ELEMENTS

OF THE

BRANCHES

OF

NATURAL PHILOSOPHY

CONNECTED WITH

MEDICINE.

VIZ.

CHEMISTRY,	HYDROSTATICS,
OPTICS,	ELECTRICITY, and
ACOUSTICS,	PHYSIOLOGY.

Including the Doctrine of the

ATMOSPHERE, FIRE, PHLOGISTON, WATER, &c.

Together with

BERGMAN's TABLES OF ELECTIVE ATTRACTIONS, with EXPLANATIONS and IMPROVEMENTS.

THE SECOND EDITION, CORRECTED, WITH ADDITIONS.

By J. ELLIOT, M.D.

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T O

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AND

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SIR,

A WORK intended for the inſtruction of the younger members of the medical profeſſion ſeems to have a peculiar claim to the patronage of the ingenious Editor of the ELEMENTS OF ANATOMY. Give me leave, therