſee no attempts to aſcertain with preciſion the force of the miſſile weapon, or to ſtate the efficacy of the battering ram, by meaſures of the momentum, and compariſon of it with the reſiſtance oppoſed to it. The engineers were contented with very vague notions on theſe points.

Ariſtotle, in his 20th Mechanical Queſtion, and Galen in ſome occaſional obſervations, are the only authors of antiquity whom we recollect as treating the force of impulſe as a quantity ſuſceptible of meaſure. Their obſervations are extremely vague and trivial, chiefly directed, however, to the diſcrimination of the force of impulſe from that of preſſure.

In more modern times, great additions had already been made to the aſſiſtance we had derived from the impulſive efficacy of bodies in motion. Water-mills and wind-mills had been invented, and had been applied to ſuch a variety of purpoſes, that the engineers were faſt acquiring more diſtinct notions of the force of impulſe. Naval conſtructions was changed in ſuch a manner, that there hardly remained any thing of the ancient rigging. The oblique action of wind and water were now found even more effective than the direct; and ſhips could now ſail with almoſt any wind. All theſe things fixed the attention of the engineers and of the ſpeculatiſt on the numberleſs modifications of the force of impulſe.

But it ſoon appeared that this was a refined branch of knowledge, and required a more profound ſtudy than any other department of the ſcience of motion. At the ſame time, it was equally clear, that it was alſo of ſuperior importance. Mills worked by cattle, or by mens hands, were everywhere giving place to wind and water mills; and a ſhip alone appeared to every intelligent mechanician to be the greateſt effort of human invention, and moſt deſerving his careful ſtudy. All theſe improvements in the arts of life derived their efficacy from the impulſe of bodies. The laws of impulſion, therefore, became the objects of ſtudy to all who pretended to philoſophical ſcience. But this is a branch of ſtudy wholly new, and derives little aſſiſtance from the mechanical ſcience already acquired; for that was confined to the determination of the circumſtances which regulated the equilibrium of forces, either in their combined action on bodies in free ſpace, or by the intervention of machines. But in the production of motion by impulſe, the equilibrium is not ſuppoſed to obtain; and therefore its rules will not ſolve the moſt important queſtion, "What will be the preciſe motion?"

Galileo, to whom we are indebted for the firſt diſcoveries in the doctrine of free motions, was alſo the firſt who attempted to bring impulſion within the pale of mathematical diſcuſſion. This he attempted, by endeavouring to ſtate what is the force or energy of a body in motion. The very obſcure reflections of Ariſtotle on this ſubject only ſerved to make the ſtudy more intricate and abſtruſe. Galileo's reflections on it are void of that luminous perſpicuity which is ſeen in all his other writings, and do not appear to have ſatiſfied his own mind. He has recourſe to an experiment, in order to diſcover what preſſure was excited by impulſion. A weight was made to fall on the ſcale of a balance, the other arm of which was loaded with a conſiderable weight; and the force of the blow was eſtimated by the weight which the blow could thus ſtart from the ground. The reſults had a certain regularity, by which ſome analogy was obſerved between the weights thus ſtarted and the velocity of the impulſe; but the anomalies were great, and the analogy was ſingular and puzzling; it led to many intricate diſcuſſions, and ſcience advanced but ſlowly.

2
Laws of impulſion diſcovered by Wallis, Wrenn, and Huyghens

At laſt the three eminent mathematicians, Dr Wallis, Sir Chriſtopher Wrenn, and Huyghens, about the ſame time, and unknown to each other, diſcovered the ſimple and beautiful laws of colliſion, and communicated them to the Royal Society of London in 1668 (Phil. Tranſ. n° 43—46.). Sir Chriſtopher Wrenn alſo invented a beautiful method of demonſtrating the doctrine by experiment. The bodies which were made to ſtrike each other were ſuſpended by threads of equal length, ſo as to touch each other when at reſt. When removed from this their vertical ſituation, and then let go, they ſtruck when arrived at the loweſt points of their reſpective circles, and their velocities were proportional to the chords of the arches through which they had deſcended. Their velocities, after the ſtroke, were meaſured,

meaſured, in like manner, by the chords of their arches of aſcent. The experiments correſponded preciſely with the theoretical doctrine.

In the mean time, this ſubject had keenly occupied the attention of philoſophers, who found it to be of a very abſtruſe nature; or, which is nearer the truth, they indulged in great refinement in proſecuting the ſtudy. The firſt attempts to meaſure the impulſive force of bodies, by ſetting it in oppoſition to preſſures, which had long been meaſured by weights, gave riſe to ſome very refined reflections on the nature of theſe two kinds of forces. Ariſtotle had ſaid that they were things altogether diſparate. If ſo, there can be no proportion between them. Yet the analogy obſerved in the experiments above mentioned of Galileo, ſhewed that impulſe could be gradually augmented, till it exceed any preſſure. This indicates ſameneſs in kind, according to Euclid himſelf. A curious experiment of Galileo's, in which the impulſe of a vein of water was ſet in equilibrio with a weight, ſeemed not only to eſtabliſh this identity beyond a doubt, but even to ſhew the origin of preſſure itſelf. The weight in one ſcale is ſuſtained as long as the ſtream of water continues to ſtrike the other ſcale. In this experiment, therefore, preſſure is equivalent to continual impulſe. But *continual* impulſe is not conceivable: we muſt conſider the impulſe of the ſtream as the *ſucceſſive* impulſe of the different particles of water, at intervals which are altogether indiſtinguiſhable.

From theſe conſiderations were deduced two very momentous doctrines: 1. That preſſure is nothing but repeated impulſe; 2. That although preſſure and impulſe are the ſame in kind, they are incomparable in magnitude. The impulſe is equal to the weight of a column of water, whoſe length is the height neceſſary for communicating the velocity. Now this is inceſſant; and the weight is ſuſtained during any the ſmalleſt moment of time, by the impulſe, not of the whole column, but of the inſenſible portion of it which is then making its ſtroke. Impulſe, therefore, is infinitely greater than preſſure.

3
Impulſe ſaid to be the only cauſe of motion.

Theſe abſtruſe ſpeculations have a charm for certain ingenious ſpeculative minds; and when indulged, will lead them very far. Accordingly, it was not long before ſome of the moſt ingenious philoſophers of Europe taught that impulſe was the ſole origin of preſſure. There is but one moving power (ſaid they) in mechanical nature: This is impulſe.—*Nihil movetur* (ſays Euler) *niſi a contiguo et moto.* Moreover, having been long and familiarly converſant with the actions of animals, and the actions of moving bodies, and conceiving, with ſufficient diſtinctneſs, that impenetrable bodies cannot move without moving thoſe with which they are ſurrounded and in contact, they imagined that they fully underſtood how all this diſplacement of bodies is carried on; and therefore they maintained, that any motion is fully explained when it is ſhewn to be a caſe of impulſion: But they ſaw many caſes of motion where this impulſion could not be exhibited to the ſenſes. Thus, the fall of heavy bodies, the mutual approach or receſs of magnetic and electric bodies, exhibited no ſuch operation. But even here their experience helped them to an explanation. Air is an inviſible ſubſtance, and its very exiſtence was for a long time known to us only by means of its impulſe. As we ſee that preſſures are generated by the impulſe of water and of air, may there not be fluids ſtill more ſubtle than air, by whoſe inviſible impulſe bodies are made to fall, and magnets are made to approach or avoid each other? The impoſſibility of this cannot be demonſtrated, and the laws of impulſe had not as yet been ſo far inveſtigated as to ſhew that they were incompatible with thoſe productions of motion. It was therefore an open field for diſcuſſion; and the philoſophers, without farther heſitation, adopted, as a firſt truth, that ALL MOTION WHATEVER IS PRODUCED BY IMPULSION. The buſineſs of the philoſopher, therefore (ſay they), is to inveſtigate what combination of inviſible impulſions is competent to the production of any obſerved motion; ſuch as the fall of a heavy body, the elliptical motion of a planet, or the polarity of a magnetic needle. The curious diſpoſition of iron-filings round a magnet encouraged this kind of ſpeculation: It looks ſo like a ſtream of fluid; but it is a number of quieſcent fragments of iron. This does not hinder us from *ſuppoſing* ſuch a ſtream, not of iron-filings, but of a magnetic fluid, which will arrange (ſay the atomiſts) thoſe fragments, juſt as we ſee the flote-graſs in a brook arranged by a ſtream of water. Fluids, therefore, moving in ſtreams, vortices, and a thouſand different ways, have been ſuppoſed, in order to *explain*, that is, to bring under a general known law of mechanical Nature, all thoſe caſes of the production of motion where impulſion is not obſerved by the ſenſes.

As we have gradually become better acquainted with the laws of the production of motion by impulſion, we have been able to explode many of thoſe proffered explanations, by ſhewing that the genuine reſults of the ſuppoſed inviſible motions, that is, the impulſions which they would produce, are very unlike the motions which we attempt to explain. It has been ſhewn that the vortices ſuppoſed by Des Cartes, or by Leibnitz, or by Huyghens, cannot exiſt; and they have been given up. But it is anſwered to all thoſe demonſtrations of futility, that ſtill the axiom remains. Motion is produced only by impulſe; but we have not yet diſcovered all the poſſibilities of impulſion; and we muſt not deſpair of diſcovering that preciſe ſet of inviſible motions, and conſequent impulſions, of which the phenomena before us is the neceſſary reſult.

4
The application of this principle is hazardous.

But this is by no means ſufficient authority for deſerting the rule of philoſophizing, ſo prudently and judiciouſly recommended by Sir Iſaac Newton; namely, not to admit as the cauſe of phenomenon any thing that is not *ſeen* to operate in its production. The prudence of this reſtriction is evident; and it has alſo been ſufficiently ſhewn (PHILOSOPHY, *Encycl.* n° 48. &c.), that true philoſophical explanation, or extenſion of knowledge, is unattainable, if this rule be not ſtrictly adhered to. We therefore require a cogent reaſon for a practice that opens the door to every abſurdity, and that cannot give us the knowledge which we are in queſt of. What, then, is the reaſon that always induces philoſophers to have recourſe to impulſion for the explanation of a phenomenon, and to reſt ſatisfied in every caſe where it can be clearly proved that the phenomenon is really a caſe of impulſion? We ſay that we inquire into the reaſon why a body falls, and that we will be ſatisfied if it can be ſhewn us that it has received a number of impulſions downward. Do we inquire why a body in motion puts another body in motion by hitting it? And if we do, have we diſcovered the reaſon? We believe that none of the philoſophers, who have recourſe to inviſible impelling fluids, ever aſk a reaſon for motion by impulſion. Indeed they ſhould not, otherwiſe it would ceaſe to be a firſt principle of explanation. Other philoſophers, indeed (namely, ſuch as aſk no reaſon for the weight of a body, but the FIAT of the ALMIGHTY), require an explanation of motion by impulſe, and think that, in almoſt every caſe, they have found it out.

If the philoſophers aſk no reaſon for this production of motion, they muſt (that it may ſerve as a principle of explanation) ſay that impulſiveneſs is an original property of matter, either contingent or eſſential. Accordingly, we believe that this, or ſomething like this, has been aſſumed as a principle by the greater part of mechanicians. It has been aſſumed, as we have obſerved in the article Dynamics, *Suppl.* that a *moving body* poſſeſſes the power of producing motion in another body by hitting it; and they call it the IMPULSIVE FORCE *of moving bodies*—the FORCE INHERENT *in a moving body*. The reader will have obſerved, in our manner of treating that article, and alſo in ſeveral paſſages of different articles of the *Encyclopædia Britannica*, that we do not conſider this aſſumption as very clearly authoriſed by obſervation, or deducible by abſtract reaſoning, from the firſt principles of philoſophy. There is no branch of natural philoſophy on which ſo many ingenious diſſertations have been written; and perhaps there is none that has been more ſucceſsfully proſecuted: Yet this is the only part of the ſcience of motion that has given riſe to a ſerious diſpute; a diſpute that has divided, and ſtill divides, the mechanicians of Europe.

Some may think it preſumptuous in us, in a Work of this kind, which only aims at collecting and exhibiting in one view the *exiſting ſcience* of Europe, to pretend to give new doctrines, or to decide a queſtion which has called forth all the powers of a Leibnitz, a Bernoulli, a Jurin, a M'Laurin, &c. But we make no ſuch pretenſions; we only hope that, by ſeparating the queſtion from others with which it has, in every inſtance, been complicated, and by conſidering it apart, ſuch notions may be formed, in perfect conformity to the principles adopted by all parties, that the myſtery, which has gradually gathered like a cloud, may be diſpelled, and all cauſe of difference taken away. We apprehend that this requires no very extenſive knowledge, but merely a ſtrict attention to the conceptions which we form of the actions of bodies on each other, and a preciſion in the uſe of the terms employed in the diſcuſſion.

5 Inquiry into its truth.

We truſt that our philoſophical readers perceive and approve of our anxiety to eſtabliſh (in the article Dynamics, *Suppl.*) the leading principles of mechanical philoſophy, from which we are to reaſon in future on acknowledged FACTS, or LAWS of human thought. It is not ſo much the queſtion, What is the eſſence of material Nature, from which all the appearances in the univerſe proceed? as it is, What do we know of it? how do we come by this knowledge? and what uſe can we make of it? The tænia knows nothing of the ſolar ſyſtem, and man is ignorant of the cauſe of impulſiveneſs. Other intelligent creatures may have ſenſes, of which this is the proper object; and others, of a ſtill more exalted rank, may perceive the operations of mind as clearly as we perceive thoſe of matter, while they are equally ignorant with ourſelves of the cauſes which connect the conjoined events in either of thoſe operations. But "known unto God, and to Him alone, are ALL His works!"

6 We learn the exiſtence of matter chiefly by means of touch.

To accompliſh this purpoſe, we directed the reader's attention to what paſſes in his own mind when he thinks on the mechanical phenomena of Nature; on what he calls body; on the perceptions which bring it into his view, and which give him all the notions that he can form of its diſtinguiſhing, its characteriſtic properties. How does he learn that there is matter in a particular place? He has more than one mean of information; and each of theſe informs him of peculiar qualities of the thing which he calls *matter*. Many appearances ſuggeſt to his mind the preſence of a body. Shew a monkey or a kitten (and even ſometimes a human infant) a mirror, and it will inſtantly grope round it to find a companion. Why does the creature grope about ſo? It is not contented with the firſt indication of matter, and nothing will ſatisfy it but touching or graſping what is behind the mirror. It is by our ſenſe of touch alone that we get the irreſiſtible conviction that matter or body is perceived by us, and it never fails to give us the perception; nay, we have the perception even in ſome caſes where the experienced philoſopher thinks himſelf obliged to doubt of its truth. Some ſenſations, ariſing from ſpaſm, cannot be diſtinguiſhed from the feeling of touch; and the patient inſiſts that ſomething preſſes on the diſeaſed part, while the phyſician knows that it is only a nervous affection. Every perſon will think that a cobweb touches his face when an electrified body is brought near it, and will try to wipe it off with his hand. But the modern philoſopher ſees good reaſon for aſſerting, that in this inſtance our feeling gives us very inaccurate, if not erroneous, information. He ſhews that the fact, of which our feeling truly informs us, is the bending of the ſmall hairs or down which grow on the face, and that theſe only have been touched; and the followers of Epinus deny that even this has been demonſtrated.

7 The excitement of touch is accompanied by the feeling of exerted preſſure.

The philoſopher adopts this mode of perception as unqueſtionable, and allows that, and that alone, to be matter, which invariably produces this ſenſation by contiguity. But engaged in ſpeculations which fix his attention on the external object, he neglects and overlooks the inſtrument of information, and its manner of producing the effect, juſt as the aſtronomer overlooks the teleſcope, and the union and decuſſation of the rays of light which form the picture by which he perceives the ſatellite of Jupiter travel acroſs his diſk. The philoſopher finds it convenient to generaliſe the immenſe variety of touches which he feels from external bodies, and to conſider them as the operations of one and the ſame diſcriminating quality, a PROPERTY inherent in the external ſubſtance BODY: and he gives it a name, by which he can excite the ſame notion in the minds of his hearers. It is worth while to attend to what has been done in this matter, becauſe it gives much information concerning the firſt principles of mechaniſm. An exquiſite painting has ſometimes ſuch an appearance of prominence, that one is diſpoſed to draw the finger along it, and we expect to feel ſome roughneſs, ſome *obſtruction*, ſomething that prevents the finger

ger from going over the place. Perhaps we doubt, and want to be aſſured. We preſs a little cloſer; but feel no obſtruction; and we deſiſt. The very firſt appearance, therefore, which this indicating quality, viewed as the *property* of external matter, has in our conceptions, is that of an obſtruction, an obſtacle, to the exertion of one of our natural powers. The power exerted on this occaſion is familiarly and *diſtinctively* known by the name of PRESSURE. This is the name of our own exertion, our own action; and, in this inſtance, and (we think, in this alone, the word is uſed purely, primitively, and without figure. When we ſay that a ſtone preſſes on the ground, we ſpeak figuratively, as truly as when we ſay that the candleſtick ſtands, and the ſnuffers lie, on the table. It is a perſonification, authoriſed by the ſimilarity of the effects and appearances. Further, when we ſpeak of our preſſure on any thing, with the intention of being preciſe in our communication, we ſpeak only of what obtains in the touching parts of the finger and the thing preſſed, paying no attention to the long train of intermediate exertions of the mind on the nerves, the nerves on the muſcular fibre, the fibre on the articulated machine, and the machine on the touching part of the finger. And thus the exertion of the ſentient and active being is attributed to the particles of lifeleſs inactive matter at the extremity of the finger, and theſe are ſaid to preſs immediately on the touching parts of the external body. And, laſtly, as this our exertion is unqueſtionably the perceived employment of a faculty in us, which we call *force*, *power*, *ſtrength*, diſtinguiſhing it from every other faculty by theſe names; we ſay (but figuratively), that force or power is exerted at the tips of the fingers, and we call it the FORCE OF PRESSURE.

8 And preſſure is conceived or ſuppoſed in almoſt every production of motion.

By far the greateſt part of our actions on external bodies is with the intention of putting them out of their preſent ſituations; and we can hardly ſeparate the thought of exerted preſſure from the thought of motion produced by it. Therefore, almoſt at its firſt appearance in the mind, preſſure comes before us as a MOVING POWER. Nay, we apprehend, that the more we ſpeculate, and the more we aim at preciſion in our conceptions, we ſhall be the more ready to grant that we have no clear *conception* of any other moving power. No man will contend that he has any conception at all of the power exerted by the mind in moving the body. It is of importance to reflect on the manner in which this notion is extended to all other productions of motion. We think that this will ſhew, that in every caſe we ſuppoſe preſſure to be exerted.

9 Examination of the inſtances of this perception.

The philoſopher proceeds in his ſpeculations, and obſerves that one man can preſs on another, and can puſh him out of his place, in the ſame way as he removes any other body; and he cannot obſerve any difference in his own exertions and ſenſations in the two caſes. But the man who is puſhed has the ſame feelings of touch and preſſure. By withdrawing from the preſſure, he alſo withdraws from the ſenſation; by withſtanding or reſiſting it, he feels the preſſure of the other man; and what he feels is the ſame with what he feels when he preſſes on the other perſon, or on any piece of matter. The ſame ſenſations of touch are excited. He attributes them to the preſſure of the other perſon. Therefore he attributes the ſame ſenſations to the counter preſſure of any other body that excites them. Farther, he can reſiſt to ſuch a degree that he is not puſhed from his place. In this caſe, the greateſt preſſure is exerted, and is felt by both. Each feels that the more he reſiſts, the greater is the mutual preſſure. And each feels that, unleſs he *not only do not reſiſt, but alſo withdraw himſelf* from the preſſure of the other, he will be preſſed, and the other will feel counter preſſure, the ſame in kind with what is produced by his reſiſtance, though leſs in degree.

10 They are generally figurative.

All theſe things are diſtinctly and invariably felt; but they require attention, in order to be ſubjects of recollection and after-conſideration. From this, and no other ſources, are derived all our notions of corporeal preſſure, of counter preſſure, of action, re-action, of *reſiſtance*, and of *inactivity* or *inertia*. Our notions of moving power, of the mobility of matter, and of the neceſſity of this power to produce motion in matter, have the ſame origin. Our notions alſo of the reſiſtance of inanimate matter, indicated by the expenditure of actual preſſure, are formed from the ſame premiſes: the counter-preſſure, or what at leaſt produces the ſame feelings in the perſon who is the mover, is conſidered as the property of dead matter; becauſe we feel, that if *we* do not exert real force, we are diſplaced by the ſame preſſure that would diſplace a lifeleſs body of the ſame bulk.

11 We obſerve many preſſures.

Theſe direct inferences are confirmed as we extend our acquaintance with things around us. We can exert our force in bending a ſpring, and we feel its counter-preſſure, preciſely ſimilar to that of another man. We feel that we muſt continue this preſſure, in order to keep it bent; and that as we withdraw our preſſure, the ſpring follows our hand, ſtill producing ſimilar feelings in our organs of touch, and requiring ſimilar exertions of our ſtrength to keep it in any ſtate of tenſion. Theſe phenomena are interpreted as indications of preſſures actually exerted by the ſpring, and quite different from what we ſhould feel from its mere reſiſtance to being moved. This action reſembles our own exertion in every particular; it produces all the effects of preſſure; it will ſqueeze in the ſoft flexible parts of our body with which we act on it; it will compreſs any ſoft body, juſt as we do ourſelves; it will put bodies in motion. Farther, we can ſet the action of one ſpring in oppoſition to that of another, and obſerve that each is bent by bending the other; and we ſee that their touching parts exert preſſure, for they will compreſs any ſoft body placed between them.

Thus, then, in all thoſe caſes, we have the ſame notion of the power immediately exerted between the two bodies, animated or inanimated. It is always preſſure. If indeed we begin to ſpeculate about the *modus operandi* in any one of theſe inſtances, we find that we muſt ſtop ſhort. How our preſſure excites the feeling of preſſure in the other perſon, or how it produces motion, eludes even conjecture—So it is—Nay, how our intention and volition cauſes our limb to exert this preſſure, or how the ſpringineſs of a ſpring produces ſimilar effects, remains equally hid from our ken. Unwearied ſtudy has greatly advanced our knowledge of theſe ſubjects in one reſpect. It has pointed out to us a train of operations, which go on in our animal frame before the oſtenſible preſſure is produced; we have diſcovered ſomething of their kind, and of the order in which they proceed; we have gone farther, and have diſcovered, in ſome of the preſſures exerted by lifeleſs matter, ſimilar trains of intervening operations. In the caſe of a ſpring, we have diſcovered that there is a certain combination of the properties of all its parts neceſſary for the viſible exertion. But what is the principle which thus makes them co-operate, we cannot tell, any more than in our own exertions of preſſure. Such being the origin of our notions on theſe ſubjects, it is no wonder that all our language is alſo derived from it. Force, power, preſſurre, action, re-action, reſiſtance, impulſion, are, without any exception, words immediately expreſſive of our own exertions, and applied metaphorically to the phenomena of matter and motion.

Laſtly, when we ſee a body in motion diſplace another body by hitting it, and endeavour to form a notion of the way in which this motion is immediately produced, fixing our attention on what paſſes in the very inſtant of the change, we find ourſelves ſtill obliged to ſuppoſe the thing we call preſſure. We can have no other conception of it; and there is no violence in this act of the imagination. For we know, that if we are joſtled from our place, and forcibly driven againſt another perſon, we put that perſon in motion without any intention or action of our own; and we experience, in doing this, that the very ſame feelings of touch and preſſure are excited as in the inſtances of the ſame motions produced by exerted preſſion. We alſo ſee, that when a body ſtrikes another, and puts it in motion, it makes an impreſſion or dimple in it if ſoft, or breaks it if brittle; and, in ſhort, produces every effect of preſſure. A ball of ſoft clay makes a dimple in the ball of ſoft clay which it diſplaces, and is dimpled by it. Springy bodies compreſs each other in their colliſions, and reſile from each other. In ſhort, in every caſe of this claſs, mutual preſſure, indicated by all its ordinary effects, appears to be the intermedium by which the changes of motion are immediately produced; and the previous motion of the ſtriking body ſeems to be only the method of producing this preſſure.

12
Preſſure is the only diſtinct notion of a moving power.

From this copious induction of particulars, and careful attention to the circumſtances of each, we think it plain, that preſſure is the only clear notion that a mind, not familiar with ſcrupulous diſcuſſion, forms of moving power; and therefore that it is very ſingular to think of excluding it from the liſt, and ſaying that impulſion is the only power in nature, and the ſource of all preſſure.

It may perhaps be ſaid, that the mutual immediate action to which the vulgar, and many philoſophers, have erroneouſly given the metaphorical name preſſure, is indeed the real cauſe of motion, or change of motion; but ſtill it is now properly called impulſion, becauſe it is occaſioned only by the previous motion of the impelling body. We conceive clearly (they may ſay) how this previous motion produces the impulſion. Since matter is impenetrable, we ſee clearly that a ſolid body, or a ſolid particle, cannot proceed without diſplacing the bodies with which it comes into contact; we have notions of this as clear as thoſe of geometry; whereas, how preſſure is produced, is inconceivable by us. If we preſs a ball ever ſo ſtrongly againſt another, and remove the obſtacle which prevented its motion, it will not move an inch, unleſs we *continue* to follow it, and preſs it forward; but we ſee a moving body produce compreſſion, bend ſprings, make pits in ſoft bodies, and produce all the effects of real animal preſſure. Impulſe, therefore, is the true cauſe of motion, and the ſolicitation of gravity is nothing but the repeated impulſe of an inviſible fluid.

But, in the firſt place, let it be obſerved, that both parties profeſs to *explain* the phenomena of mechanical nature, that is, to make them eaſier conceived by the mind. Now it may be granted, that could we have any previous conviction of a fluid continually flowing toward the centre of the earth, we could have ſome notion of the production of a downward motion of bodies, but not more explanation than we have without it, becauſe impulſiveneſs is as little underſtood by us as preſſure.

13
Many preſſures are inexplicable by impulſion.

But there are thouſands of inſtances of moving forces where we cannot conceive how they can be produced by the impulſe of a body already in motion. There appear to be many moving powers in nature, independent of, and inexplicable by, any previous motion; theſe may be brought into action, or occaſions may be afforded for their action, in a variety of ways. The mere will of an animal brings ſome of them into action in the internal procedure of muſcular motion; mere vicinity brings into action powers which are almoſt irreſiſtible, and which produce moſt violent motions. Thus a little aquafortis poured on powdered chalk contained in a bombſhell, will burſt it, throwing the fragments to a great diſtance. A ſpark of fire brings them into action in a maſs of gunpowder, or other combuſtibles. And here it deſerves remark, that the greater the maſs is to which the ſpark is applied, the more violent is the motion produced. It would be juſt the contrary, if the motion were produced by impulſe. For in all caſes of impulſion, the velocity is inverſely proportional to the matter that is moved. When a ſpring is bent, and the two ends are kept together by a thread, a preſſure is excited, which continues to act as long as the thread remains entire. What contrivance of impelling fluid will *explain* this, or give us any conception of the total ceſſation of this preſſure, when the thread is broken, and the ſpring regains its quieſcent form?

14
All preſſures do not produce a ſenſible motion.

We can explain, in a moſt intelligible manner, why the hardeſt preſſure produces no ſenſible motion in the caſe referred to above. We can conceive, with ſufficient diſtinctneſs, a tube filled with ſteel wires, coiled up like cork ſcrews, and compreſſed together into $\frac{1}{10}$th of their natural length. A tube of 10 inches long will contain 100 of them. While in this ſtate, compreſſed by a plug, we can ſuppoſe each of the ſprings to be tied with a thread. Suppoſe now that the thread of the ſpring next the piſton is burnt or cut; it will preſs on the piſton, and force it out, accelerating its motion till it has advanced one inch; after this, the piſton will proceed with a uniform motion. It is plain that the velocity will be moderate, perhaps hardly ſenſible, becauſe the preſſure acted on it during a very ſhort time. But if two ſprings have been ſet at liberty at the ſame inſtant, the preſſure on the piſton will be continued through a ſpace of two inches, and the final velocity will be greater, becauſe the ſame (not a double) preſſure will be exerted through a double ſpace. Unbending four ſprings at once, will give the piſton a double velocity (See Dynamics, *Suppl.* n° 95.) Now the effect of the motion of the ſecond ſpring is to keep the preſſure of the firſt

firſt in action during a longer time, by following it, and keeping it in a ſtate of compreſſion. There is nothing ſuppoſed of this kind in the caſe of ſtrong preſſure alluded to; and therefore no motion is produced when the obſtacle is removed, except what the inſenſible compreſſion produces by accelerating the body along an inſenſible ſpace. If all the 100 ſprings are diſengaged at once, the piſton will be accelerated through 100 inches, and will acquire ten times the velocity that one ſpring can communicate. (*N. B.* The force expended in moving the ſprings themſelves is not conſidered here).

It is in this way only that the previous motion of the impelling body acts in producing a conſiderable motion. The whole proceſs will be minutely conſidered by and bye.

15
Impulſion is no more clearly conceived than preſſure.

We may now aſk, how it is ſo clear a point, that a ſolid body in motion muſt diſplace other bodies? This ſeems to be the very point in queſtion, Is the affirmative deduced from our notion of ſolidity? What is our notion of ſolidity, and whence is it derived? We apprehend that even this primary notion is derived from preſſure. It is by handling a thing, and finding that we cannot put our hand into the place where it is without diſplacing it, that we know that it is material. All this is indicated to us by the feeling excited by our preſſure. We feel this property always as an obſtacle; and therefore ſay, that by this property it reſiſts our preſſure. Nay, there are caſes where even the philoſopher prefers this quality to impulſiveneſs as a teſt of matter. To convince another that the jar out of which he has poured the water that filled it is not empty, but full of matter, he dips the mouth of the jar into water, and ſhows, that although he preſs it down till the ſurrounding water is above the bottom of it, the water has hardly gotten half an inch into the jar; there is ſomething there which keeps it out; there is matter in it. He then opens a hole in the bottom of the jar; the water immediately riſes on the inſide of the jar, and fills it. He ſays that the preſſure of the water has driven the matter out by the hole; and he *confirms* the materiality of what is expelled by holding a feather above the hole. It is agitated, ſhewing that the expelled thing has impulſiveneſs, another property (he ſays) of matter: what filled the jar was air, and air in motion is wind. The philoſopher can exhibit ſome new caſes, where ſomething like impulſiveneſs appears. A ſlender magnet may be ſet on one end, the ſouth pole, for inſtance, and will ſtand in that tottering ſituation. If a perſon bring the north pole of a powerful magnet haſtily near the upper end, it will be thrown down, juſt as it may be blown down by a puff of wind; therefore (ſays the philoſopher) there may be appearances of impulſion, and I may imagine that there is impelling matter; but nothing but matter excludes all other matter from its place: this property, therefore, is the ſureſt teſt of its preſence.

Thus we ſee, that our notion of ſolidity or impenetrability (a name ſtill indicating an obſtacle to preſſure), gives us no clearer conception of the productions of motion by impulſion than preſſure does; for it is the ſame, or indicated by the ſame ſenſations.

16
Motion does not impel by transfuſing inherent force or inherent motion.

The queſtion now ſeems to be reduced to this—Since the ſtrongeſt preſſure of a quieſcent body does not produce motion, or excite that kind of preſſure which is the immediate cauſe of motion, while a body in motion, exciting but a very moderate preſſure (as may be ſeen by the trifling *compreſſion* or dimpling), produces a very conſiderable motion, how is the previous motion conducive to this purpoſe? The anſwer uſually given is this: A body in motion (by whatever cauſe) perſeveres in that motion by the *inherent force;* when it arrives at another body, it cannot proceed without diſplacing that body. The nature of the inherent force is ſuch, that none of it is loſt, and that a portion of it paſſes into the other body, and the two bodies inſtantly proceed with the ſame quantity of motion that was in the impelling body alone. This is an exact enough narrative of the general fact, but it gives no great *explanation* of it. If the impelling body perſeveres in its motion by means of its inherent force, that force is exerted in performing its office, and can do no more. The impelled body ſeems as much to poſſeſs an inherent force; for the ſame marks and evidences of preſſure on both ſides are obſerved in the colliſion. If both bodies are ſoft or compreſſible, both are dimpled or compreſſed. We are as much entitled, therefore, to ſay, that part of the force by which it perſeveres at reſt, paſſes into the other body. But the reſt, or quieſcence of a body, is always the ſame; yet what paſſes into the impelling body is different, according to its previous velocity. We can form no conception how the half of the inherent force of the impelling body is expended by every particle, paſſes through the points of contact, and is diſtributed among the particles of the impelled body; nay, we cannot conceive this halving, or any other partition of the force. Is it a thing *ſui generis*, made up of its parts, which can be detached from each other, as the particles of ſalt may be, and really are, when a quantity of freſh water is put into contact with a quantity of brine? We have no clear conception of this; and therefore this is no elucidation of the matter, although it may be an exact ſtatement of the viſible fact.

17
This involves abſurdities.

Let us take the ſimpleſt poſſible caſe, and ſuppoſe only two particles of matter, one of which is at reſt, and the other moves up to it at the rate of two feet per ſecond. The event is ſuppoſed to be as follows: in the inſtant of contact, the two particles proceed with half of the former velocity. Now this inſtant of time, and this preciſe point of ſpace, in which the contact is made, is not a part of either the time or ſpace before colliſion, or of thoſe after-colliſion; it is the boundary between both; it is the laſt inſtant of the former time, and the firſt inſtant of the latter time; it belongs to both, and may be ſaid to be in both. What is the ſtate or condition of the impelling particle in this inſtant? In virtue of the previous motion, it has the determination, or the force, or the power, to move at the rate of two feet per ſecond; but, in virtue of the motion after colliſion, it has the determination or power of moving at the rate of one foot per ſecond. In one and the ſame inſtant, therefore, it has two determinations, or only one of them, or neither of them. And it may, in like manner, be ſaid of the impelled body, that, in that inſtant, it was both at reſt, and moving at the rate of one foot per ſecond. This ſeems inconceivable or abſurd.

18
Impulſiveneſs is not an intuitive property of matter.

It is not perhaps very clear and demonſtrable, nor is it intuitively certain, that the moving body or particle muſt diſplace the other at all. All that we know is, that matter is moveable, and that cauſes of this motion exiſt in nature. When they have produced this motion, they have performed their taſk, and the motion is their complete effect: the particle continues in this condition for ever, unleſs it be changed by ſome cauſe; but we do not ſee any thing in this condition that enables us to ſay what cauſes are competent to this change, and what are not. Is it either intuitive or demonſtrable, that the *mere exiſtence* of another particle is not a ſufficient or adequate cauſe? Is it certain that the arrival at another particle is an adequate cauſe? or can we prove that this will not ſtop it altogether? The only concluſion that we can draw with any confidence is, that "two particles, or two equal bodies, meeting with equal velocities, in oppoſite directions, will ſtop." But our only reaſon for this concluſion is, that we cannot aſſign an adequate reaſon why either ſhould prevail. But this form of argument never carries luminous conviction, nor does it even give a deciſion at all, unleſs a number of caſes can be ſpecified which include *every poſſible reſult*. This can hardly be affirmed in the preſent caſe.

19
But an obſerved fact.

We apprehend that the next caſe, in point of ſimplicity, has ſtill leſs intuitive or deductive evidence; namely, when bodies meet in oppoſite directions with equal quantities of motion. It is by no means eaſy, if it be at all poſſible, to ſhew that they muſt ſtop. The proof proceeds on ſome notion of the manner in which the impulſion, exerted on one particle, or on a few of each body, namely, thoſe which come into contact, is diſtributed among all the particles. A material atom is moved only when a moving force acts on it, and each atom gets a motion preciſely commenſurate to the force which actuates it. Now, it is ſo far from being clear, how a force impreſſed on one particle of a ſolid body occaſions an equal portion of itſelf to paſs into every particle of that body, and impel it forward in the ſame direction, that the very authors who aſſume the preſent propoſition as an elementary truth, claim no ſmall honour for having determined with preciſion the moving forces that are exerted on each particle, and the circumſtances that are neceſſary for producing an equal progreſſive motion in each. It was by no means an eaſy problem to ſhew, that the motion of the body (eſtimated by an average taken of the motions of every particle) is preciſely that which is announced by this propoſition. We muſt alſo conſider how this inveſtigation is conducted. It is by aſſuming, that whatever force connects a particle a with a particle b, or whatever force a exerts on b, the particle b exerts an equal force on a in the oppoſite direction—Surely no logician will ſay that this is an intuitive truth. The contrary is moſt diſtinctly conceivable. It was a *diſcovery* of the aſtronomers, that every deflection toward the ſun is accompanied by an equal deflection of the ſun. It was a *diſcovery*, that a piece of iron attracts a loadſtone; and it was a *diſcovery* (and we dare not yet affirm it to be without exception), that every action of bodies is accompanied by an equal and contrary re-action. But this is by no means a firſt principle. It is the expreſſion of a moſt generally obſerved fact, a ſum total of knowledge. When received on this authority, it is fully competent to ſolve every caſe of impulſion, independent of all obſcure and illogical doctrines of force inherent in moving bodies, of force of inertia, of communication of motion, &c.

The impoſſibility of conceiving the detachment of part of the *force* inherent in A, and transferring *this* part into B, and the ſimilar impoſſibility of conceiving the imparting to B ſome of the *motion* that was in A, ſhould make us reject any propoſition involving ſuch conceptions, and refuſe its admiſſion as an elementary truth. Much more ſhould we reject a propoſition that obliges us to ſuppoſe that a particle of matter has two determinations, forces, motions, or call them by any other name, in one and the ſame inſtant. One of theſe neceſſarily excludes the other. Indeed this was ſo evident, even to the moſt eminent partizans of the doctrine of the transfuſion of inherent force, and others conſequent on it, that they found themſelves obliged to deny that there was ſuch a thing in the world as a perfectly hard body, in which the motion muſt be inſtantaneouſly changed into another, differing from it by any ſenſible quantity. The exiſtence of perfectly hard bodies is poſitively denied by the celebrated mathematician of Baſle, John Bernoulli, in his Diſſertation on the Communication of Motion, which contended for the prize given by the Academy of Sciences at Paris 1710. His reaſon for this rejection is ſingular, and ſomewhat amuſing. "In the colliſion of perfectly hard bodies, the *conſervatio virium vivarum*, demonſtrated by the moſt eminent mathematician (Mr Leibnitz), to be a law of nature, would be broken without any effect being produced. He does not obſerve, that it is as completely broken by elaſtic bodies in the inſtant of greateſt compreſſion. A Britiſh philoſopher, *nullius addictus jurare in verba magiſtri*, aſked, What will be the caſe of two encountering atoms of matter? Without calling them hard, we muſt conceive that they acquire their changes of motion in the inſtant of mutual contact, and that they acquire them *totally*, being ατομοι, indiviſible. No anſwer has been given, or indeed can be given, but what implies the ſame difficulty. From all that has been ſaid, we muſt conclude, that this branch of mechanical philoſophy is not put, by thoſe philoſophers, into the condition of an elementary foundation of clear and demonſtrative ſcience; that the transfuſion, or transference, either of force or motion, is not a thing of which we have a diſtinct conception; and that it neceſſarily leads us into very untenable doctrines. Far leſs does it ſeem ſafe for us to confide ſo much in its clearneſs and certainty, as to affirm, that impulſion is the ſole moving force in mechanical nature, and the ſource of what we call preſſure.

All this difficulty and obſcurity has ariſen from our arrogant notion, that we are competent judges of firſt *principles*; whereas we muſt acknowledge, that we can only perceive ſuch as are properly related or accommodated to our intellectual powers: theſe powers, being ſpecific and peculiar, cannot judge of principles of the firſt claſs, but of thoſe only that are *ſuitably* compounded. We can never know or comprehend any eſſential property of matter—we can only know the *relative* properties of *ſuch matter as we ſee*.

20
Therefore to be learned only by obſerving nature.

Therefore let us quit entirely the barren and trackleſs fields of abſtraction, and reſt ſatisfied with contemplating *what* the Author of Nature has exhibited to our view, and *ſuch* as he has been pleaſed in his wiſdom to exhibit it. We grant that there are no bodies open to our inſpection which are perfectly hard, receiving finite changes of motion in an inſtant. It has not pleaſed God

God to put any ſuch within our reach. When God created matter, it was with the purpoſe of forming a beautiful univerſe of this matter. He therefore gave it properties which fitted it for this purpoſe. It is this matter only that he has expoſed to the wondering view of man. Thanks to his bounty, he has alſo given us properties of mind, by which this adaptation, when perceived by us, becomes a ſource of dignified pleaſure to the obſerver.—A Newton, to whom "*Jovis omnia plena*," a Daniel Bernoulli, were rapt almoſt into ecſtacy by a ſingle atom, when they obſerved how its properties, and only ſuch properties, fitted it for making part of a world, which

> Unwearied, and from day to day,
> Should its CREATOR's power diſplay.

Let the unhappy La Place conſider theſe properties, which enſure the permanency of the ſolar ſyſtem through ages of ages, as proofs of fataliſm, as qualities eſſential to matter. But this Gallic torch effaces the bloom of life from the univerſe, the expreſſion of the Supreme Mind which ſhines from within; and it ſpreads over the countenance of Nature the ghaſtly paleneſs of univerſal death. But let us Britons rather follow the example of our illuſtrious countryman, and ſolace ourſelves with every diſcovery which tends to quicken our perception of Nature's *animated* charms. Let us liſten to the conjectures of him who had already diſcovered ſo many, and who endeavoured to remove the veil which concealed the reſt.

21 Moving powers are inherent in all matter. Newton's conjecture improved by Boſcovich.

Newton, in his maturity of judgment, after having collected much information from his unwearied experiments in magnetiſm, in chemiſtry, in optics, &c. ſaid, that "he ſtrongly ſuſpected, that, in the ſame manner as the bodies of the ſolar ſyſtem were connected by gravitation, ſo the particles of ſublunary bodies were connected together, and affected each other, by means of forces which acted at ſmall, and, in many caſes, inſenſible diſtances; producing the phenomena of coheſion, in all its forms of hardneſs, elaſticity, ductility, ſoftneſs, fluidity, by which their mechanical actions on each other were modified and regulated." Father Boſcovich, one of the firſt mathematicians of Europe, was the firſt who gave this conjecture of Newton's the attention that it ſo highly deſerved. Other writers indeed, ſuch as Keill, Freind, Boerhaave, &c. took occaſional notice of it, and even made ſome uſe of it in their attempts to explain ſome complicated phenomena of nature. But they were ſo careleſs in their employment of Newton's conjecture, ſo completely neglected his cautious manner of proceeding, indulged ſo wantonly in hypothetical aſſumptions, and reaſoned ſo falſely from them, that they brought his conjecture into diſcredit. Boſcovich, on the contrary, copied Newton with care, and ſecured his progreſs as he advanced by the aid of geometry; eſtabliſhing a ſet of uncontrovertible propoſitions, which muſt be the inevitable reſults of the premiſes adopted by him. He then proceeded to compare theſe with the phenomena of nature; and he ſhews that the coincidence is as complete as can be deſired. All this is done in his *Theoria Philoſophiæ Naturalis*, firſt publiſhed at Vienna in 1759. We have given a very ſhort account of it in the article BOSCOVICH, *Suppl.*; but it hardly goes beyond the enunciation of the general principles, and the indication of its applicability to the purpoſes intended. His application to the production of motion by the colliſion of bodies, is peculiarly ſatisfactory. But as the work is written chiefly with the view of gaining the approbation of perſons well inſtructed in natural philoſophy, it can hardly be called an elementary work, or be employed for the inſtruction of perſons entering on the ſtudy. We ſhall attempt to explain this important law of mechaniſm in a way that will give our readers a diſtinct notion (and, we apprehend, a juſt one) of the procedure of Nature in all the caſes of impulſion *that we can obſerve*. We hope to do this, by conſidering the changes of motion produced by moving bodies in a certain ſeries of familiar caſes, where the procedure of nature may be diſtinctly obſerved, and where it is uniformly conceived by every ſpectator; and which will gradually lead the mind to thoſe caſes where the procedure is not obſerved with diſtinctneſs; but the ſimilarity to the former caſe is concluded by ſo fair analogy, that we imagine no perſon will controvert it. We ſhall begin by attending to the manner in which two magnets in motion affect each other's motions; a phenomenon that is familiarly known in the general, although, perhaps, few perſons have attended to it minutely.

Plate xxix.

22 Examination of the mutual action of magnets.

Let us, therefore, ſuppoſe two magnets, A and B (fig. 1.) equal in weight (in the firſt inſtance). Let them be made to float on water, by placing them on pieces of cork. Let them be placed with their north poles touching each other. Let A be held faſt, and let B be at liberty to move. We know that it will gradually recede from A, with a motion that would continually accelerate, were it not for the reſiſtance of the water. What is the inference drawn from this appearance? Surely this, that either a moving power, inherent in A, repels B, or that B avoids A, by an evaſive power inherent in itſelf. It is immaterial for our purpoſe which opinion we adopt. Let us ſay that A repels B. This admits more conciſe language than the other If we prevent this motion of B by means of a very ſlender ſpring applied to its remote end, we ſhall obſerve that the ſpring is bent back a little, juſt as if we were puſhing away the magnet gently with the finger; and we obſerve, that the bending of the ſpring is ſo much the greater as B is nearer to A. We can judge of the intenſity of the force by which B is actuated, by the bending of the ſpring.—This force is equal to the *weight* of any body that will bend the ſpring to the ſame degree. This force is analogous, therefore, to the weight, the preſſure of gravity, and we may call it a preſſure, and meaſure it by grains weight. Every force that can bend a ſpring will move a body. This is a well known fact. Therefore it is next to certain, that it is this force which cauſes B to recede from A; nay, if we compare the motion of B with what *ſhould* reſult from the action of a force having this very intenſity, and varying in the ſame manner by a change of diſtance from A, taking in the diminution which the reſiſtance of the water muſt occaſion, we ſhall find the motions preciſely the ſame. All this can be diſcovered by DYNAMICS, n° 95, &c. Therefore we muſt conclude that this, and no other, is the cauſe of the receſs of B.

If, inſtead of placing B in contact with A, we place it at a diſtance from it, and puſh it toward A with an initial velocity, ſomewhat leſs than it would have acquired

quired in that place by its receſs from A, we ſhall find that it will approach A with a motion gradually retarded, till it ſtop at a ſmall diſtance from A; and will now recede from it again with an accelerated motion. In ſhort, we ſhall find that its whole motion to and from A is preciſely the ſame with what reſults from a ſimilar computation by n° 95 of DYNAMICS.

The whole of this phenomenon is conceived by every beholder, who has not imbibed ſome peculiar theory of a ſtream of impelling fluid, as the indication and effect of a repulſive force exerted by A on B, or of a quality of B, by which it recedes from A.

If now B be held faſt, and A be ſet at liberty, it is obſerved to be repelled by B, or to recede from B, in the ſame manner, and with the ſame force.

Thus, the two magnets appear to affect each other's motions, and are thought, and ſaid, by all to repel each other. The effect appears curious, but excites no farther thought in moſt minds: it is only the ſpeculatiſt that begins to ſuſpect that he has not conceived it properly.

Now, let us ſuppoſe that B is afloat on the ſurface of the water, and at reſt; and that A is puſhed towards it, by a ſingle ſtroke, cauſing it to move ſo moderately that it ſhall not ſtrike B, but have its motion deſtroyed by the repulſion before it reaches it; and let us farther ſuppoſe, that the initial velocity of A was exactly meaſured—the fact will be as follows. As ſoon as A comes within a certain diſtance of B, its motion begins to be affected; it gradually diminiſhes, and at length it ceaſes entirely, and A remains ever after perfectly ſtill. But it is alſo obſerved, that in the inſtant that A ſlackens its motion, B begins to move; that it gradually accelerates in its motion, and at laſt acquires the initial velocity of A, with which it proceeds, till the reſiſtance of the water brings it to reſt; perhaps at a conſiderable diſtance from A. This experiment is very amuſing, and the initial velocity of A may be increaſed in each ſucceeding trial, till at laſt it ſtrikes B. Even then the general appearance remains the ſame: A is brought to reſt and remains at reſt, neither reſiling nor advancing forward; and B moves off with the initial velocity of A. What we wiſh to be particularly noticed is, that as long as the initial velocity of A is leſs than a certain quantity (depending on the ſtrength of the magnets), the motion is communicated to B, or, to expreſs it more cautiouſly, motion is produced in B, without any thing happening that can get the name of impulſion with propriety. In the ordinary conceptions and language of mankind, impulſe always ſuppoſes actual contact; and impulſion is equivalent to a blow or a ſtroke. Both of theſe are indeed metaphorical terms, as well as impulſion. Perhaps the word "to hit," expreſſes this particular caſe more purely, and it is perhaps without any figure, and is the appropriate word. We do not ſpeak at preſent of the conception and language of philoſophers, but of perſons taking an unconcerned view of things, without any intention of ſpeculating farther about the matter.

Appearances perfectly ſimilar are obſerved in electrified bodies. If we hang two equal bunches of very light downy feathers by two equal linen threads, ſo as to hang cloſe by each other like pendulums without touching, and if, after having electrified them ſo that they repel each other to ſome diſtance, we draw one of them, which we ſhall call A, conſiderably aſide from the perpendicular, and then let it go to ſwing like a pendulum; we ſhall obſerve, that inſtead of accelerating till it reach the loweſt point of its vibration, its motion will be retarded; it will ſtop entirely when its thread is perpendicular, and will remain at reſt. In the mean time, the other bunch B will acquire motion, which will gradually increaſe till it equal the motion of A in its maximum ſtate; and with this it would proceed for ever, were it not riſing like a pendulum in the arch of a circle. The general fact is the ſame as in the caſe of the magnets. The moving body is brought to reſt, in which ſtate it continues, and the quieſcent body moves off with an ultimate velocity, equal to the initial velocity of the other; and all this happens without contact or impulſion, but is produced by the mutual repulſion of the electrified bodies.

If this general fact be compared with what happens in the colliſion of two billiard balls, it will be found perfectly ſimilar in every reſpect, but that of the contact and the impulſion, properly ſo called. The impelling ball is brought to reſt, and remains at reſt; and the impelled ball moves off with the velocity of the impelling ball.

This being the caſe, it is plain that we may derive ſome information from the motion of the magnets, that muſt greatly aſſiſt us in our conceptions of what paſſes in the rapid, if not inſtantaneous, production of motion in a billiard ball, by hitting it with another. In the caſe of the magnets, we perceive, and can diſcriminate, a progreſſive train of changes, which terminate in a final change, perfectly ſimilar to the change in the impulſion of the billiard ball. This will juſtify a very minute attention to, and ſtatement of, all the circumſtances.

23
Firſt caſe.
A moving toward B at reſt.

Let us attend to the proceſs of this operation, and the production of motion in the magnet originally at reſt, and the abolition of it in the one originally in motion; and let us reflect on what paſſes in our minds when we try to explain it to ourſelves. The trials mentioned at firſt, when one magnet was held faſt, ſhew us that each magnet repels or avoids the other, and that this action is found to be equal on both ſides, producing equal compreſſion of the ſpring employed for aſcertaining the intenſity of this repulſion when the diſtances are the ſame. This is the fact. It is no leſs a fact, that equal moving forces, ſuch as equal preſſures muſt be ſuppoſed to be, produce equal changes of motion in their own direction. Therefore, as ſoon as A comes to ſuch a diſtance from B that the mutual action takes place, both magnets are affected, and equally affected; that is, equal changes of motion are produced on each, but in oppoſite directions. The motion of A is diminiſhed, perhaps $\frac{1}{100}$th part in $\frac{1}{10}$th of a ſecond, and (let it be carefully remembered) while A paſſes over a certain ſpace, ſuppoſe the 10th of an inch. During this ſmall portion of time, B acquires as much motion as A loſes. This is not the motion loſt by A. This is inconceivable; for motion is not a thing, but a condition. But it is an *equal degree* of motion. B has paſſed over a ſmall ſpace during this time, perhaps the 50th part of an inch, with an almoſt imperceptible motion,

motion, that is gradually accelerated from nothing. Since A is moving faſter than B, it muſt ſtill gain upon it; and therefore the mutual repulſion will increaſe; and in the next 10th of a ſecond this force will take another and greater portion of A's original velocity from it, and will add a greater velocity to that already acquired by B. And thus, in every ſucceeding minute portion of time, the motion of A will be more and more diminiſhed, and that of B as much increaſed, by the equal, though continually increaſing, ſimultaneous repulſions acting in oppoſite directions. It is evident, that it is poſſible that the velocity of A may be ſo much diminiſhed, and that of B ſo much increaſed, that the remaining velocity of A ſhall be juſt equal to the acquired velocity of B. Till this happens, the diſtances of the magnets have been continually diminiſhing; for A has been moving faſter than B, and gaining on it. If the operation of the mutual repulſions could be ſtopped at this inſtant, both magnets would move forward for ever with equal velocities.

24 They acquire a common velocity x;

It is of particular importance to know what this common velocity is. This is determined by our previous knowledge, that the magnets repel or avoid each other with equal forces. Theſe forces may vary by a variation of diſtance; but the force acting on A is always equal and oppoſite to the force acting at the ſame time on B. This is the uncontroverted fact (the authority for which ſhall ſoon be conſidered). Theſe equal forces muſt therefore produce equal and oppoſite changes of motion. The motion acquired by B is equal to that loſt by A. But the magnets being ſuppoſed equal, and moving with equal velocities, they have equal quantities of motion. Therefore the motion acquired by B, or that loſt by A, is equal to what remains in A; that is, A has loſt half of its motion, and therefore half of its velocity; or the common velocity is half of the primitive velocity of A.

It was for the ſake of a ſomewhat eaſier diſcuſſion that we ſuppoſed the magnets to be of equal weights. But it is almoſt equally eaſy to aſcertain what this common velocity will be in any other proportion of the quantities of matter in A and B. It is a matter of unexcepted experience, that whatever be the weight or ſtrength of two magnets, their actions on each other are always equal. Therefore the ſimultaneous force muſt always produce equal changes of motion in the two bodies. But the change of motion is expreſſed by the product of the quantity of matter and the change of velocity. Therefore let A and B repreſent the quantities of matter in the magnets; and let a be the primitive velocity of A, and x the velocity which obtains when both are moving with one velocity. The velocity loſt by A is $a - x$. Therefore we muſt have $B x = A \times \overline{a - x}$, $= A a - A x$; and $A a = A x + B x$, $= \overline{A + B} \times x$, and $x = \frac{A a}{A + B}$. *The common velocity is therefore obtained by dividing the primitive quantity of motion by the ſum of the quantities of matter.*

25 Namely, $x = \frac{A \times a}{A + B}$

This may be conceived more compendiouſly in another way. Since B acquires as much motion as A loſes, the whole quantity of motion is the ſame as before: Therefore the common velocity muſt be had by dividing this quantity of motion by the whole quantity of matter. But we wiſhed to make the reader keep his attention fixed on the ſteps of procedure, and ſee the connection of each with the cauſes.

We ſhall find that this period of the whole proceſs, namely, the moment when both bodies have acquired a common velocity, and the preciſe magnitude of this velocity, are points of peculiar importance in the doctrine of impulſion; indeed they almoſt comprehend the whole of it.

26 But this does not continue, and the magnets ſeparate.

But this is a ſtate that cannot continue for a moment in the example before us. The repulſive or evaſive forces are ſtill acting on both magnets, and ſtill diminiſh the motion of A, and equally increaſe the motion of B. Therefore the velocity of A, in the very next moment, muſt be leſs than that of B; and B has, during this moment, gained on A, or has removed farther from it. This continues; A is ſtill retarded, and B is accelerated; and therefore gains more and more upon A, or ſeparates farther and farther from it. This muſt continue as long as the mutual repulſions are ſuppoſed to act. If we ſuppoſe that the *ſenſible* action of theſe forces is limited to ſome determinate diſtance, the mutual action will ceaſe when B has got to that diſtance before A. We may call it *the inactive diſtance*. After this, A and B will proceed with the velocities which they have at that inſtant. Let us inquire into theſe final velocities; and thus complete our acquaintance with the proceſs.

27 The common velocity is attained at the inſtant of neareſt approach.

We ſee (and it is important) that the magnets are in their ſtate of greateſt proximity at the inſtant of their moving with a common velocity, and that after this they gradually ſeparate, till they are again at their inactive diſtance. During this ſeparation they attain diſtances from each other equal to what they had during the period of their mutual approach. At theſe diſtances the repulſions are the ſame as before, and act in the ſame direction. Therefore, in each moment of ſeparation, and at each diſtance, A ſuſtains the ſame diminution, and B gets the ſame augmentation of its motion, as when they were at the ſame diſtance in the period of their mutual approach. The ſums total, therefore, of theſe equal augmentations and diminutions muſt be equal to the augmentation and diminution during the approach. Therefore the whole diminution of A's motion muſt be double of the diminution ſuſtained during the approach; and the whole augmentation of B's motion muſt, in like manner, be double of that acquired during the approach of A. Hence we eaſily ſee, that when the magnets are ſuppoſed equal, A muſt be brought to reſt; for in the period of approach it had loſt half of its velocity. It muſt now have loſt the whole. For ſimilar reaſons B muſt finally acquire the primitive velocity of A; for in the inſtant of greateſt proximity, it had acquired the half of it.

28 Repulſion is a cauſe adequate to the obſerved effect.

Thus we ſee that the equal mutual repulſions are preciſely adequate to the production of the changes of motion that are really obſerved; and muſt therefore be admitted as the immediate cauſes of theſe changes.

29 Effect when the magnets are unequal.

It is equally eaſy to aſcertain the final velocities when the magnets are of unequal ſizes; for the equality of their mutual repulſions is not affected by any inequality of their magnitudes. Their ſeparations, and the changes of motion during theſe ſeparations, will be the ſame with their approaches and the correſponding changes of motion; and the whole change on each will be double of the change ſuſtained at the inſtant of greateſt

greateſt proximity and common velocity. Hence we learn that the final velocity of B is $2x$, or $\frac{2Aa}{A+B}$; and the final velocity of A is $\frac{\overline{A-B}\times a}{A+B}$ For the primitive velocity of A being a, and the common velocity, in the inſtant of neareſt approach being $\frac{Aa}{A+B}$, the loſs of velocity is $a-\frac{Aa}{A+B}$, $=\frac{Aa+Ba-Aa}{A+B}$ $=\frac{Ba}{A+B}$. Therefore the final loſs of velocity is $\frac{2Ba}{A+B}$, and the remaining final velocity is $a-\frac{2Ba}{A+B}$, $=$ $\frac{Aa+Ba-2Ba}{A+B}$, $=\frac{\overline{A-B}\times a}{A+B}$.

30 II. Caſe. Both magnets in motion in one direction.

Let us, in the next place, ſee what will be the reſult when both of the magnets are in motion at the beginning of their mutual action. And, firſt, let both move in one direction. Let A, moving with the velocity a, overtake B, moving in the ſame direction with the velocity b, leſs than a. Moreover, let the velocities a and b be ſuch, that their differences $a-b$ is ſomewhat leſs than the ſum of the velocities α and β, which the mutual repulſions of the magnets would generate in them, if the magnets were placed in contact, and allowed to recede from each other till they get beyond their acting diſtance.

Theſe things being premiſed, let the magnets be ſet in motion in the ſame direction with the above-mentioned velocities a and b. The magnet A muſt gain on B, and at laſt come ſo near it, that the mutual repulſions begin to act on both. It is plain, that the motion of A will be diminiſhed, and that of B increaſed, by equal quantities, during every minute portion of the time of their mutual action. It is alſo evident, that the velocity of A may be ſo much diminiſhed, and that of B ſo much increaſed, that they ſhall be rendered equal. Alſo this will happen before the magnets touch one another; becauſe the original difference of their quantities of motion has been ſuppoſed leſs than the motion which the repulſive forces are able to generate or extinguiſh, by acting on them through the whole diſtance which gives occaſion to their action. Therefore the difference of the velocities is leſs than the ſum of the velocity α, which the mutual repulſion can take from A, and the velocity β, which it can give at the ſame time to B. The magnets will gradually approach, and the mutual repulſions, and conſequent diminution of A's, and augmentation of B's motion, will gradually increaſe, till the ſum of α and β is juſt equal to the difference of a and b; that is, till the bodies are moving with one velocity. If the mutual repulſions were annihilated at this inſtant, the bodies would move forward with this common velocity. What this is we determine with great facility, as we did in the former caſe: Becauſe the repulſions produce equal and oppoſite changes of motion in the magnets, as much is taken from $A\times a$ as is added to $B\times b$; and the ſum of $A\times a$, and $B\times b$, is equal to the ſum of $A\times x$ and $B\times x$, or $\overline{A+B}\times x=A\times a+B\times b$, and $x=\frac{Aa+Bb}{A+B}$. Therefore *the common velocity is had by dividing the ſum of the primitive quantities of motion by the ſum of the quantities of matter.*

31 Common velocity $=\frac{Aa+Bb}{A+B}$ but the magnets ſeparate, and the change is doubled in each.

But the repulſive forces continue to act as in the former caſe. The motion of A is ſtill more diminiſhed, and that of B augmented: Therefore the velocity of B muſt now exceed the velocity of A, and the magnets muſt ſeparate. Reaſoning in the ſame way as in the former caſe, it is evident that the mutual action does not ceaſe till the magnets have ſeparated to their inactive diſtance from each other, and that the whole change of motion in each is double of the change that it had ſuſtained when they were in their greateſt proximity, and moving with a common velocity. Theſe conſiderations enable us to aſcertain the final ſtate of each. The common velocity is $\frac{Aa+Ab}{A+B}$. Therefore the change made on the velocity of A, at the inſtant of greateſt proximity, is $a-\frac{Aa+Bb}{A+B}$, or $=$ $-\frac{B\times\overline{a-b}}{A+B}$, and the final velocity of A is $a-$ $\frac{2B\times\overline{a-b}}{A+B}$. In like manner, the change produced on the velocity of B is $=\frac{Aa+Bb}{A+B}-b$, or $=+$ $\frac{A\times\overline{a-b}}{A+B}$, and the final velocity of B is $b+$ $\frac{2A\times\overline{a-}}{A+B}$. We may alſo obtain the final velocity of each, by taking its initial velocity from twice the common velocity.

If, in this example of two magnets in motion, we ſuppoſe them of equal weight, we ſhall find that they will finally proceed with exchanged velocities. For when $A=B$, it is plain that $a-\frac{2B\times\overline{a-b}}{A+B}$ is $=$ $a-1\times\overline{a-b}$, $=a-a+b$, $=b$: and $b+$ $\frac{2A\times\overline{a-b}}{A+B}$ is $=b+1\times\overline{a-b}$, $=b+a-b$, $=a$. This caſe is eaſily ſubjected to experiment, and will be found fully confirmed, if we take into account the retardations occaſioned by the reſiſtance of the water to the motions.

31 Magnets moving in oppoſite directions.

Let us, in the next place, ſuppoſe the magnets to be moving in oppoſite directions with the velocities a and b; and (in order that the magnets may not ſtrike each other) let the ſum of a and b be leſs than the ſum of α and β, which the repulſions of the magnets would produce by repelling them from contact to their inactive diſtance.

As ſoon as the magnets arrive at their acting diſtance, their mutual and equal repulſions immediately begin to diminiſh both of their motions; and in any minute portion of the period of their approach, equal quantities of motion are taken from each. It is evident, that if the primitive quantities of motion have been equal; that is, if A and B have been moving with velocities reciprocally proportional to their quantities of matter, then, when the motion of one of them has been annihilated by their mutual repulſion, the motion of the other will be be deſtroyed at the ſame time, and both will be brought to reſt. Were the repulſions annihilated at this inſtant, they would remain at reſt. But becauſe thoſe forces continue their actions, the magnets will ſeparate again, regaining, at every diſtance, the velocity which they had, when at that diſtance, during their mutual approach; and when they have reached their inactive diſtance, they will have regained each its original momentum and velocity, but in the oppoſite direction. This needs no farther comment; but muſt be kept in mind, becauſe this caſe has a preciſe counterpart in the colliſion of ſolid bodies, meeting each other in oppoſite directions with equal momenta. But if the momentum of one exceed that of the other, thus, if $A \times a$ be greater than $B \times b$, then, when the magnet B is brought to reſt, A has ſtill a momentum remaining equal to $A\,a - B\,b$. Having therefore a certain velocity, while B has none, it muſt approach ſtill nearer to B, and a ſtill greater repulſion will be exerted on B than if A had alſo been brought to reſt, but ſtill repelling B. Since B is now acquiring motion in the direction oppoſite to its former motion, and A is ſtill loſing motion, a time muſt come when the motion of A is ſo much diminiſhed, and that of B ſo much augmented, that they are moving with a common velocity in the direction of A's primitive motion. The reaſoning employed in the foregoing examples ſhew us, that, in the preſent caſe alſo, this ſtate of common velocity is alſo the ſtate of the greateſt proximity, and that the magnets ſeparate again, till they attain their diſtance of inaction, and that the total change in each is double of what it was in their ſtate of greateſt proximity.

32 Common velocity $= \frac{A\,a - B\,b}{A + B}$ but the change is doubled by the ſubſequent ſeparation.

To find this common velocity, recollect, that when the momentum of B was extinguiſhed, that of A was ſtill $= A\,a - B\,b$. From what has been already ſaid on the other caſes, we know that when the common velocity obtains, the whole momenta are ſtill equal to $A\,a - B\,b$. Therefore the common velocity x muſt be $= \frac{A\,a - B\,b}{A + B}$.

The velocity loſt by A muſt therefore be $a - \frac{A\,a - B\,b}{A + B}, = \frac{B \times \overline{a+b}}{A + B}$, and the final velocity will be $a - \frac{2\,B \times \overline{a+b}}{A + B}$. The final motion of A will be in the ſame direction as at firſt, if a be greater than $\frac{2\,B\,\overline{a+b}}{A + B}$, otherwiſe it will be in the oppoſite direction.

In like manner, the change of velocity in B is $b + \frac{A\,a - B\,b}{A + B}$, becauſe the former velocity b is deſtroyed, and the new velocity is $\frac{A\,a - B\,b}{A + B}$ in the oppoſite direction. This is $= \frac{A \times \overline{a+b}}{A + B}$, and the final velocity of B is $= b - \frac{2\,A \times \overline{a+b}}{A + B}$.

33 The changes of motion in the magnets are ſimilar to thoſe in the colliſion of bodies.

Thus we have ſhewn, in the caſe of magnets acting on each other by repulſive forces, or actuated by forces equivalent to repulſive forces, how changes of motion are produced, which have a great reſemblance to thoſe which are ſeen in the colliſion of ſolid bodies. The motions which obtain in the inſtant of greateſt proximity are preciſely ſimilar to what *are obſerved* in the colliſion of unelaſtic bodies. Their common velocity after colliſion is always $= \frac{A\,a + B\,b}{A + B}$, or $= \frac{A\,a - B\,b}{A + B}$, according as the bodies were moving in the ſame or in oppoſite directions. The final motions of the magnets are alſo preciſely ſimilar to what *are obſerved* in the colliſion of perfectly elaſtic bodies. We took the inſtance of magnets, becauſe the object is familiar; but we can ſubſtitute, in imagination, an abſtract repulſive force in place of magnetiſm, and we can aſſign it any intenſity, and any law and limits of action we pleaſe. We can imagine it ſo powerful, that although its action be limited to a very ſmall, and even inſenſible diſtance, it ſhall always reduce the meeting bodies to a common velocity before they come into actual contact; and therefore without any real impulſion, as impulſion is commonly conceived.

There are ſome farther general obſervations that may be made on thoſe motions which are of importance.

34 Theſe changes are proportional to the relative motion,

1. We ſee that the changes of motion, and conſequently the actions, are dependent on the relative motions only, whatever the abſolute motions may be: For changes are always as $a - b$ when the bodies are moving in one direction, and as $a + b$ when they are moving in oppoſite directions. Now $a \pm b$ is the relative motion.

35 And reciprocally as the quantities of matter.

2. The change of velocity in each of the two bodies is inverſely as its quantity of matter, or is proportional to the quantity of matter in the other body. The changes in A and B are $\frac{B \times \overline{a \pm b}}{A + B}$ and $\frac{A \times \overline{a \pm b}}{A + B}$. The changing forces being equal on both ſides, produce equal changes in the quantities of motion; and therefore produce changes of velocity that are inverſely as the quantities of matter.

36 CONSERVATIO MOMENTORUM.

3. During the whole proceſs, the ſum of the momenta, or quantities of motion, remains the ſame, if the bodies are moving in one direction: if they are moving in oppoſite directions, it is the difference of momenta that remains the ſame; for in every inſtant of the proceſs equal changes of momentum are made in oppoſite directions. When the motions are in the ſame direction, as much is taken from the one as is added to the other; and therefore the *ſum* remains unchanged. When the motions are in oppoſite directions, equal quantities are taken from both; and therefore the *difference* remains unchanged. This is called the CONSERVATIO MOMENTORUM; and it is uſually enunciated by ſaying, that the quantity of motion, eſtimated in one direction, is not changed by the equal and oppoſite actions of the bodies. This is a particular caſe of a general law affirmed by Des Cartes, that the quantity of motion in the univerſe remains always the ſame when eſtimated in *any* one direction.

37 CONSERVATIO VIRIUM VIVARUM.

4. When the whole proceſs is completed, the ſum of the products made by multiplying each body by the ſquare of its final velocity, is equal to the ſum of the products made by multiplying each body into the ſquare of its initial velocity. For when the proceſs is completed, the two bodies are at the ſame diſtance from each other as when the mutual action began. There-

fore, during the proceſs, each body has paſſed over an equal ſpace, and in every ſimilar point it has been acted on by an equal force (although this force be different in different points of this ſpace). Therefore, in every inſtant, the ſimultaneous products of the quantity of matter by the momentary variation of the ſquare of the velocity are equal on both ſides; and therefore the products of the quantity of matter by the whole change of the ſquare of the velocity are alſo equal on both ſides. See Dynamics, *Suppl.* n° 95. and 110. where $v \dot{v} = \frac{\dot{f} s}{m}$; and therefore $m v \dot{v} = \int \dot{s}$, and $m \times V^2 - v^2$, or $n \times v^2 - V^2 = \int f \dot{s}$. Now, ſince theſe changes are in oppoſite directions, as much is added to one product as is taken from the other, and the ſum of the products of the quantities of matter by the ſquares of the final velocities, is equal to the ſum of the products of the ſame quantities of matter by the ſquares of the initial velocities.

Theſe two theorems are not principles, but general facts.

This is a particular caſe of the famous CONSERVATIO VIRIUM VIVARUM, claimed as a mighty diſcovery by the partizans of Leibnitz, and aſcribed to him; but he has no claim whatever to the diſcovery. It was communicated to the Royal Society of London in 1668 by Huyghens, as one of the general laws of impulſion, obtaining in what he calls *hard bodies*. Several of the Leibnitzian ſchool, indeed, extended it farther than Huyghens had done; ſome of them indeed very lately. The obſervation of this general law was ſoon applied to many excellent purpoſes in the ſolution of very intricate problems; becauſe it often ſaved the trouble of tracing the intermediate ſteps of a complicated proceſs. Aſſured that theſe products were invariable, the mathematician found it an eaſy matter to ſtate what conditions of the queſtion inſured this equality of products; and thus the problem was ſolved. In this manner Daniel Bernoulli gives moſt elegant ſolutions of ſome, otherwiſe almoſt intractable, problems in Hydraulics. For ſuch reaſons, as a mighty aid in mechanical inveſtigation, the diſcovery of Huyghens is extremely valuable. Its merit in this reſpect is perfectly ſimilar (though perhaps ſomewhat greater) to Des Cartes's obſervation of the *conſervatio momentorum.* It is alſo like the obſervation or diſcovery of Maupertuis, which he calls *the law of ſmalleſt action* (indeed it is the ſame under a different aſpect), or La Grange's *law of virtual velocities*, or D'Alembert's *law of equilibrium of action*;—all of theſe are general facts, laws by which the changes of motion are *obſerved* to proceed. But their authors have vaunted them as principles, as cauſes, from which to conclude effects; whereas they are really inductions from particular inſtances. We muſt alſo obſerve, that this law of *conſervatio virium vivarum* was not deduced either by Huyghens or any of the Leibnitzian ſchool, by reaſoning from more general principles. It was an expiſcation of ſameneſs in events, diverſified by other circumſtances. We do not recollect any author who has given what can be called a demonſtration of it, deducing it from principles or laws ſtill more general. We apprehend that the preſent caſe of its truth has been ſo demonſtrated by us. The *principle* is, that "a moving force is to be meaſured by the change of motion produced by it:" And the law to which this principle is applied is, that "the mutual repulſions of magnets are equal and oppoſite;" and the application is made by means of the "39th propoſition of the firſt book of Newton's *Principia.*" Our principle, which is the ſame with Sir Iſaac Newton's ſecond law of motion, is really an axiom of human thought. The propoſition is the conſequence logically drawn from this axiom; and the law of magnetiſm is an obſerved fact. We hope to ſhew, by and bye, that this propoſition, which is our n° 95. of Dynamics, is found to obtain in *every* inſtance that has been or can be given of the *conſervatio virium vivarum*, and that this *conſervatio* is only another way of expreſſing the propoſition. Having done this, we ſhall not think ourſelves chargeable with vanity when we ſay, that we have given the firſt demonſtration of this famous law. We cannot refuſe ourſelves ſome ſatisfaction at having done this; becauſe it has been ſo highly eſteemed, chiefly for the ſupport derived from it for the Leibnitzian meaſurement of the force of moving bodies by the *ſquare of the velocity* which it communicates; whereas it is the logical conſequence of the force being proportional to the *ſimple velocity.* We have only taken a weapon out of the hands of a plunderer, and reſtored it to its lawful owner, Sir Iſaac Newton. *Non ita certandi cupidus, quam propter amorem:* For we muſt ſay,

> *Tu pater et rerum inventor, tu patria nobis*
> *Suppeditas precepta, tuiſque ex, inclute, chartis*
> *Floriferis ut apes in ſaltibus omnia libant,*
> *Omnia nos itidem depaſcimur aurea dicta*
> *Aurea, perpetuâ ſemper digniſſima vitâ.*

We truſt that our reader will not think that this minute diſcuſſion of the mutual actions of magnets or other repelling bodies, in which we have engaged him, has been thrown away, ſince it has enabled us to apprehend clearly a caſe of two ſuch general laws as the *conſervatio momentorum*, and the *conſervatio virium vivarum.*

38 *Vis viva* loſt in the colliſion of unelaſtic bodies.

5. In the moment of greateſt vicinity and common velocity, there is a certain determinate loſs of the *vires vivæ*, or products of the matter by the ſquare of the velocity; and this loſs is proportional to the ſquare of the relative motion. The *vires vivæ*, at the commencement of the mutual action, are $= A a^2 + B b^2$ (I.) In the moment of greateſt proximity, the quantity of matter $A + B$ is moving with the common velocity $\frac{A a + B b}{A + B}$; therefore the *vires vivæ* are $= \overline{A + B} \times \frac{\overline{A a + B b}^2}{\overline{A + B}} = \frac{\overline{A a + B b}^2}{A + B}$, $=$

$$\frac{A^2 a^2 + B^2 b^2 + AB \times 2 a b}{A + B} \text{ (II.)}$$

$$\text{I.} \times \overline{A + B} = A^2 n^2 + B^2 b^2 + AB \times \overline{a^2 + b^2}.$$

$$\text{II.} \times \overline{A + B} = A^2 a^2 + B^2 b^2 + AB \times 2 a b.$$

$$\text{Difference} \quad - \quad - \quad - \quad AB \times \overline{a - b}^2.$$

Loſs of *vis viva* $= \frac{AB}{A + B} \times \overline{a - b}^2$, a quantity that is proportional to $\overline{a - b}^2$, the ſquare of the relative velocity $a - b$.

Had the bodies been moving in oppoſite directions, then (II.) $\times \overline{A + B}$ would have been $A^2 a^2 + B^2 b^2 - AB \times 2 a b$, and the difference from $\overline{A a^2 + B b^2} \times A + B$ would have been $= AB \times \overline{a + b}^2$, proportional to the ſquare of the relative velocity $a + b$.

Such

Phyſical cauſe of this loſs.

Such is the fact; and we ſhall find it of importance in the great debate about the force of moving bodies. Let us inquire into the phyſical or mechanical cauſe of it. In the moment of common velocity, the bodies are nearer to each other than they are at the beginning and at the end of their mutual action. Therefore (when they are moving in one direction) the body A, which follows, has been retarded through a ſpace which is greater than the ſpace along which the preceding body B has been accelerated. But, becauſe the ſimultaneous forces acting on the bodies along theſe unequal ſpaces are always equal, the area which meaſures the diminution of the ſquare of A's velocity (Dynamics, n° 95.) muſt exceed the area which expreſſes the augmentation of the ſquare of B's velocity, and there muſt be a loſs of *vires vivæ*. Now, we learned above, that the mutual action is the ſame when the relative velocity is the ſame; and therefore the approximation, which is the occaſion of this action, muſt be the ſame. And it is demonſtrated in Dynamics, n° 93. that the area, whoſe abſciſſa is the ſpace deſcribed, and ordinates the forces, expreſſes the ſquare of the generated or extinguiſhed velocity. This is evidently the relative velocity of the bodies, becauſe they are brought to a common velocity in the inſtant of greateſt proximity; that is, their relative velocity is deſtroyed.

39
The motion of the common centre of gravity is not changed by the mutual action.

6. During the whole proceſs, the common centre of poſition or gravity (A) is moving uniformly with the velocity $\frac{A\,a \pm B\,b}{A+B}$. For the motion of the centre of poſition is the average of the motion of every particle of matter in both bodies. $A\,a$ is the ſum of the motions of every particle of matter in A, and $B\,b$ is the ſum of the motions of every particle in B, before the mutual actions began. Therefore $A\,a + B\,b$ is the whole motions when the bodies are moving in the ſame direction with their different velocities. The number of particles is $A + B$: Therefore, if the whole motions be equally divided among all the particles, the velocity of each muſt be $\frac{A\,a + B\,b}{A+B}$. This is the average motion, or the motion of the centre of poſition, deduced from the notion we wiſh to impreſs of the character of this centre, as the index of the poſition and motion of any aſſemblage of matter. This velocity may be deduced more eaſily from its geometrical property. It is a point ſo ſituated between A and B, that its diſtance from each is reciprocally proportional to the quantities of matter in A and B, as is well known of the centre of gravity. It is equally plain, that when the bodies are moving in oppoſite directions, the average velocity x muſt be $= \frac{A\,a - B\,b}{A+B}$. Thus we ſee, that the motion of the centre of poſition, before the magnets have begun to act on each other, is the ſame with its motion when their mutual repulſion is the greateſt; namely, at the moment of their greateſt vicinity. It has continued the ſame during the whole proceſs: For we have already ſeen, that the ſum or difference of the momenta, or $A\,a \pm B\,b$, remained always the ſame; conſequently $\frac{A\,a \pm B\,b}{A+B}$, or x, the motion of the centre, remains always the ſame. Therefore the propoſition is demonſtrated. It is, indeed, a truth much more general than appears in the preſent inſtance. *If any number of bodies be moving with any velocities, and in any directions, the motion of the centre of poſition is not affected by their mutual, equal, and oppoſite, actions on each other.*

40
The motions, in relation to the centre, are reciprocally as the bodies.

7. During the whole motion, the motion of the bodies relative to each other, is to the motion of one of them, relative to the centre of poſition, as the ſum of the bodies is to the other body: For when they were moving with a common velocity, this velocity was the ſame with that of the centre; and they are then at reſt, relative to each other, and relative to the centre. And becauſe their diſtances from the centre are inverſely as the bodies, their changes of diſtance, that is, their motions relative to the centre, are in the ſame proportion: and the ſum of their motions relative to the centre is the ſame with their motions relative to each other. Therefore $A + B : A = a - b$: motion of B relative to the centre. Indeed we ſaw, that in their mutual action, the change of B's motion was $= \frac{A \times \overline{a - b}}{A+B}$, and the change of A's motion was $= \frac{B \times \overline{a - b}}{A+B}$.

41
The bodies ſeparate with the ſame relative velocity which they approached.

Hence we learn, that while the centre moves uniformly, the bodies approach it, and then recede from it, with velocities reciprocally proportional to their quantities of matter. This will be found a very uſeful corollary. We may alſo ſee that their final velocity of mutual receſs is equal to that of their firſt approach, or, their relative motions are the ſame in quantity after the action is over as before it began, but in oppoſite directions.

All theſe general facts, which are diſtinctly appreciable, and very perceivable, in this example of magnets, or electrified bodies, are equally appreciable in all caſes of mutual repulſions, however ſtrong theſe may be; and although the ſpace through which they are exerted ſhould be ſo ſmall as to elude obſervation, and though the whole proceſs ſhould be completed in an inſenſible moment of time.

42
An interpoſed ſpring has the ſame effect with the mutual repulſions.

It ſcarcely needs any comment to make it clear that the very ſame changes of motion muſt take place, if a ſolid body A ſhould come up to another ſolid body B, at reſt, or moving more ſlowly in the ſame direction, or moving in the oppoſite direction; provided that there be a ſpring interpoſed between them, which may hinder

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(A) See the article Position in this *Supplement*; where it will be demonſtrated, that the centre of gravity (determined in the uſual manner) is the point by whoſe ſituation and motion we eſtimate with the greateſt propriety the ſituation and motion of the aſſemblage, of which it is the centre: it is therefore called the CENTRE OF POSITION. The reader is only deſired at preſent to recollect, that the centre of gravity, or poſition of two bodies, is ſituated in the line joining their centres; and that its diſtance from each is inverſely as their quantities of matter; and that the diſtance and motion of the centre is the medium or average of all the diſtances or motions.

A from ſtriking B; for, as ſoon as A touches the ſpring, it begins to preſs it againſt B, and, therefore, to compreſs the ſpring. It cannot carry the ſpring before it, without the ſpring's puſhing B before it. Preſſure on B is required for this purpoſe. This is ſupplied by that natural power which we call elaſticity, which is inherent in the ſpring, whether it be in motion or at reſt. It is not in *action*, but in *capacity*, *faculty*, *capability*, *power*, or by whatever name we may chooſe to expreſs the poſſeſſion. The occaſion required for its exertion is compreſſion. This is furniſhed by the motion of A; for A cannot advance without compreſſing it. This inherent force of the ſpring is *known* to act with perfect equality at both ends, in oppoſite directions. It exerts equal and oppoſite preſſures on A and on B; it diminiſhes the motion of A, and equally augments the motion of B (if both are moving that way). A is retarded, and B is accelerated; A is ſtill moving faſter than B; and therefore the compreſſion and the conſequent reaction of the ſpring increaſes, and ſtill more retards A and accelerates B. After ſome time, both bodies, with the ſpring compreſſed between them, are moving with equal velocities; the ſpring, however, is ſtrongly reacting on both, and muſt now cauſe them to ſeparate; ſtill retarding A, and accelerating B—They muſt ſeparate more and more, till the ſpring regain its quieſcent form, and its elaſtic reaction ceaſe entirely. During its reſtitution, its preſſures are the ſame as during its compreſſion, therefore, the whole change produced on each of the bodies muſt be double of what it was when the ſpring was in its ſtate of greateſt compreſſion, and the bodies were moving with a common velocity. In ſhort, the whole proceſs in this example muſt be preciſely ſimilar to that of the magnets in every circumſtance relating to the changes of motion in A and B. The common velocity muſt be $= \frac{A a \pm B b}{A + B}$. The final velocity of A muſt be $= a - \frac{2 B \overline{a \pm b}}{A + B}$, and that of B muſt be $= b + \frac{2 A \overline{a \pm b}}{A + B}$. The motion of the common centre muſt be unaffected by the action of the ſpring, and the motion of each body, relative to the centre, muſt be reciprocally as its quantity of matter, &c. &c.

43
The changes of motion are produced by the inherent forces which connect the particles.

We apprehend that this proceſs can ſcarcely be called impulſion; A has not ſtruck B. The changes of motion can ſcarcely be aſcribed to forces inherent in A or B, in conſequence of their being in motion. Any perſon, not already warped by a theory, will (we think) aſcribe them to a force inherent in the ſpring; inherent in it, whether at reſt or in motion, and only requiring a *continued* compreſſion as the proper opportunity for its continued exertion. This ſpring may be ſuppoſed to make a part of B, or of A, or of both; and then, indeed, the force may be ſaid to be inherent in either, or in both. But it is not the peculiar force inherent in motion, or in moving bodies *only*—it is the force of *elaſticity*, inherent in part of the body, but requiring a continued *compreſſion* for the production of a continued *repreſſion*. The effect of this reaction is modified by the very occaſion of the compreſſion. This may be the elaſticity of another ſpring. In this caſe it will only compreſs that ſpring.—It may be the advance of a body in motion; the reaction produces a retardation of that motion; it may be the obſtacle of a quieſcent body—it will give it motion; or, it may be the abſtruction by a body moving more ſlowly away than the ſpring is preſſed forward—it will accelerate that motion. Thus, in all theſe caſes, we cannot help diſtinguiſhing the immediate cauſe of theſe changes of motion from the ſuppoſed force of a moving body. Nay, the proceſs of motion is ſimilar, even when we ſuppoſe that the ſpring is not a thing external to the body, although attached to it; but that the whole body, or both bodies, are ſpringy, elaſtic, and therefore compreſſible. As ſoon as the bodies come into ſenſible contact, compreſſion *muſt* begin; for we may ſuppoſe the bodies to be two balls, which will therefore touch only in one point. The mutual preſſure, which is neceſſary in order to produce the retardation of A, and the acceleration of B, is exerted only on the foremoſt particle of A, and the hindmoſt particle B; but no atom of matter can be put in motion, or have its motion any way changed, unleſs it be acted on by an adequate force. The force urging any individual particle, muſt be preciſely competent to the production of the very change of motion which obtains in that particle. Except the two particles which come into contact in the colliſion, all the other particles are immediately actuated by the forces which connect them with each other; and the force acting on any one is generally compounded of many forces which connect that particle with thoſe adjoining. Therefore, when A overtakes B, the foremoſt particle of A is immediately retarded—the particles behind it would move forward, if their mutual connection were diſſolved in that inſtant; but, this remaining, they only approach nearer to the foremoſt ſtriking particles, and thus make a compreſſion, which gives occaſion for the inherent elaſticity to exert itſelf, and, by its reaction, retard the following particles. Thus each ſtratum (ſo to conceive it), continuing in motion, makes a compreſſion, which occaſions the elaſticity to react, and, by reacting, to retard the ſtratum immediately behind it. This happens in ſucceſſion: the compreſſion and elaſtic reaction begin in the anterior ſtratum, and take place in ſucceſſion backward, and the whole body gets into a ſtate of compreſſion. Things happen in the ſame manner in B, but in the contrary direction, the foremoſt ſtrata being the laſt which are compreſſed. All this is done in an inſtant (as we commonly, but inaccurately ſpeak), that is, in a very ſmall and inſenſible moment of time; but in this moment there is the ſame gradual compreſſion, increaſe of mutual action, greateſt compreſſion, common velocity, ſubſequent reſtitution, and final ſeparation, as in the caſe of bodies with a ſlender ſpring interpoſed, or even in the caſe of the mutually repelling magnets. In all the caſes, the changes of motion are produced by the elaſticity or the repulſion, and not by the transfuſion of the force of motion. The changing force is indeed inherent in the bodies, but not becauſe they are in motion; the uſe of the motion is to give occaſion, by continued compreſſion, for the continued operation of the inherent elaſticity. The whole proceſs may be very diſtinctly viewed, by making uſe of bodies of ſmall firmneſs, ſuch as foot-balls, or blown bladders. If blown bladders are uſed, each loaded with ſand, or ſomething that will require more force, and conſequently

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Internal proceſs of change through the ſubſtance of each body.

conſequently more compreſſion to impel it forward; we ſhall obſerve the compreſſion of both to be very conſiderable, and that a very ſenſible time elapſes during the proceſs of colliſion. This may even be obſerved very diſtinctly in a foot-ball, which is always ſeen to reſt a little on the toe before it flies off by the ſtroke. When one foot-ball is ſtrongly driven againſt another, they plainly adhere together for ſome time, and then the ſtricken ball flies off.

If we return to the example of the two balls with the ſpring interpoſed, we may make ſome farther uſeful obſervations. When the ſpring is in its ſtate of greateſt compreſſion, and the balls are moving with a common velocity, we can ſuppoſe that the ſpring is arreſted in that ſituation by a catch. It is evident that the two bodies will now proceed in contact with this velocity, which we have ſhewn to be $= \frac{A\,a \pm B\,b}{A + B}$.

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Nature of imperfect elaſticity.

Now, in the conſtitution of ſuch maſſes of tangible matter as we have the opportunity of ſubjecting to our experiments, we find a ſtate of aggregation which very much reſembles this. Some bodies are almoſt perfectly elaſtic, that is, when their ſhape is changed by external preſſure; and that preſſure is removed, they recover their former ſhape completely, and they recover it with great promptitude. Glaſs, ivory, hard ſteel, are of this kind. But moſt bodies either do not recover it completely, or they recover it very ſlowly—ſome hardly recover it at all. A rod of iron will, when conſiderably bent, not nearly recover its ſhape; a rod of lead ſtill leſs; and a rod of ſoft clay will hardly recover it in any degree. Theſe, however, are but gradations of one and the ſame quality: if the quieſcent form of a body is very little diſturbed, it will recover it again. Thus, a common ſoft iron wire of N° 6. and 12 inches long, if twiſted once round, will return completely to its original form, and will allow this to be repeated for ever; but if it be twiſted $1\frac{1}{2}$ turns, it will untwiſt only 1: and in this new form, it will twiſt and untwiſt one turn as often as we pleaſe. Even a rod of ſoft clay, $\frac{1}{10}$th of an inch in diameter, and 7 feet long, will bear one twiſt as often as we pleaſe; but if twiſted 4 times, will untwiſt itſelf only one turn, and will do this as often as we chooſe. In ſhort, it appears that the particles of bodies, uſually called unelaſtic, will admit a ſmall change of diſtance or ſituation, and will recover it again, exhibiting perfect elaſticity, in oppoſition to very ſmall forces; but if they are forced too far from this ſituation, they have no tendency to return to it completely, but find intermediate ſituations, in which they have the very ſame connections with the ſurrounding particles; and in this new ſituation, they can again exhibit the ſame perfect elaſticity, in oppoſition to very ſmall forces. Mr Coulomb conceives ſuch bodies to conſiſt of elaſtic particles: they manifeſt perfect elaſticity, ſo long as the forces employed to change their ſhape do not remove the particles from their preſent contacts; but if they are removed from theſe, they ſlide on to other ſituations, where they again exhibit the ſame appearances. To underſtand this fully, the reader may conſult the article Boscovich of this *Supplement*—The fact is ſufficient for our preſent purpoſe. Now, in this variable conſtitution, where the particles may take a thouſand different ſituations, and ſtill cohere, it is plain, that when a body has been dimpled by compreſſion, the particles have nothing to bring them back to their firſt ſituation when the compreſſing force is removed: the utmoſt elaſticity to be expected, is that which will not extend to one ſhift of ſituation; therefore, the reſtitution is altogether inſenſible. This is the caſe with all ſoft bodies, ſuch as clay—the ſame quality is manifeſted in all ductile bodies, ſuch as lead, ſoft iron and ſteel, ſoft copper, ſoft gold.

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Effect of this colliſion.

Now let one of theſe bodies ſtrike another. The compreſſion, or the ſliding of the particles over each other, requires force, or mutual preſſure—This being accompanied by a reaction perfectly equal, muſt operate, during the compreſſion, preciſely as the equal repulſive forces did. It will take as much momentum from A as it gives to B; ſo that $A\,a \pm B\,b$ will remain invariably the ſame, and a common velocity will at laſt obtain, $= \frac{A\,a \pm B\,b}{A + B}$. The compreſſion can proceed no farther, and the two bodies muſt now proceed in contact with this velocity.

And thus we ſee, that in the caſe of compreſſible, but unelaſtic bodies, the changes of motion are produced by the coheſive forces inherent in the bodies; but not inherent in them becauſe they are in motion. We ſee clearly in this way, how the pendulum uſed by Robins and his followers gave a true meaſure of the velocity of the ball. All the while that it was penetrating into the pendulum, overcoming the coheſion as it went in, this coheſion was acting equally in both directions. While the fibre was breaking, it was pulling both ways; it was holding back the ball which was breaking it, and it was pulling forward the parts to which it ſtill adhered; and when it broke at laſt, it had produced equal effects on the ball and on the pendulum in oppoſite directions. By ſuch a proceſs, the pendulum was gradually accelerated, and acquired its utmoſt velocity when the ball had ceaſed to penetrate:. Therefore, this velocity muſt be $= \frac{A.a}{A + \text{pend}^{m}.}$

What ſhould we now expect to happen in the colliſion of bodies? Such bodies as exhibit perfect elaſticity, when examined by bending, or other fit trials, ſhould have their motions changed preciſely like the magnets, or bodies which repel or avoid each other at ſenſible diſtances. Bodies which exhibit no elaſticity whatever, ſhould continue in contact after colliſion. The common velocity in theſe ſhould be $\frac{A\,a \pm B\,b}{A + B}$. The perfectly elaſtic bodies ſhould ſuſtain changes of motion which are preciſely double of the changes ſuſtained by unelaſtic bodies, and ſhould ſeparate after colliſion with a relative velocity of receſs or ſeparation, preciſely equal to their relative velocity of mutual approach. And bodies poſſeſſing imperfect elaſticity, ſhould ſuſtain changes of motion which differ from the changes on unelaſtic bodies, preciſely in proportion to the degree of elaſticity which they are *known* to poſſeſs. And, laſtly, if the changes of motion which obtain in the colliſion of bodies, are preciſely thoſe which would reſult from the operation of thoſe inherent forces of elaſticity and coheſion, NO OTHER FORCE WHATEVER CONCURS IN THEIR PRODUCTION: For we know that thoſe forces *do operate* the colliſion; we ſee the compreſſion and reſtitution which are their effective cauſes, and their immediate effects. If any other force were ſuperadded, we ſhould ſee its effects alſo, and the motions would be different from what they are.

Now the fact is, that *we have never ſeen a body that is not, in ſome degree, compreſſible.* It has not pleaſed the Almighty Creator to make any ſuch here below. Aſſuredly He has not found ſuch to be of uſe for the purpoſes He had in view in this our ſublunary world. We know of no body that is perfectly unchangeable in its ſhape and dimenſions. It is therefore no loſs whatever to us, although we ſhould not be able to ſay *à priori* what their motions will be in colliſion. We cannot even fairly gueſs them, by reaſoning from what we obſerve in other bodies: For it is juſt as likely that their motions may reſemble thoſe of perfectly elaſtic bodies as thoſe of unelaſtic bodies; for we find that bodies of the moſt extreme hardneſs are generally highly elaſtic. Diamond, cryſtal, agate, quartz. and ſuch like, are the moſt elaſtic bodies we know. Philoſophers, however, rather think that the motions of perfectly hard bodies will reſemble thoſe of unelaſtic bodies; becauſe elaſticity ſuppoſes compreſſion. We do not pretend to ſay with confidence, what would be the motion of a ſingle atom of matter (which cannot admit of compreſſion) which is hit by another in motion. We ſee all the particles of terreſtrial matter connected with each other by certain modifications of the general force of coheſion, ſo as to produce various forms of aggregation; ſuch as aërial fluidity, liquid fluidity, rigidity, ſoftneſs, ductility, firmneſs or hardneſs; all of which are combined with more or leſs elaſticity. Theſe tangible forms reſult from certain poſitive properties of the material atoms of which the particles are compoſed; and, in all the caſes which come under our obſervation, theſe properties produce preſſures of one kind or another; all of which are moving forces. They are inherent in the particles and atoms: therefore when ſuch atoms are in motion, theſe forces are in a condition which affords occaſion for a *continuation* of this preſſure that is competent to the production of motion in another particle. But what would be the event of the meeting of atoms diveſted of ſuch forces, we profeſs not to know, or even to conceive.

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The obſerved effects of colliſion are perfectly conformable to the propoſitions now eſtabliſhed.

The fact alſo is, that all the changes of motion, commonly called impulſions, *which have been obſerved*, are preciſely ſuch as have been deſcribed. Unelaſtic bodies proceed in contact with the velocity $\frac{A\,a \pm B\,b}{A + B}$. Perfectly elaſtic bodies ſeparate after colliſion, and each ſuſtains double of the change that is ſuſtained by an unelaſtic body. Bodies of imperfect elaſticity differ from the two ſimple caſes, preciſely in the proportion of the elaſticity diſcoverable by other trials. The mutual actions are obſerved to be in the proportion of their relative motions, whatever the real motions may he. For not only are the changes of progreſſive motion exactly in this proportion, but the compreſſions and changes of figure, which we conſider as the immediate occaſions of thoſe actions, are alſo obſerved to be in the ſame proportions, *in all caſes that we can obſerve and meaſure with accuracy.* All theſe things can be aſcertained with great preciſion by means of the colliſion of pendulous bodies in the way pointed out by Sir Chriſtopher Wren (a method attributed by the French to their countryman Mariotte, but really invented by Wren, and exhibited to the Royal Society of London the week after he communicated his theory of impulſion).

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Extenſive proof of the univerſality of equal action and reaction.

We muſt alſo infer from theſe facts, that the actions of bodies on each other are mutual, equal, and oppoſite. This is really an inference from the phenomena, and not an original or firſt principle of reaſoning. The contrary is conceivable, and therefore not abſurd. In the ſame way that we can conceive a magnet repelling iron, without imagining that the iron repels the magnet, we may conceive a golden ball capable of impelling a leaden ball before it, without conceiving that the leaden ball will impel the golden ball. We do not find this eaſy indeed; becauſe the contrary is ſo familiar, that the one idea inſtantly brings the other along with it. We apprehend it to be impoſſible to demonſtrate, that a leaden ball will not ſtop as ſoon as it hits the golden ball, or *vice verſa*. But all our experience ſhews us, that the preſſures exerted in contact are mutual, equal, and oppoſite. The ſame thing is obſerved in the forces which connect the parts of bodies. A quantity of ſand or water balanced in a ſcale will remain in equilibrio in whatever way it is ſtirred about; its parts always exert the ſame preſſure on the ſcale: ſo does a body ſuſpended by a ſtring or reſting on the ſcale, by whatever points it is ſupported. This could not be if the particles did not exert mutual and equal forces; nor could the phenomena called impulſions be what they are, if the preſſures occaſioned between the particles by the compreſſions and dilatations were not mutual and equal. This law of action and reaction muſt be admitted as univerſal, though contingent, like gravity. Doubtleſs it reſults from the properties which it has pleaſed the great Artiſt to give to the matter of which He has formed this world. There is one way in which we can conceive, moſt diſtinctly, how this may be a univerſal property of matter. If we grant the reality of attractions and repulſions *e diſtanti*, and ſuppoſe that every primary atom of matter is preciſely ſimilar to every other atom in all its properties, and that this aſſemblage of properties conſtitutes it a material atom; it follows, that every atom exerts the ſame attractions and repulſions, or has the ſame uniting and evaſive tendencies, and then the law of action and equal reaction follows of courſe. This is ſurely the very notion that any perſon is diſpoſed to entertain of the matter. And if mechanical force and mobility are the qualities which diſtinguiſh what is material from mind or other immaterial ſubſtances, the law of equal and contrary reaction ſeems nearly allied to the claſs of firſt principles.

Of all the phenomena that indicate this perfect equality of action and reaction, the moſt ſuſceptible of accurate examination is the ſameneſs or equality of action when the relative motions are equal. Now there is no phenomenon more certain than this. In conſequence of the rotation of the earth round its axis, and its revolution round the ſun, it is plain that all our experiments and obſervations are on relative motions only. Now, we not only find that the actions of two bodies ſubjected

ted to experiment are equal when the relative motions are equal, but we find that all our meaſures of action on a ſingle body are proportional to the apparent motions which they produce. It requires preciſely the ſame force to impel a ball eaſtward, weſtward, ſouth, or north, at 12, or 3, or 6, or 9 o'clock: yet the real motions are immenſely different in all theſe caſes, and it is only the relative motions that have the proportions which we obſerve. Another very important point deducible from our experiments is, that the ſame *preſſure* produces the ſame change of motion, whatever may be the velocity. We know this by obſerving, that when the mutual dimpling or compreſſion is the ſame, the change of motion is the ſame, whatever be the hour of the day. This could not be if it required a greater preſſure to change the velocity 100000 into 100001, than to change the velocity 1 into the velocity 2. Yet this is one of Leibnitz's great metaphyſical arguments for proving that the force accumulated, and now inherent, in a moving body, is proportional to the ſquare of its velocity. We beg that this may be kept in remembrance.

It muſt be granted, that what we have already ſaid on the ſubject of impulſion may be called an *explanation;* for it deduces the phenomena from general and unqueſtionable principles, and from acknowledged laws of Nature. The only principle uſed is, that a moving force is indicated, characteriſed, and meaſured, by the motion which it produces. It is an acknowledged law of Nature, that preſſures are moving forces; alſo, that moving forces appear in caſes where we obſerve neither preſſures nor impulſions, and which we call repulſions or evaſive tendencies; that theſe are mutual and equal: and we have ſhewn, how a certain ſet of changes of motion reſult from them, and have ſtated diſtinctly the whole proceſs: we ſhewed, that theſe phenomena are ſimilar to thoſe of common impulſion; and we then ſhewed in what manner the motion of a body *gives occaſion* to the exertion of various moving forces, called *elaſticity*, *coheſion*, &c. and that this exertion muſt produce motions ſimilar to thoſe produced by repulſions *e diſtanti;* and, laſtly, we inferred, from the perfect ſameneſs of thoſe reſults with the actual phenomena of impulſion, that thoſe corpuſcular forces are the immediate and *only* cauſes of the changes called impulſions, and commonly aſcribed to a *peculiar* force inherent in a moving body.

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Why does the philoſopher *attempt* to explain gravitation, &c. by impulſion?

From a collective view of the whole, we think it clear, that the opinion that impulſion is the ſole cauſe of motion is unwarranted. We ſee that the phenomena of impulſion are brought about by the *immediate* operation of preſſure; and we ſee numberleſs inſtances of preſſure, in which we cannot find the ſmalleſt trace of impulſion. It is therefore a moſt violent and unwarranted opinion, which aſcribes to repeated unperceived impulſions all thoſe ſolicitations to motion by which, or in conſequence of which, the motions of bodies are affected by diſtant bodies, or bear an evident relation to the ſituation and diſtance of other bodies; as in the examples of planetary deflection, terreſtrial gravitation, magnetical and electrical deflexions, and the like. There is nothing in the phenomenon of the preſſure of gravity that ſeems to make impulſion more neceſſary or more probable than in the preſſure of elaſticity, whether that of a ſpring or of an expanſive fluid. The admiſſion of an unperceived fluid to effect thoſe impulſions is quite unwarranted, and the explanation is therefore unphiloſophical, even although we ſhould perceive intuitively that an atom in motion will put another into motion by hitting it. We apprehend that this cannot be affirmed with any clear perception of its truth.

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Impulſion is ſuppoſed to be better underſtood and more familiar.

On the whole, therefore, we muſt aſcribe that contented acquieſcence in the explanations of gravitation, and other attractions and repulſions, by means of impulſe (if the acquieſcence be not pretended), to the frequency and familiarity of impulſion, and perhaps to the perſonal ſhare and intereſt we have in this mode of producing motion. We know that it is always objected that nothing is explained, when we ſay that A repels B, or that B avoids A; but we muſt ſay in return, that nothing is explained, when we ſay that A impels B by hitting it, or that B flies away from the ſtroke. Why ſhould it not be allowed to uſe the term repelling power, when it is allowed to uſe the term impelling power, the force of impulſe, inertia? All theſe terms only expreſs phenomena. Does the word body expreſs any more?

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It is not better underſtood.

The maxim, that a body cannot act *where* it is not, any more than *when* it is not, is a quaint and lively expreſſion, and therefore has conſiderable effect: It may be granted; for we apprehend that we underſtand ſo little about *when* and *where*, that we cannot demonſtrate the affirmative or negative in either caſe, and that they are on a par with reſpect to our knowledge of them. We can have no doubt, however, of the fact, that our mind can be affected by an external object that is merely recollected. And we apprehend, that we know nothing of the difference between body and mind but what we have learned by experience. Body, for any thing that we aſſuredly know to the contrary, may affect, or be affected by, a diſtant body, as well as mind may be. It is therefore worth while to pay ſome farther attention to the phenomena, in order to ſee whether this experience is ſo univerſal and unexpected as is believed. As Mr Cotes, and many of Newton's diſciples, are accuſed of explaining many phenomena by attraction and repulſion which their opponents affirm to be caſes of impulſion; it is not impoſſible but that ordinary obſervers, who have no preconceived theories, may imagine impulſions to obtain in caſes where a more accurate inſpection would convince them that no impulſion has happened.

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Enquiry into the familiarity of impulſion. Inſtances of a foot-ball.

When we kick away a foot-ball, we conſider it as a ſort of ſolid continuous body; yet we know that it muſt be filled with compreſſed air. It may not be impoſſible to have it of its round ſhape without being ſo filled: but we know that, in this condition, it would not fly away from our foot by the ſtroke; we ſhould only force in the ſide which we kick, and the flaccid ſkin would lie at our feet. But when it is filled with ſtrongly compreſſed air, we can form to ourſelves a pretty diſtinct notion how it is made to move off. Our foot preſſes on a part of the ſkin: this compreſſes the air againſt the anterior part of the bag, and forces it away. If we reflect more ſeriouſly on the proceſs, we can ſtill conceive it clearly enough, by thinking on a row of aereal particles, reaching from the part ſtruck by the foot to the anterior part, each touching the other, and therefore forcing the anterior part forward. The air is conceived to conſiſt of a number of little ſpherules in contact, each of which is compreſſible; and we think the operation illuſtrated by ſuppoſing each to be like a little veſicle or bladder. This we believe to be the uſual way of conceiving the conſtitution of expanſive fluids: But this will not agree at all with the known properties of air; for it can be ſtrictly demonſtrated, that if ſuch a collection of elaſtic veſicles be compreſſed into the half of their ordinary bulk, every veſicle will be changed from a ſphere into a perfect cube, touching the adjoining cubes in every point of its ſix ſides, and ſtrongly preſſed againſt them. It can alſo be demonſtrated, that if a leaden cube of one inch be included in the box, and placed with its ſides parallel to the ſides of the box, and the compreſſion be then made, all the little cubic veſicles will acquire the ſame poſition. If the box be now turned upſide down, it can be demonſtrated that the weight of this leaden cube will not be ſufficient for overcoming the reſiſtance of the compreſſed cubes. This compreſſed maſs will not be fluid, but will require a very conſiderable force to preſs the leaden cube through it, juſt as we find ſuch a force neceſſary for moving a body through melted glaſs: the particles no longer ſlide on each other like uncompreſſed ſpherules; each will require about half of the compreſſing force, in order to overcome the friction, or obſtruction like friction, produced in ſliding along the ſurface of the contiguous cubes. But we know that air remains perfectly fluid, although vaſtly more compreſſed than this. This, therefore, cannot be like the conſtitution or form of air. Moreover, it is well known that air has been made ten times denſer than its ordinary ſtate, and is then perfectly fluid. It has alſo been made a hundred times rarer, and it ſtill remains perfectly fluid. In this ſtate its particles muſt be ten times farther removed from each other than in the former ſtate, of a thouſand times greater denſity. Yet we know that this rare air is compreſſed with a force equal to the weight of a ſtratum of mercury $\frac{1}{3}$d of an inch in thickneſs, and that if $\frac{1}{7}$d of this preſſure be removed, it will expand till it is 150 times rarer than common air; that is, there is ſome force which puſhes the particles ſtill farther from each other. This force evidently extends beyond the tenth particle of air that is made ten times denſer than common air. Therefore the elaſticity of air does not ariſe from the contact of particles, which are elaſtic like blown up bladders, but from ſome force which extends beyond the adjoining particles. There is no greater reaſon, therefore, for ſuppoſing, that the particles of air touch each other, than for ſuppoſing that the two magnets touch each other becauſe they repel. A row of magnets floating on quickſilver, and placed with their ſimilar poles fronting each other, and very near, will tend to ſeparate, and they require to be held in by a ſtop put at each end of the canal; and if one ſtop be gradually withdrawn the magnets will all ſeparate, and exhibit the general mechanical effects of a row of aerial particles ſeparating by the removal of preſſure. There ſeems, therefore, to be the ſame neceſſity for the operation of an intervening impelling fluid for producing this ſeparation or elaſticity of the aereal maſs, as for ſeparating the magnets.

Is very doubtful.

The reſult of theſe remarks ſeems to be, that the impulſion of a foot-ball is not brought about in the way that is commonly imagined, by the excitement of corporeal preſſure at the points of contact of the two foot balls. For we ſee it almoſt demonſtrated, that the progreſſive motion of the anterior part of one of the balls has been produced without contact, or, at leaſt, by the *intervention* of repulſions acting at a diſtance.—May not this obtain, even in the points in which we ſuppoſe the two balls actually to touch, in the act of impulſion?

53
Many caſes of doubtful contact.

But farther—Every perſon has obſerved the brilliant dew-drops lying on the leaves of plants. Every perſon acquainted with Newton's optical diſcoveries, muſt be convinced that the dew-drop is not in mathematical contact with the leaf; if it were, it could have no brilliancy. Moſt perſons have obſerved the rain drops of a ſummer ſhower fall on the ſurface of water, and roll about for a few ſeconds, exhibiting the greateſt brilliancy. They cannot, therefore, be in mathematical contact with the water. There muſt be a ſmall diſtance between them, and therefore ſome force which keeps them aſunder, and carries the weight, that is, counteracts the downward preſſure of the rain-drop. We know that ſome inſects with long legs can run about on the ſurface of water; and if we lift them carefully, and ſet them on glaſs, their feet do not wet it. Put a little ſpirit of wine into this water, and make it lukewarm, and the inſect inſtantly ſinks up to the belly, and cannot move about as before: Its feet will now wet a glaſs. A well-poliſhed ſteel needle, even of conſiderable ſize, if perfectly clean and dry, will float on water without being wetted: It is obſerved to make a conſiderable, depreſſion on the ſurface of the water, juſt as a heavy bar of iron would make when laid on a feather-bed—the needle diſplaces a quantity of water equal to itſelf in weight, yet does not touch it, for it is not wetted. If it be previouſly wetted, it will not diſplace any water, and will not float. There is ſomething, therefore, which keeps the water at a diſtance from the feet of the inſect, and from the needle, exerting a certain upward preſſure on them. The preſſure and the reaction are indeed very ſmall; but they would produce a very ſenſible motion if continued ſufficiently long in proper circumſtances. Here would be a production of motion, which moſt perſons would call an impulſion—yet there would be no ſtroke, no contact, and therefore no true impulſion.

We now beg the reader to attend minutely to Newton's famous experiment with the object glaſſes of long teleſcopes, which we have mentioned circumſtantially in the article OPTICS, *Encycl.* n° 63—68.

54
Very remarkable caſe of convex lenſes falſely ſeeming to touch.

When the upper glaſs is very thin and light, no colour appears at the point of contact: but by preſſing it down with ſufficient force, we ſhall have a black or unreflecting ſpot in the middle, ſurrounded by a ſilvery ring, and then by a ſeries of rings of various colours, according to the diſtance between the parts of the glaſſes where the colours appear. Newton has counted 50 of theſe rings. He ſhews, by a careful computation from the known figure of the glaſſes, that the differences between the diſtances which exhibit theſe colours are all preciſely equal, and that each is about $\frac{1}{8900}$ of an inch. Therefore, ſuppoſing that the glaſſes are in mathematical contact where the unreflecting ſpot appears, making one continuous maſs of glaſs, their diſtance at the outermoſt ring muſt not be leſs than $\frac{50}{9000}$ of an inch, or $\frac{1}{180}$ of an inch. Therefore, when

Impulſion.

when one glaſs carries the other, without any appearance of colour at the middle, we muſt conclude that there is a repulſion exerted between the neareſt parts, at a diſtance not leſs than $\frac{1}{180}$ of an inch, ſufficient for ſupporting the upper glaſs. It requires an increaſe of preſſure to produce the firſt appearance of colour; and when the preſſure is ſtill more increaſed, new colours appear in the middle, and the colour formerly there is now ſeen in a ſurrounding ring; theſe multiply continually, by new ones ſpreading from a central ſpot. A great preſſure at laſt produces the unreflecting ſpot in the centre, which, unlike to all the coloured ſpots which had emerged in ſucceſſion, is ſharply defined, and never round, but ragged, and it is immediately ſurrounded by a bright ſilvery reflection. The ſhape of this ſpot depends on the figure of the ſurfaces; for, on turning the upper lens a little round its axis, the inequalities of the edge of the ſpot turn, in ſome degree, with it. This ſeemingly trifling remark will be found important by the mechanician: A ſtill farther increaſe of preſſure enlarges the unreflecting ſpot, and the dimenſions of all the rings—When the preſſure is gradually withdrawn, the rings ſhrink in their dimenſions, the unreflecting ſpot diſappears firſt, and each ring in ſucceſſion contracts into a ſpot, and vaniſhes. Here we have, by the way, an explanation of the brilliancy of dew-drops: they come ſo near, perhaps, that the neareſt point reflects the ſilvery appearance—but they do not touch; the inſtant that they touch a wetted part, making one maſs of tranſparent matter, all brilliancy is gone.

55 They repel each other;

Here then are inconteſtible proofs of a force, be its origin what it may, which keeps the glaſſes aſunder, and even cauſes them to ſeparate; which manifeſts itſelf by withſtanding preſſure; and therefore is, itſelf, a preſſure, or equivalent to a preſſure—It varies in its intenſity by a change of diſtance; but we have not been able to aſcertain by what law. It muſt not be meaſured by the ſimple variation of the external preſſure; for ſince we ſee that, even before any colour appears in the centre, the weight of the upper lens is ſupported, we muſt conclude that the glaſſes are exerting at leaſt an equal force all around the circumference of the outermoſt ring. It is evident, that the computation of the whole force, exerted over all the coloured ſurface, muſt be difficult, even on the ſimpleſt hypotheſis concerning the law of repulſion: we can only ſay that it increaſes by a diminution of diſtance. It is very eaſy to compute the increaſe of external preſſure, which would ſuffice if the repelling force were equal at all diſtances; or if it varied according to any ſingle power of the diſtances. We have tried the inverſe ſimple, duplicate, and triplicate ratio; but the fact deviated widely from them all. The repulſion does not change nearly ſo much as in the ſimple inverſe ratio of the diſtances, if the glaſſes be ſuppoſed to touch in the whole ſurface of the unreflecting ſpot. But we found, that if we ſuppoſe them ſeparated, though at a diſtance equal to forty times the difference of diſtance at which the colours change, that is, $\frac{1}{121}$ of an inch, the preſſures employed in the experiment accord pretty well with a repulſion inverſely as the diſtance, but ſtill with a very conſiderable deviation in the great preſſures. In the courſe of a number of experiments with a favourite pair of lenſes, we broke the uppermoſt by too ſtrong a preſſure. We then cut out of it, with a lapidary's hollow drill, a piece of $\frac{1}{4}$ of an inch in diameter, and perfectly round, and we ſqueezed it on the other by a meaſured preſſure, till we produced a colourleſs ſpot of nearly $\frac{1}{8}$th of an inch in diameter, with a ſilvery margin. Computing from this, we thought ourſelves warranted to ſay, that not leſs than 800 pounds are neceſſary for producing a black ſpot of one inch ſquare!

56 And may impel without touching

Now, what is the conſequence of all this in the doctrine of impulſion? Surely this:—If a lump of this glaſs ſtrike another lump, and put it in motion, and if the mutual preſſure in the act of colliſion do not exceed 700 pounds on the ſquare inch, the motion has been produced without mathematical contact, and the production can no more be called impulſe than the motion of the magnet in our firſt experiment. The changes of motion have been the operation of moving forces, ſimilar to the force of magnetiſm; and if a ſtream of truly impelling fluid be neceſſary for producing the motion of the magnet, it is equally neceſſary for producing the motion of the piece of glaſs.

It may be ſaid here, that we cannot compare impulſe and preſſure. A ſlight blow will ſplit a diamond which could ſupport a houſe. A ſlight blow may therefore be enough for exciting all the preſſure neceſſary for producing mathematical contact. We muſt here appeal to what every man feels on this occaſion. We doubt exceedingly whether any perſon will think that, when one piece of glaſs gives another a gentle blow, and puts it into motion, with the velocity of a few inches per ſecond, a blow which he diſtinctly hears, there has been exerted a preſſure at all approaching to 800 pounds per ſquare inch.—We have ſuſpended a pair of lenſes, by an apparatus ſo ſteady and firm, that they could touch only at the centres of each ſurface; and, having placed ourſelves properly, we could ſee, with ſufficient diſtinctneſs, the momentary appearance of the coloured ſpot at the inſtant of colliſion. We ſaw this, with the fulleſt confidence that it was of no conſiderable breadth in a moderate ſtroke, and that it was very ſenſibly broader when the ſtroke was more violent. We did not truſt our own eye alone, but ſhewed it to perſons ignorant of philoſophy, and even to children, often without telling them what to look for, but aſking them what they ſaw. From all the information that we could gather, none of the preſſures came near to what muſt have been neceſſary for producing the black ſpot. This could not be miſtaken: for although the outer rings are but faint, there are five or ſix near the centre which are abundantly vivid for affecting the eye by the momentary flaſh. Beſides, the dimenſions of the lenſes, and the weight of the metal cells in which they were fixed, were ſuch as muſt have cauſed them to ſplit before the black ſpot could be produced in the centre.

And certainly do ſo, even in violent ſtrokes.

Theſe things being maturely conſidered, we imagine that few perſons will now doubt the juſtice of our aſſertion, that in all theſe examples, the motions have been produced without mathematical (or rather geometrical) contact.—And we imagine alſo, that few will refuſe granting that this is not peculiar to glaſs, but obtains alſo in the colliſion of other bodies. We have not thought of any method for putting this beyond doubt; but we have better reaſons than mere likelihood for being of this opinion. Every one acquainted with the

Newtonian diſcoveries in optics, knows that this curious appearance of the coloured rings is the conſequence of the action of tranſparent bodies on the rays of light, by which theſe are bent aſide from their rectilineal courſe, and that this deflection takes place at a diſtance from the diaphanous body; a diſtance which the ſagacity of the great philoſopher has enabled us to meaſure. Now, it is known that metals and other opaque bodies produce the very ſame deflections of the rays, bending them toward themſelves at one diſtance, and from them at other diſtances; in ſhort, attracting or repelling them as the diſtance varies. Nothing but prepoſſeſſion can hinder a perſon from aſcribing ſimilar effects to ſimilar cauſes, and, therefore, thinking it almoſt certain that this mutual repulſion is not peculiar to glaſs, but common to all ſolid bodies.

To all this we may ſurely add the celebrated experiment of Mr Huyghens; in which it is evident, that a ſmooth plate of metal attracts another, even although there be a ſilk fibre interpoſed between them. (See *Phil. Tranſ.* n° 86.) Is it not highly probable, that at a ſmaller diſtance the bodies repel each other? For we obſerve, that metals, as well as tranſparent bodies, attract the rays at one diſtance and repel them at another.

57 Impulſion is not ſo familiar as is believed.

Surely our readers will now grant, that the production of motion by impulſion, as diſtinguiſhed from the production by action *e diſtanti*, is not ſo familiar a phenomenon as was imagined, and that it may even be ſaid to be rare in compariſon: for the inſtances of moderate impulſes are numberleſs. The claim of this mode of explaining difficult phenomena by impulſion, has therefore loſt much of its force; and we ſee much leſs reaſon for calling in the aid of inviſible fluids, in order to *explain* the action of gravity, magnetiſm, and electricity.

58 Still greater doubts. Obſervations on a ſoap bubble.

But we have ſtill more important information from the optical diſcovery of Newton. Let the reader turn again to Optics, *Encycl.* n° 65, and read the account of the phenomena exhibited by the ſoap-bubble. The bubble is thinner and thinner as we approach the very uppermoſt point of it. It alſo exhibits numerous rings, which vary in their colour, in the ſame order as in the ſpace between the lenſes. Theſe rings come to view in the ſame manner. Firſt, a coloured ſpot appears in the ſummit of the bubble; this becomes a ring, and is ſucceeded by another ſpot, as the bubble grows thinner in that part, by the gradual ſubſiding of the watery film. At laſt a black ſpot appears at top, well defined, but of irregular ſhape, ſurrounded by a ſilvery ring. This ſpot, when viewed very narrowly, is obſerved to reflect a very minute portion of light, without *ſeparating* the differently colorific rays of which it conſiſts; but it *contains* them all, as may be proved by viewing it through a priſm. After ſome little time the bubble burſts.

Surely we muſt infer from this, that there is a certain thickneſs of the tranſparent plate which renders it unfit for the vivid reflection of light. Does it not legitimately follow from this, that the unreflecting ſpot between the lenſes ceaſes to entitle us to ſay, that they are in contact in that place? All that we can conclude from its appearance is, that the diſtance ſtill between the glaſſes is too ſmall to fit the place for the vivid reflexion of light. This concluſion is indiſputable. Were it refuſed, we are furniſhed with an inconteſtible proof by the ſame bountiful hand. Newton aſcribed the colours to the reflection of the plate of air between the glaſſes, and expected the ceſſation of them when the air is removed. His friend Mr Boyle had lately invented a commodious air pump. The trial was made, and young Newton found himſelf miſtaken; for the colours ſtill appeared, and he even thought them more brilliant. He then tried the effect of water, expecting that this would diminiſh their luſtre. So it did; and he found that the dimenſions of the rings were diminiſhed in the proportion of 4 to 3; namely, the proportion of the refractions of glaſs and water. By this time Newton had diſcovered the curious mechanical relation between bodies and the rays of light; and his mind was wholly abſorbed by the diſcovery, and by the revolution he was about to make in the mathematical doctrines of optics. Unfortunately for us, he did not, at that time, attend to the mighty influence which the diſcovery would have on the whole of mechanical philoſophy, and therefore occupied himſelf only with ſuch phenomena as ſuited his preſent purpoſe. A moſt important phenomenon paſſed unnoticed. In repeating Sir Iſaac Newton's experiments, we found that the diameters of the rings decreaſed in the proportion of 4 to 3 only in certain circumſtances. When the upper lenſe was preſſed on the other by a heavy metal ring, ſo as to produce three or four coloured rings, we found that when water got between them, ſometimes no colours whatever appeared; ſometimes there was a ring or two, and the diameters were diminiſhed in a much greater proportion than Newton had aſſigned. Well aſſured of the extreme nicety of all his proceedings, we were much puzzled with this diſcrepancy, and mentioned it to a moſt reſpectable and intelligent friend, the late Dr Reid of the univerſity of Glaſgow, a mathematician and naturaliſt of the firſt rank. He thought it not improbable that the glaſſes ſeparated from each other, lifting up the weight, by attracting the water into the interſtice, in the ſame manner that we obſerve wood to ſwell with moiſture. We immediately got an apparatus which compreſſed the glaſſes by means of four ſcrews; and now we ſaw Newton's proportion moſt ſtrictly obſerved. But in proſecuting the experiment, we found that the introduction of the water *always* effaced a very ſmall ſpot. This happened after precautions had been taken to prevent all ſeparation of the glaſſes. As the proportion of 4 to 3 has a relation to refractive power, although we have not been able to deduce it as a neceſſary conſequence, we nevertheleſs conſidered it as a ſufficient proof that the diſtances of the glaſſes *had not changed* by introducing the water between them. Therefore we think ourſelves well entitled to conclude, that the diſappearance of the black ſpot was not owing to a ſeparation of the glaſſes, which admits the water into the empty ſpace; and we affirm, that before the entry of the water, there was room for it in the place which reflected no light; that is, that although the glaſſes were preſſed together with a very great force, they were not in contact.

Remark.

It deſerves remark, that in endeavouring to produce the black ſpot, when water is between the glaſſes, we found great and unaccountable anomalies. Sometimes a moderate increaſe of preſſure produced it, and ſometimes we were not able to produce it by any preſſure.

Several lenſes were broken in the trial. We are led to think that the thickneſs which gives the ſilvery reflection is much greater than the 8900th part of an inch, and that it is not the ſame in all glaſſes. But we were interrupted in theſe experiments, and indeed in all active purſuits, by bad health, which has never permitted their renewal. The ſubject is of great importance to the curious mechanicians, and we earneſtly recommend it to their attention. There is ſomething very remarkable in the abrupt ſenſation of the coloured reflection. At a certain thickneſs *all* colours are reflected, without ſeparation, producing the whiteneſs of ſilver. The ſmalleſt diminution of it hinders the *vivid* reflection of *all* colours, and then there ſeems to ſucceed a thickneſs which equally reflects a ſmall proportion of *all* without ſeparation. The fineſt poliſh that can be given to glaſs in the tool of the artiſt, leaves irregularities which occaſion the irregular ragged figure of the ſpot. It is worth trying, whether ſmoothing the ſurfaces (both) by a ſoftening heat will remove this ruggedneſs. If it does, without deſtroying the ſharp termination, it will prove the abrupt paſſage from *eſſe* to *noneſſe*.

The laſt remark to be made on this important experiment in optics is, that the diſtance between the glaſſes which is unfit for vivid reflection, cannot be determined by means of the other meaſurable intervals. It may be equal to many of them taken together. The ſame muſt be granted with reſpect to the thickneſs of the black ſpot on the top of the ſoap bubble. We attempted to meaſure this thickneſs by letting a drop (of a known weight) of ſpirit of turpentine ſpread on the ſurface of water. As it ſlowly enlarged in ſurface, it decreaſed in thickneſs, and produced, in regular order, ſeveral of the more compounded colours of the Newtonian ſeries. But before it came to the 20th ring from the centre, it became very irregular and ſpotty.

59 Contact is not proved in colliſion.

The inference to be drawn from this combination of the two optical facts is remarkable and important. It is, that we have no authority for affirming that the changes of motion by the colliſion of bodies is brought about by abſolute contact in any inſtance whatever. The glaſſes are not in contact where there is vivid reflection; and we have no proof that they are in contact in the black ſpot, however great the compreſſion may be.

60 Therefore impulſion cannot explain gravitation;

It is hardly neceſſary now to ſay, that all attempts to explain gravitation, or magnetiſm, or electricity, or any ſuch apparent action at a diſtance by the impulſions of an unſeen fluid, are futile in the greateſt degree. Impulſion, by abſolute contact, is ſo far from being a familiar phenomenon, that it may juſtly be queſtioned whether we have ever obſerved a ſingle inſtance of it. The ſuppoſition of an inviſible impelling fluid is not more gratuitous than it is uſeleſs; becauſe we have no proof that a particle of this fluid does or can come into contact with the body which we ſuppoſe impelled by it, and therefore it can give no explanation of an action that is apparently *e diſtanti*.

61 But impulſion may be explained by continued preſſure.

The general inference from the whole ſeems to be, that, inſtead of explaining preſſure by impulſe, we muſt not only derive all impulſe from preſſure, but muſt alſo aſcribe all preſſure to action from a diſtance; that is, to properties of matter by which its particles are moved without geometrical contact.

This collection of facts conſpires, with many appearances of fluid and ſolid bodies, to prove that even the particles of ſolid, or ſenſibly continuous bodies, are not in contact, but are held in their reſpective ſituations by the balance of forces which we are accuſtomed to call attractions and repulſions. The fluidity of water under very ſtrong compreſſions (which have been known to compreſs it $\frac{1}{12}$th of its bulk), is as inconſiſtent with the ſuppoſition of contact as the fluidity of air is. The ſhrinking of a body in all its dimenſions by cold, nay, even the bending of any body, cannot be conceived without allowing that *ſome* of its ultimate unalterable atoms change their diſtances from each other. The phenomena of capillary attraction are alſo inexplicable, without admitting that particles act on others at a diſtance from them. The formation of water into drops, the coaleſcence of oil under water into ſpherical drops, or into circular ſpots when on the ſurface, ſhew the ſame thing, and are inexplicable by mere adheſion. In ſhort, all the appearances and mutual actions of tangible matter concur in ſhewing, that the atoms of matter are endowed with inherent forces, which cauſe them to approach or to avoid each other. The opinion of Boſcovich ſeems to be well founded; namely, that at all ſenſible diſtances, the atoms of matter tend toward each other with forces inverſely as the ſquares of the diſtances, and that, in the neareſt approach, they avoid each other with *inſuperable* force; and, in the intermediate diſtances, they approach or avoid each other with forces varying and alternating by every change of diſtance. See the article Boscovich, *Suppl.*

62 Phyſical contact explained.

From all that has been ſaid, we learn that phyſical or ſenſible contact differs from geometrical contact, in the ſame manner as phyſical ſolidity differs from that of the mathematician. Euclid ſpeaks of cones and cylinders ſtanding on the ſame baſe, and between the ſame parallels. Theſe are not material ſolids, one of which would preſs the other out of its place. Phyſical contact is indicated, immediately and directly, by our ſenſe of touch; that is, by exciting a preſſure on our organ of touch when it is brought ſufficiently near. It is alſo indicated by impulſion; which is the immediate effect of the preſſure occaſioned by a ſufficient approximation of the body impelling to the body impelled. The impulſion is the completion of the ſame proceſs that we deſcribed in the example of the magnets; but the extent of ſpace and of time in which it is completed is ſo ſmall that it eſcapes our obſervation, and we imagine it to be by contact and in an inſtant. We now ſee that it is ſimilar to all other operations of accelerating or retarding forces, and that no change of velocity is inſtantaneous; but as a body, in paſſing from one point of ſpace to another, paſſes through the intermediate ſpace; ſo, in changing from one velocity to another, it paſſes through all the intermediate degrees without the ſmalleſt *ſaltus*.

We thus avoid many abſurdities.

And in this way is the whole doctrine of impulſion brought within the pale of dynamics, without the admiſſion of any new principle of motion. It is merely the application of the general doctrines of dynamics to caſes where every accelerating or retarding force is oppoſed by another that is equal and contrary. We have found that the opinion, that there is inherent in a moving body a peculiar force, by which it perſeveres in motion, and puts another in motion by ſhifting into it, is as uſeleſs as it is inconſiſtent with our notions of motion and of moving forces. The impelled body is moved by the inſuperable repulſion exerted by all atoms of matter when brought ſufficiently near. The retardation of the impelling body does not ariſe from an *inertia*, or reſiſting ſluggiſhneſs of the body impelled, but becauſe this body alſo repels any thing that is brought ſufficiently near to it. We can have no doubt of the exiſtence of ſuch cauſes of motion. Springs, expanſive fluids, cohering fibres, exhibit ſuch active powers, without our being able to give them any other origin than the FIAT of the Almighty, or to comprehend, in any manner whatever, how they reſide in the material atom. But once we admit their exiſtence and agency, every thing elſe is deduced in the moſt ſimple manner imaginable, without involving us in any thing incomprehenſible, or having any conſequence that is inconſiſtent with the appearances. Whereas both of theſe obſtructions to knowledge come in our way, when we ſuppoſe any thing analogous to force inherent in a moving body ſolely becauſe it is in motion. It forces us to uſe the unmeaning language of force and motion paſſing out of one body into another; and to ſpeak of force and velocity as things capable of diviſion and actual ſeparation into parts. The force of inertia is one of the bitter fruits of this miſconception of things. It is amuſing to ſee how metaphyſicians of eminence, ſuch as D'Alembert, endeavour to make its operations tally with acknowledged principles. In his celebrated work on dynamics, the moſt elaborate of all his performances, he explains how a body, whoſe maſs is 1, moving with the velocity 2, muſt ſtop another body whoſe maſs is 2, moving with the velocity 1, in the following manner: He ſuppoſes the velocity 2 to conſiſt of two parts, and that, in the inſtant of colliſion, one of the parts deſtroys the motion of one half of the other body, and then the other part deſtroys the motion of the other half. Theſe are words; but in vain ſhall we attempt to accompany them by clear conceptions. His diſtinction between the force of inertia and what he calls the active forces of bodies, ſuch as the force of bodies which ſtrike each other in oppoſite directions, is equally unſuſceptible of clear conceptions. Active forces (ſays he) abſorb a part of the motion; but when inertia takes part of the motion from the ſtriking body, this motion paſſes wholly into the body that is ſtricken, none of it being abſorbed or really deſtroyed. He demonſtrates this by the equation $A \times \overline{a - x} = B \times \overline{x - b}$, which is a mere narration of facts, but no deduction from the nature of inertia, nor even any eſtabliſhment of that nature by philoſophical argument. And in attempting to give ſtill clearer notions (being ſenſible that ſome great obſcurity ſtill hangs about it), he ſays, "Inertia therefore, and properly ſpeaking, is the mean of communicating motion from one body to another. Every body reſiſts motion; and it is by reſiſting that it receives it; and it receives preciſely as much as it deſtroys in the body which acts on it." Surely almoſt every word of this ſentence is doing violence to the common uſe of language. What can be more incomprehenſible than that a body reſiſts motion only when it receives it? Should a man be thought to reſiſt being puſhed out of his place when he actually allows another to diſplace him, and not to reſiſt when he firmly keeps his place? All theſe difficulties and puzzling queſtions vaniſh when we give over ſpeaking of inertia as ſomething diſtinguiſhable from the active forces or cauſes of motion which we find in bodies, and diſtinguiſh by the names of elaſticity, coheſion, magnetiſm, electricity, weight, &c. and which philoſophers have claſſed under one name, accelerating or retarding force, according as its direction chances to be the ſame, or the oppoſite to that of the motion under conſideration. To ſuppoſe it a *peculiar* faculty by which a body maintains its condition of motion or reſt, is contrary to every conception that we can annex to the words faculty, power, force. It is frivolous in the extreme to ſay, that ſnow has the faculty of continuing white or cold; or that it reſiſts being melted becauſe it melts, or becauſe heat muſt be employed to melt it.

63
Strongeſt argument for inertia is the compoſition of force with a previous motion.

The only argument that we know for giving the name force to the perſeverance of matter in its ſtate of motion (or rather for aſcribing this perſeverance to the exertion of a peculiar faculty), which appears to deſerve any attention, is one that we do not recollect the expreſs employment of for this purpoſe, namely, the compoſition of a previous motion with the motion which a known force would produce in the body at reſt. We know that if a body be moving eaſtward at the rate of four feet per ſecond, and a force act on it which would impel it from a ſtate of reſt at the rate of three feet per ſecond to the ſouth, the body will move at the rate of five feet per ſecond in the direction E. 36° 52′ S. We know alſo, that if a force act on this body at reſt, ſo as to give it a motion eaſtward at the rate of four feet per ſecond, and if another force act on it at the ſame inſtant, ſo as to give it a motion to the ſouth at the rate of three feet per ſecond, the body will move at the rate of five feet per ſecond in the direction E. 36° 52′ S. In this inſtance, the body previouſly in motion ſeems to poſſeſs ſomething equivalent to what is allowed to be a moving force. Why therefore refuſe it the name? The anſwer is eaſy. The term force has been applied, by all parties, to whatever produces a *change* of motion, and is meaſured by the *change* which accompanies its exertion. There is ſome difference between the parties about the way of eſtimating this meaſure; but all agree in making, not the motion, but the change of motion, the baſis of the meaſurement. Now we ſhewed, at great length, in the article DYNAMICS, that the *change* of motion, in every caſe, is that motion which, when compounded with the former motion, conſtitutes the new motion. Did we take the new motion itſelf as the characteriſtic and meaſure of the changing force, it would be different in every different previous ſtate of the body, and would neither agree with our general notion of force, nor with the knowledge that we have of the actual preſſures and other moving forces that we know. The ſole reaſon why the previous motion is equivalent with a force is, that the only mark or knowledge that we have of a moving force is the motion which it is conceived to produce. The force is equivalent with the previous motion, becauſe we know nothing of it but that motion; and the name that we give it, only marks ſome external thing to which it has an obſerved relation. We call it magnetiſm or electricity, becauſe we obſerve that a magnet or an electrified body gives *occaſion* to its appearance. We never obſerve the reſiſtance of *inertia*, except in caſes where we know, from other circumſtances, that moving forces

Anſwered.

forces inherent in bodies are really brought into action. The inertia of the ball which has been moved by a ſtroke of another, is inferred from the diminution of that other's motion. But this is occaſioned preciſely in the ſame way as the diminution of the motion of the magnet A in the firſt example; an event which every unprepoſſeſſed perſon aſcribes to the repulſion of B in the oppoſite direction, and not to its inertia.

We truſt that our readers are not diſpleaſed with this detail of the procedure of Nature in the phenomena of impulſion. It has been prolix; becauſe we apprehend, that the too ſynoptical manner in which the laws of colliſion have always been delivered, leaves the mind in great obſcurity concerning the connection of the events. General facts have been taken for philoſophical principles and elementary truths; whereas they were deductions from the ſum total of our knowledge. They were very proper logical principles for a ſynthetical diſcuſſion; but their previous eſtabliſhment as general facts was neceſſary. We have eſtabliſhed the two moſt general facts from which the reſult of every colliſion may be deduced with the utmoſt eaſe. The firſt is, that in the inſtant of greateſt compreſſion, the common velocity is $= \frac{A\,a \pm B\,b}{A + B}$; and we have ſhewn that this is applicable to the colliſion of unelaſtic bodies. The ſecond is, that the change in perfectly elaſtic bodies is double of the change in unelaſtic bodies. The *conſervatio momentorum*, and the *conſervatio virium vivarum*, are alſo general facts; or rather they are the ſame mentioned with thoſe above, conſidered in another aſpect. They may all be uſed as the principles of a ſynthetic treatiſe of impulſion; and they have been ſo employed. Each has its own advantages.

64 Principle of ſmalleſt action.

Mr Maupertuis gives a treatiſe on the Communication of Motion, that is, of impulſion or colliſion, which has the appearance of being deduced from a new principle, which he calls the PRINCIPLE OF SMALLEST ACTION. He ſuppoſes that perfect Wiſdom will accompliſh every thing by the ſmalleſt expenditure of action; and he chanced to obſerve, in the equations employed in the common doctrine of impulſion, a quantity which is always a minimum. He chooſes to conſider this as the expreſſion of the action.

His principle or axiom, deduced from the perfect wiſdom of God, is thus expreſſed: "When any change happens in nature, the quantity of action neceſſary for it is the ſmalleſt poſſible." And then he adds,

"In mechanical changes, the quantity of action is the product of the quantity of matter in the body by the ſpace paſſed over, and by the velocity of the motion." This is evidently the meaſure adopted long before by Leibnitz (ſee *Phil. Tranſ.* vol. xliii. p. 423, &c.), and it is equivalent to $m\,v^2$; becauſe the ſpace multiplied by the velocity is as the ſquare of either. We refer to Dr Jurin's remarks on this paſſage for proof that this is by no means a juſt meaſure of action; and only obſerve here, that we can form no other notion of velocity than that of a certain ſpace deſcribed in a given time. The change produced is not the actual deſcription of a line, but the determination to that motion. It is in this reſpect alone that the condition of the body is changed; and therefore the product $m\,v$, and not $m\,s\,v$, is the proper meaſure of the action. On the authority of this maxim of divine conduct, Maupertuis inveſtigates the reſults which will make this quantity a minimum, and aſſerts that theſe *muſt* be the laws of colliſion. Luckily this inveſtigation is extremely ſimple, and very neat and perſpicuous; and it gives very eaſy ſolutions. For example, the unelaſtic body A, moving with the velocity a, overtakes the unelaſtic body B, moving with the velocity b. Both move after the colliſion with the velocity x. This velocity is required. To determine this, we muſt make $A \times \overline{a - x}|^2 + B \times \overline{x - b}|^2$ a minimum; or $A\,a^2 - 2\,A\,a\,x + A\,x^2 + B\,x^2 - 2\,B\,b\,x + B\,b^2$ is a minimum. Therefore $- 2\,A\,a\,\dot{x} + 2\,A\,x\,\dot{x} + 2\,B\,x\,\dot{x} - 2\,B\,b\,\dot{x} = 0$, or $2\,A\,a + 2\,B\,b = 2\,A\,x + 2\,B\,x$, and $x = \frac{A\,a + B\,b}{A + B}$; as we have already ſhewn it to be.

The amiable and worthy author grew more fond of his theory, when he ſaw what he imagined to be its influence extended to an immenſe variety of the operations of nature. Euler demonſtrated, that the quantity called *action* by Maupertuis was a minimum in the planetary motions, and indeed in all curvilineal motions in free ſpace. But all the while, this principle of leaſt action is a mere whim, and the formula which is ſo generally found a minimum has no perceptible connection with the quantity of action. In many caſes to which Maupertuis has applied it, the concluſions are in direct oppoſition to any notion that we can form of the economy of action. Nay, it is very diſputable whether it does not, on the contrary, expreſs the greateſt want of economy; namely, a minimum of effect from a given expenditure of power. In the caſe of impulſion, this minimum is the mathematical reſult of the equality and oppoſition of action and reaction. Maupertuis might have pleaſed his fancy by ſaying, that it became the infinite wiſdom of God to make every primary atom of matter alike; and this would have anſwered all his purpoſe.

65 Enquiry into the diſtribution of impulſe from the point that is ſtruck.

There ſtill remains to be conſidered a very material circumſtance in the doctrine of impulſion, which produces certain modifications of the motions that are of mighty practical importance. We have contented ourſelves with merely ſtating the moving force that is brought into action in the points of phyſical contact; but have not explained how this produces the progreſſive motion of every particle of the impelled body, and what motion it really does produce in the remote particles. A body, beſides the general progreſſive motion which it receives from the blow, is commonly obſerved to acquire alſo a motion of rotation, by which it whirls round an axis. It has not been ſhewn, that when a body has received an impulſe by a blow in a particular direction on one point, it will proceed in that direction, or in what direction it will proceed. Experience ſhews us, that this depends on circumſtances not yet conſidered. The billiard player knows, that by a ſtroke in one direction he can make his antagoniſt's ball move in a direction extremely different.

Theſe are queſtions of great intricacy and difficulty, and would employ volumes to treat them properly. We have already enlarged this article till we fear that we have exhauſted the reader's patience, and deviated from the proportion of room juſtly allowable to IMPULSION. We muſt therefore limit our attention to ſuch things only as ſeem elementary, and indiſpenſably neceſſary

ceſſary for a uſeful application of the doctrine of impulſion.

With reſpect to the *direction* of the motion produced by impulſion, the very example juſt now borrowed from billiard playing, ſhews that it is important, and by no means obvious. We are ſorry to ſay, that we have nothing to offer in ſolution of this queſtion that will be received by all as demonſtration. It is comprehended in the following propoſition, which we bring forward merely as a matter of fact.

66
Action of bodies by contact is perpendicular to the touching ſurface.

The direction of the ſtroke or preſſure exerted by two bodies in phyſical contact, is always perpendicular to the touching ſurfaces. Of this truth we have a very diſtinct and pretty example and proof by the billiard table. If two balls A and B (fig. 2.) are laid on the table in contact, and A is ſmartly ſtruck by a third ball C in any direction Cc, ſo that the line aA, which joins the point of contact a with the centre A, may make an obtuſe angle with the line AB, joining the centres of the two balls, the ball B will always fly off in the direction ABF. The preſſure on B, which produces the impulſion, is evidently exerted at the point b of contact, and the direction BF is perpendicular to the plane GbH, touching both balls in the point b. The primary ſtroke is at a, and acts in the direction aA, although C moved in the direction Cc. Had A been alone, it would have gone off in the direction aA produced. But the force acting in the direction aA is equivalent to the two forces ad and dA, of which dA preſſes the ball on B at b, and produces the motion. In like manner, another ball E, ſo laid that bBe is obtuſe, will fly off in the direction ED, which may even be oppoſite to Cc. Theſe are matters of fact; not indeed preciſely ſo, becauſe billiard balls are not perfectly elaſtic, reſtoring their figure with a promptitude equal to that of their compreſſion; and alſo becauſe there is a little friction, by which the point a of the ball A is dragged a little in the direction of C's motion. This may both give a twirl to A, and diminiſh its preſſure on B. The general reſult, however, is abundantly agreeable to the doctrines now delivered. But we wiſh to ſhew on what properties of tangible matter this depends; and although we dare not hope for implicit belief, we expect ſome credit in what we ſhall offer.

Demonſtration.

We have evident proof, that at a diſtance which is not unmeaſureable by its minuteneſs, and certainly far exceeds the 900th part of an inch, bodies repel each other with very great force. This diſtance alſo far exceeds the diſtance between the particles, if theſe are diſcrete. Let mn (fig. 3.) be the diſtance at which a particle repels another, and let P be a particle ſituated at a leſs diſtance than mn from the ſurface AC of a ſolid body. With a radius PA, equal to mn, deſcribe a ſegment of a ſphere ABC, and draw PB perpendicular to AC. It is plain that every particle of matter in the ſegment ABC repels the particle P, and that it is not affected by any more. Let D be any ſuch particle. It repels P in the direction DP. But there is another particle d ſimilarly ſituated on the other ſide of PB. This will repel P with equal force in the direction dP. Therefore the two particles D and d will produce a joint repulſion in the direction BP. The like may be ſaid of every particle and its correſponding one on the other ſide of PB. Therefore the joint repulſion of all the matter in the ſegment will have the direction BP. It is plain, that the radius of curvature of every ſenſible figure may be conſidered as immenſely great in compariſon of mn; and therefore the propoſition is manifeſt.

This is a propoſition of very great importance to the artiſt and the engineer, as well as to the philoſopher. In all the connections of engines and machines, the mutual action is regulated by this fact. The mutual preſſure at the contacts of the teeth of wheels and pinions depend ſo much on it, that it is eaſy to make them of ſuch a ſhape that they ſhall produce no force whatever that is of any ſervice; and it requires a ſkilled attention to their forms to obtain the ſervice we want. This will be conſidered with ſome care in the article MACHINE.

Having thus diſcovered the *direction* of the real impulſion, and that it may be very different from that of the force exerted, we proceed to conſider what will be the direction and velocity of the motion, and whether it will be accompanied with any rotation.

67
A ſtroke, whoſe action paſſes through the centre of a poſition of ſolid body, impels it without rotation.

Our readers are acquainted with the elementary mechanical property of the centre of gravity. If a body be ſupported at this point by a force acting vertically upwards, and equal to the united weight of every particle of matter in it, it will not only remain at reſt, but will have no tendency to incline to either ſide; that is, the upward force balances the weight of the whole body, and the mechanical momenta of all the heavy particles balance each other, like the weights in the ſcales of a ſteelyard. That this may be the caſe, we know that if the weight of every particle be multiplied into the horizontal lever by which it hangs (which is a line drawn from the particle perpendicular to a vertical plane paſſing through the centre of gravity), the ſum of all the products on one ſide muſt be equal to the ſum of all the products on the other ſide. Therefore, if we ſuppoſe the particles all equal, and repreſent each by unity, the ſums of all the perpendiculars themſelves muſt be equal. How is this balancing effected? Every particle tends downwards with a certain force. It muſt therefore be kept up by a force *preciſely* equal and oppoſite. This muſt be propagated to the particle by means of the connecting corpuſcular forces. The force propagated to any particle is equal and oppoſite to the force acting on that particle, which it balanced; and if not balanced, it would produce a motion equal and oppoſite to that produced by the other force. Gravity would cauſe every particle to deſcend equally; therefore the force which, by acting on one point, excites thoſe balancing forces on each particle, would cauſe them to move equally upwards. And ſince this is true in *any* attitude of the body, it follows, that a force acting in *any* direction through the centre of gravity, will cauſe all the particles to move in that direction equally; that is, without rotation.

Hence we learn, that when the direction of the ſtroke given to any body paſſes through the centre of gravity, the body will move in that direction without any rotation. If the quantity of matter, or number of equal particles in the body, be m, the moving power P will impreſs on each particle an accelerating force f, equal to the mth part of P. Therefore $f=\frac{P}{m}$, and $P=mf$. An accelerating force is eſtimated by the velocity v, which

which it generates by acting uniformly during ſome time t, or $v = f\,t$, and $\dot{f} = \frac{v}{t}$, and $P = m\,\frac{v}{t}$, and $v = \frac{P}{m}\,t$. The ſymbol t may be omitted, if we reckon every force by the velocity which it can produce in a ſecond. Thus may all forces be compared with gravity, by taking 32 feet for the meaſure of gravity. Then $m\,v$ will expreſs the number of pounds which give a preſſure equal to the force under conſideration. Thus if the force can generate the velocity 48 feet per ſecond in 100 pounds of matter, by acting on it uniformly during a ſecond, its preſſure is equal to the weight of 150 pounds.

This is *direct* IMPULSION.

When a body A, moving with the velocity a, overtakes or meets a body B, moving with the velocity b, and the line perpendicular to their touching ſurfaces paſſes through the centres of both in the direction of their motion, all the circumſtances of the colliſion are determined by the rules already laid down. This is called DIRECT IMPULSE; and it is this which admits the application of the ſimple doctrines of impulſion, deduced, as we have done it, from the action of accelerating forces. All that was ſaid of the changes of motion produced in the magnets obtain here without any farther modification.

We may juſt be allowed to take notice of a curious obſervation of Mr Huyghens on the colliſion of perfectly elaſtic bodies. Inſtead of impelling the elaſtic ball C by the ſtroke of the elaſtic ball A, we may cauſe A to ſtrike an intermediate ball B (alſo perfectly elaſtic), which is lying in contact with C. In many caſes, the ball B will not ſtir ſenſibly from its place, and C alone will fly off. Nay, if a long row of equal billiard balls lie in contact, and one of the extreme balls be hit by another ball in the direction of the row, only the remote ball of the row will fly off. All this is eaſily ſeen and underſtood, by conſidering them as bodies mutually repelling, and placed at the limits of their mutual action. Or even ſuppoſing them elaſtic balls, at a very ſmall diſtance from each other: The ball employed to ſtrike the firſt comes to reſt, and the ſtriken ball moves off with its velocity: It ſtrikes the ſecond ball of the row, and is brought to reſt: The ſecond ſtrikes the third, and is brought to reſt: And this goes on in ſucceſſion to the laſt, which is the only one that *can* fly off. The curious obſervation of Mr Huyghens is, that a greater velocity will be communicated by a large ball to a ſmall one, if we employ the intermedium of another ball of a ſize between the two; and that the velocity will be the greateſt poſſible when the intermediate ball is a mean proportional (geometrical) between the two. This is alſo eaſily deduced from the ſimilar attention to the action of the accelerating forces, or from the ſuppoſition of ſucceſſive impulſes. From this it alſo follows that a greater velocity will be produced by the intervention of two, three, or more, mean proportionals.

68
Oblique IMPULSION.

But the direction of the ſtroke may not be the ſame with that of the motion. This is called OBLIQUE IMPULSE. The caſes of oblique colliſions are extremely different, according to the directions of the motions; and the reſults are, in many of them, far from being obvious. But we have not room for a particular treatment of them. We ſhall therefore avail ourſelves of ſome of the general facts mentioned above, by means of which we may reduce all the varieties to ſome eaſy caſes. The moſt ſerviceable general facts are: 1. That the actions of bodies on each other depend on their relative motions; and, 2. That the motion of the common centre is not changed by the colliſion. Theſe enable us to reduce all to the caſe of a body in motion ſtriking another at reſt. We have only to determine their relative motion by the propoſition in DYNAMICS, n° 67. and then to ſuperadd the common motion, which changes the relative into the true motions. Thus if two bodies A and B (fig. 4.) meet in D, deſcribing the lines AD, BD, the colliſion is the ſame as if B had remained at reſt, and A had come againſt it with the motion AB. In the mean time, the common centre of poſition has deſcribed CD. If the bodies are unelaſtic, they remain united, and proceed in the line CD produced toward E, and their common velocity will be repreſented by DE, equal to CD, if AD and BD repreſented their initial velocities If the bodies are elaſtic, they ſeparate again, and they ſeparate from the common centre in the oppoſite direction, and with the ſame velocities with which they approached it. Therefore draw a E b parallel to ACB, and make E a, E b equal to CA and CB, and then D a and D b are the paths and velocities of the bodies. All this is abundantly plain, and is a neceſſary deduction from the general principle, that the motion of the centre is not affected by any equal and oppoſite forces which connect the bodies of a ſyſtem.

69
Often accompanied by rotation.

But this great ſimplicity is not ſufficient for aſcertaining the reſults of colliſion which occur in many of the moſt important caſes. It not only ſuppoſes that AD and ED are exactly proportional to the velocities of A and B, but alſo that they meet, ſo that the plane of mutual contact is perpendicular to the line AB, and that the ſtroke on each is directed to its centre. Theſe circumſtances will not always be combined, even in the caſe of ſpherical bodies. The conſequence will be, that although the motion of the centre remains the ſame, that of the bodies may ſometimes be different. We muſt therefore give a general propoſition, which will, with a little trouble, enable the reader to determine all the motions which can take place, whether progreſſive or rotative.

70
General theorem.

Let the body A (fig. 5.), moving with the velocity V, in the direction AD, ſtrike the body B at reſt. Let F be the point of mutual contact, and bFH a plane touching both bodies in F. Draw AFP perpendicular to this tangent plane, and through G, the centre of poſition of B, draw PGC perpendicular to FP, and GI parallel to FP. Let C, in the line PG, be the ſpontaneous centre of converſion (ROTATION, *Encycl.* n° 77. &c.), correſponding to the point of percuſſion F. Join CF. Let the direction cut the tangent plane in H, and PF in A; and let AH repreſent the velocity V.

The impulſe is made at the point F, in the direction AF or FP, and the centre of poſition of the body B will advance in the direction GI, parallel to FP, the direction of the effective impulſe. But becauſe this does not paſs through the centre G, the body will advance, and will alſo turn round an axis paſſing through G, perpendicular to the plane of the lines GP, PF, and the ſpontaneous axis of converſion will paſs through

71 Efficient velocity.

ſome point C of the line PG, and will alſo be perpendicular to the ſame plane. All this has been demonſtrated in the article Rotation, n° 94, &c. Complete the parallelogram AFHE. It is plain, that the motion AH is equivalent to AE and AF. By the motion AE, A only ſlides along the ſurface of B without preſſing it, or cauſing any tendency to motion in that direction, except perhaps a little ariſing from friction. It is by the motion AF alone that the impulſe is made. Therefore let v be $= \mathrm{V} \times \frac{\mathrm{AF}}{\mathrm{AH}}$; and then $\mathrm{A} \times v$ may be called the *efficient impulſe* of the body A in the preſent circumſtances, and v the *efficient velocity*. This will be diminiſhed by the colliſion. Let x be the unknown velocity remaining in A after the colliſion, or rather in the inſtant of the greateſt compreſſion and common motion of the touching points of A and B, eſtimated in the direction FP. The effective momentum loſt by A muſt therefore be $\mathrm{A} \times \overline{v - x}$: but the ſame muſt be gained by B, and its centre G muſt move in the direction GI, parallel to FP, with this momentum; and therefore with the velocity $\frac{\mathrm{A} \times \overline{v - x}}{\mathrm{B}}$. That this may be the caſe, the point of percuſſion F muſt yield with the velocity x, becauſe the bodies are in contact. But becauſe C is the ſpontaneous axis of converſion, every particle is *beginning* to deſcribe an arch of a circle round this axis. Therefore F is beginning to move in the direction Fg, perpendicular to the momentary radius vector CF. Let Fg be a very minute arch, deſcribed in a moment of time. Draw gf perpendicular to FP. Then Ff is the motion Fg reduced to the direction FP, and will expreſs the yielding of B in the direction of the impulſe, while G deſcribes a ſpace equal to $\frac{\mathrm{A} \times \overline{v - x}}{\mathrm{B}}$, and A deſcribes a ſpace x. Therefore Fg will expreſs x. Let Pp be the ſpace deſcribed in the ſame time that Fg is deſcribed. Draw pC, cutting GK in the point I. GI is the yielding of the body B to the impulſe, and muſt therefore be equal to $\frac{\mathrm{A} \times \overline{v - x}}{\mathrm{B}}$.

The triangles Ffg and CPF are ſimilar; for the angle CFP is the complement of Ffg to a right angle: It is alſo the complement of PCF to a right angle. Therefore Fg : Ff = FC : CP. But Fg : Pp = FC : CP; becauſe the little arches Fg, Pp have the ſame angle at C. Therefore Pp = Ff, = x. It is plain, that CG : CP = GI : Pp. Therefore CG : CP $= \frac{\mathrm{A} \times \overline{v - x}}{\mathrm{B}} : x$, and $x = \frac{\mathrm{A} \times \overline{v - x} \times \mathrm{CP}}{\mathrm{B} \times \mathrm{CG}}$, or $x = v \times \frac{\mathrm{A} \times \mathrm{CP}}{\mathrm{B} \times \mathrm{CG}} - x \times \frac{\mathrm{A} \times \mathrm{CP}}{\mathrm{B} \times \mathrm{CG}}$; wherefore $x \times \mathrm{B} \times \mathrm{CG} + x \times \mathrm{A} \times \mathrm{CP} = v \times \mathrm{A} \times \mathrm{CP}$, and $x \times \overline{\mathrm{B} \times \mathrm{CG} + \mathrm{A} \times \mathrm{CP}} = v \times \mathrm{A} \times \mathrm{CP}$, and $x = v \times \frac{\mathrm{A} \times \mathrm{CP}}{\mathrm{B} \times \mathrm{CG} + \mathrm{A} \times \mathrm{CP}}$, = the velocity remaining in A, eſtimated in the direction FP.

72 Unelaſtic bodies may ſeparate.

And u, the velocity with which G will advance, is $x \frac{\mathrm{CG}}{\mathrm{CP}}$; for CP : CG = P$p$: GI, = $x : u$. It is evident that A will change its direction by the colliſion: For in the inſtant of greateſt compreſſion, it was acted on by a force $= \mathrm{A} \times \overline{v - x}$ in the direction FA. This muſt be compounded with A×V, in the direction AH, in order to obtain the new motion of A; or it may be found by compounding x, which is retained by A, with FH, which has ſuffered no change by the colliſion. The bodies will therefore ſeparate, although they be unelaſtic: If they are elaſtic, we muſt double theſe changes on each. If B was alſo in motion before the colliſion, the motion of A muſt be reſolved into two, one of which is equal and parallel to the motion of B: the other muſt be employed as we have employed the motion AH.

Expreſſions ſtill more general may be obtained for x and u; namely, by taking the formulæ for the centres of converſion and percuſſion (Rotation, n° 96, 99.)

$$\mathrm{CG} = \frac{\int p r^2}{\mathrm{B} \times \mathrm{GP}}, \text{ and } \mathrm{CP} = \frac{\int p r^2 + \mathrm{B} \times \mathrm{CP}^2}{\mathrm{B} \times \mathrm{GP}},$$

where p ſtands for a particle of matter, and r for its diſtance from an axis paſſing through G perpendicularly to the plain of the lines GP and PF. In this way we obtain

$$x = v \frac{\mathrm{A} \cdot \int p r^2 + \mathrm{A} \cdot \mathrm{B} \cdot \mathrm{GP}^2}{\overline{\mathrm{A} + \mathrm{B}} \cdot \int p r^2 + \mathrm{A} \cdot \mathrm{B} \cdot \mathrm{GP}^2}$$

73 Change of progreſſive motion greateſt when the direction of the effective ſtroke paſſes thro' the centres.

It is plain from this propoſition, that the progreſſive motion of the body depends, not only on the momentum of the impelling body, but alſo on the place where the other is ſtruck: For even although the original momentum of A be the ſame, and the obliquity of the ſtroke, making v the ſame, and the body (and conſequently $\int p r^2$) alſo remain the ſame, we ſee that x and u depend on the ratio of CP to CG. Now C and P are always on oppoſite ſides of G: Conſequently, by removing the direction FP of the impulſion farther from G, we diminiſh CG and increaſe CP; and therefore increaſe the value of $x = v \frac{\mathrm{A} \cdot \mathrm{CP}}{\mathrm{B} \cdot \mathrm{CG} + \mathrm{A} \cdot \mathrm{CP}}$; and conſequently diminiſh the value of $\mathrm{A} \times v - x$, to which $\mathrm{B} \times u$ is equal. The greateſt momentum of B is produced when the direction of the impulſe paſſes through G, and no rotation is produced. Indeed we are led, by a ſort of common ſenſe, to expect this.

74 Importance of this theory to ſeamanſhip, &c.

This inveſtigation is by no means a piece of mere ſpeculative curioſity. It is the ſolution of the greateſt problem in practical mechanics. It is in this way that we muſt proceed in computing the actions of the wind and water on the ſails and hull of a ſhip. Were it not that many circumſtances concur in determining ſeveral of the preparatory ſteps, it is evident that the taſk muſt be almoſt impracticable. But the preſſure and its direction are generally determined by experiment, without the trouble of computation; and we are ſeldom ſolicitous about the ſubſequent motion of the wind or water.

75 Impulſion on bodies confined to particular paths.

There is another queſtion in impulſion which is of the firſt practical importance—namely, when the impulſe is exerted on the parts of a machine, where the body ſtruck is not at liberty to yield freely to the ſtroke, but muſt ſlide along ſome ſolid path, or turn round ſome axis, or take ſome other conſtrained motion. The operations of moſt engines depend on this. The operation of wedges, axes, and many cutting and piercing inſtruments, and the penetration of piles, impelled

GUILLOTINE PLATE XXIX.

Fig. 1.

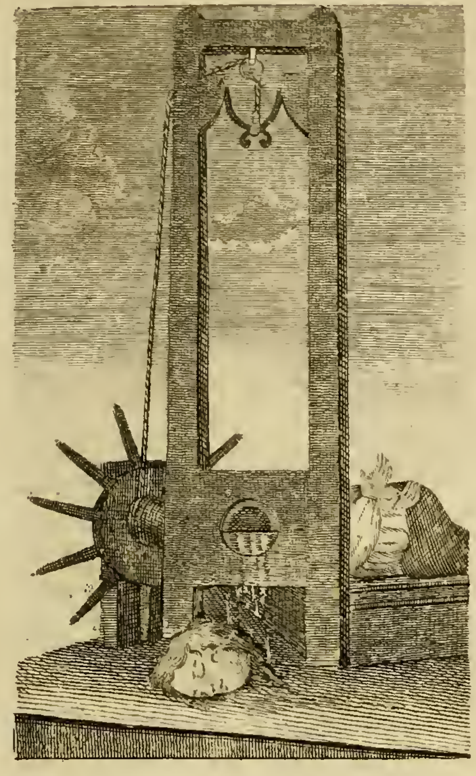
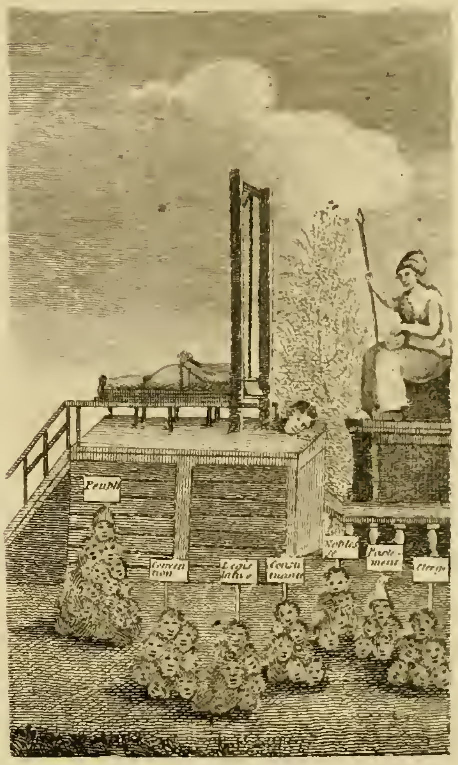


Fig. 2.



IMPULSION

Fig. 1.

Fig. 2.

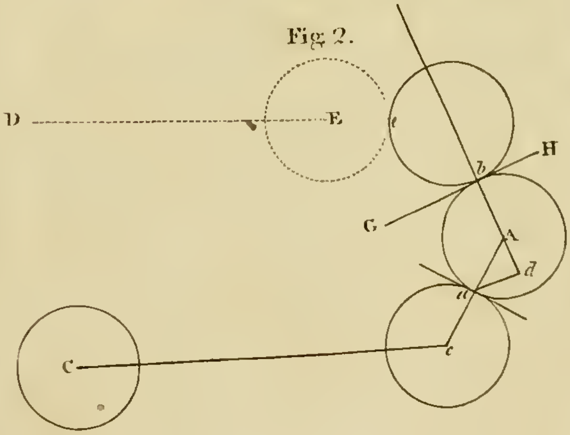


Fig. 3.

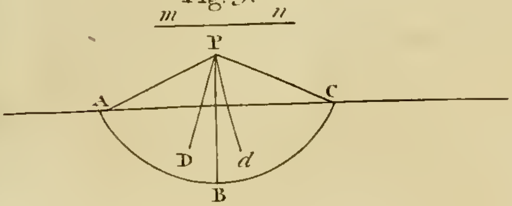


Fig. 5.

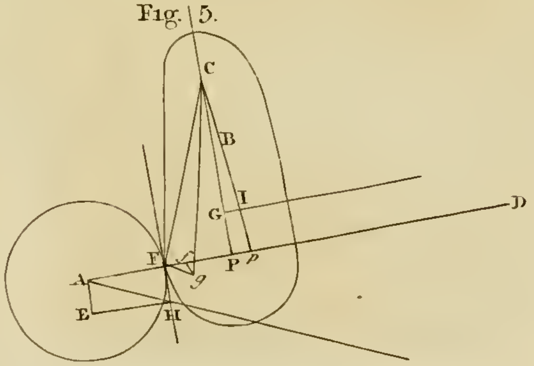
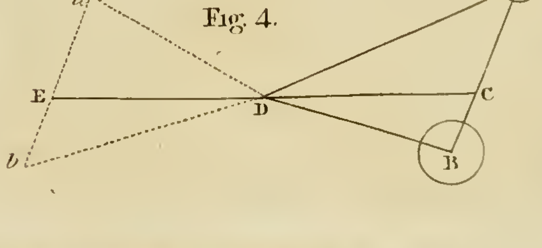


Fig. 4.



pelled by a rammer, are all aſcertained by the ſame doctrines. But the particular applications can ſcarcely be elucidated by any claſſification that occurs to us, the circumſtances of the caſe making ſuch great difference in the reſult, both in kind and degree. For example, in the ſimpleſt caſe that occurs, the driving of piles, the penetration of the pile depends, in the firſt place, on the momentum of the rammer. If the maſs of the pile be neglected, the penetration through a uniformly reſiſting ſubſtance will be as the ſquare of the velocity of the rammer (DYNAMICS, *Suppl.* n° 95.), and its abſolute quantity may be determined from a knowledge of the proportion of the weight of the rammer to the reſiſtance of the earth. But when we conſider that we have to put in motion the whole matter of the pile, we learn that a great diminution of the effect muſt take place. We ſtill can compute what this muſt be, becauſe we have the ſame momentum, with a velocity diminiſhed in a certain proportion of the ſum of the matter in the rammer and pile, to that in the rammer alone.—Another defalcation ariſes from friction, which continually increaſes as the pile goes deeper;—and a ſtill greater defalcation proceeds from the nature of the pile. If it is a piece of very dry ſtraight grained fir, it is very elaſtic, and acquires almoſt a double velocity from the ſtroke of a rammer of caſt iron. If it is moiſt and ſoft, eſpecially if it is oak, or other timber of an undulated fibre, it does not acquire ſo great velocity, and the penetration is very much diminiſhed. It is probable that a pile, headed with moiſt cork, could not be driven at all. The writer of this article found a remarkable effect of the elaſticity in the proceſs of boring limeſtone. When the boring bit was made entirely of ſteel, and tempered through its whole length to a hard ſpring temper, the workman bored three inches, in the ſame time that another bored two inches with a bit made of ſoft iron; and he would never uſe any but ſteel bits, if they could be hindered from chipping by the hammer (which muſt alſo be of tempered ſteel throughout). This has hitherto baffled many attempts. A pretty large round head, like a marlin ſpike, has ſucceeded beſt: but even this cracks after ſome days uſe. The improvement is richly worth attention; for the workman is delighted by feeling the hammer riſe in his hand after every ſtroke, and ſays that the work is not ſo hard by half. *N. B.* The ſtone cutters at Liſbon and Oporto uſe iron mallets.

76
Impulſion on machines.

The caſe of impulſion made on part of a machine moveable round an axis has been conſidered in the article ROTATION, *Encycl.* n° 72; where x is ſhewn to be $= v \times \frac{A \cdot CP^2}{\int p r^2 + A \cdot CP^2}$. But, in this formula, r denotes the diſtance of p from the point C, and not from G. $\int p r^2$ in this formula, is $B \cdot CG \cdot CP$; whereas, in the formula for a free body, where r is the diſtance of a particle from G, $\int p r^2$ is $= B \cdot CG \cdot GP$.

In the practical conſideration of this queſtion, the reader will do well to conſider the whole of that article with attention. Many circumſtances occur, which make a proper choice of the point of impulſe, and the direction of the tangent plane, of the greateſt conſequence to the good performance of the machine; and there is nothing in which the ſcientific knowledge of the engineer is of more eſſential ſervice to him. An engineer of great practice, and a ſagacious combining mind, collects his general obſervations, and ſtores them up as rules of future practice. But it is ſeldom that he poſſeſſes them with that diſtinctneſs and confidence that can enable him to communicate his knowledge to others, or even ſecure himſelf againſt all miſtakes; whereas a moderate acquaintance with theſe *elements* of real mechanics, may be applied with ſafety on all occaſions, becauſe arithmetical computations, when rightly made, afford the moſt certain of all reſults.

77
Great loſs of power by the yielding and bending of the materials.

There is a circumſtance which greatly affects the performance of machines which are actuated by impulſes, namely, the yielding and bending of the parts. When the moving power acts by repeated ſmall impulſions, it may ſometimes be entirely conſumed, without producing any effect whatever at the remote working point of the machine; and the engineer, who founds his conſtructions on the elementary theories to be had in moſt treatiſes of mechanics, will often be miſerably diſappointed. In the uſual theories, even as delivered by writers of eminence, it is aſſerted, that the ſmalleſt impulſe will ſtart the greateſt weight. But ſince impulſe is only a continued preſſure, and requires time for the tranſmiſſion of its effect through the parts of a yielding ſolid, it is plain that the motion of the impelling body may be extinguiſhed before it has produced compreſſion enough for exciting the forces which are to raiſe the remote parts of a heavy body from the ground. What blow with a hammer could ſtart a feather bed? Much oftener may we expect, that a blow, given to one arm of a long lever, will be conſumed in bending the whole of its length, ſo as to bring the remote end into action. Therefore great ſtiffneſs, and perfect elaſticity, both in the moving parts and in the points of ſupport, are neceſſary for tranſmitting the full, or even a conſiderable part, of the power of the impelling body. Perhaps not the half of the blow given by the wipers of a great forge or tilting mill to the ſhank of the hammer is tranſmitted in the *proper* inſtant of time to the hammer-head. The hammer, while it is toſſed up by the blow, is quivering as it flies. Should it reach the ſpring above it in the time of its downward vibration, it will not be returned with ſuch force as if it had hit the ſpring a moment before or after. A quarter of an inch will produce a great effect in ſuch caſes. It is found, that the minute impulſes given to the pallets of a clock or watch loſe much of their force by the imperfect elaſticity of the pendulum or balance. We muſt therefore make all the parts which tranſmit the blow to the regulating maſs of matter as continuous, hard, elaſtic, and ſtiff, as poſſible. The performance of ruby pallets is very ſenſibly weakened by putting oil on the face of them, eſpecially in the detached ſcapements, which act partly by impulſe. A wheel of hard tempered ſteel, working on a dry ruby pallet, excels all others. The intelligent engineer, ſeeing that, after all his care, much impulſion is unavoidably loſt, will avoid employing a firſt mover which acts in a ſubſultory manner, and will ſubſtitute one of continued preſſure when it is in his power. This is one chief cauſe of the great ſuperiority of overſhot water wheels above the underſhot.

We can now underſtand how it happens that Gallileo, Merſennus, and others, could compare the impulſe given

given by a falling body with the preſſure of a weight in the oppoſite ſcale of a balance, and can ſee the reaſon of the immenſe differences, yet accompanied by a ſort of regularity, in the reſults of the experiments. Galileo, Merſennus, and Riccioli, found them to be proofs that the forces of moving bodies are as their velocities; becauſe the heights from which the body fell were as the ſquares of the weights ſtarted from the ground. Graveſande found the ſame thing as long as he held the ſame opinion; but when he adopted the Leibnitzian meaſure, he found many faults in the apparátus employed in his former illuſtrations, and altered it, till he obtained reſults agreeable to his new creed. But any one who examines with attention all that paſſes in the bending of the apparatus, and takes into account the maſs of matter which muſt be diſplaced before the oppoſite arm riſes ſo far as to detach the ſpring which gives indication of the magnitude of the ſtroke, muſt ſee that the agreement is purely accidental, and may be procured for any theory we pleaſe (ſee *Graveſande's Nat. Phil.* tranſlated by Deſaguiliers, vol. i. p. 241. &c.) The propoſition, n° 95, DYNAMICS, ſuffices for explaining every thing that can happen in ſuch experiments. And it will ſhew us, that although the motion of impulſion is produced by preſſure alone, yet impulſe is incomparable with mere preſſure: It is not infinitely greater, but diſparate. A weight (which is a preſſure) bends a ſpring to a certain degree, and will derange to a certain degree the fibres of a body on which it preſſes, before it be balanced. The ſame weight, falling on this ſpring from the *ſmalleſt* height, will bend it farther, and may cruſh or ſhiver to pieces the body which would have carried it for ever. We ſhall make ſome further remarks on this ſubject, of great practical importance, under the word PERCUSSION.

78 Concluſion. THE method which we have purſued in conſidering the doctrines of impulſion, differs conſiderably from that which has generally been followed; but we truſt that it will not be found the leſs inſtructive. Although the reader ſhould not adopt our decided opinion, that we have no proof of pure impulſion ever being obſerved, and that all the phenomena which go by that name are really the effects of preſſures, analogous to gravity, he perceives that our opinion does not lead to any general laws of impulſion that are different from thoſe which are acknowledged by all. We differ only, by exhibiting the internal procedure by which they are *unqueſtionably* produced in a vaſt number of caſes, and which takes place in all that we have ſeen, in ſome degree. Our method has undoubtedly this advantage, that it requires no principle but one, namely, that accelerating forces are to be eſtimated by the acceleration which they produce. Even this may be conſidered, not as a principle, but merely as a definition—We get rid of all the obſcurity and perplexity that reſult from the introduction of inertia, conſidered as a power – a power of doing nothing; and we are freed from the unphiloſophical fiction (adopted by all the abettors of that doctrine, and even by many others) of conceiving the ſpace, in which motions are performed, and bodies act, to be carried along with the bodies in it.—This furniſhes, indeed, in ſome caſes, a familiar way of conceiving the thing, by ſuppoſing the experiments to be made in a ſhip under ſail, and by appealing to the fact, that all our experiments are made on the ſurface of a globe that is moving with a very great velocity. But it is an abſurdity in philoſophy, and, when minutely or argumentatively uſed, it does not free us from one complication of action; for, before we can make uſe of this ſubſtitution, we muſt demonſtrate, that the actions depend on the relative motions only: And this, when demonſtrated, *obliges* us to meaſure forces by the velocity which they produce.

As no part of mechanical philoſophy has been ſo much debated about as impulſion, it will ſurely be agreeable to our readers to have a notice of the different treatiſes which have been publiſhed on the ſubject:

Galilei Opera, T. I. 957. II. 479, &c.

Jo. Walliſii Tractatus de Percuſſione. Oxon. 1669.

Chr. Hugenius de Motu Corporum ex Percuſſione. Op. II. 73.

Traité de la Percuſſion des Corps, par Mariotte, Op. I. 1.

Hypotheſis Phyſica Nova, qua phenomenorum cauſæ ab unico quodam univerſali motu in noſtro globo ſuppoſito repetuntur. Auct. G. G. Leibnitzio. Moguntiæ 1671.—Leibn. Op. T. II. p. II. 3.

Ejuſdem Theoria Motus Abſtracti. Ibid. 35.

Hermanni Phoronomia. Amſt. 1716.

Diſcours ſur les Loix de la Communication de Mouvement, par Jean Bernoulli, Paris, 1727. Jo. Bern. Oper. III.

Dynamique de D'Alembert.

Euleri Theoria Corporum ſolidorum ſeu rigidorum, 1765.

Borelli (Alphons) de Percuſſione.

See alſo M'Laurin's Fluxions, and his Account of Newton's Philoſophy, for his Diſſertation crowned by the Acad. des Sciences at Paris.—Alſo Dr Jurin's elaborate diſſertations in the Phil. Tranſ. N° 479.—Alſo Graveſande's Nat. Philoſophy, where there is a moſt laborious collection of experiments and reaſonings; all of which receive a complete explanation by the 39th Prop. Princip. Neutoni I. or our n° 95. DYNAMICS. There are alſo many very acute philoſophical obſervations in *Lambert's Gedanken über die Grundlehren des Gleichgewichts, und der Bewegung.* in the ſecond part of his Gebrauch der Mathematik.—Alſo, in the works of Kaeſtner, Hamberger, and Buſch. Muſchenbroeck alſo treats the ſubject at great length, but not very judiciouſly. We do not know any work which treats it with ſuch perſpicuous brevity as M'Laurin's Account of Newton's Philoſophy.

END OF THE FIRST VOLUME.

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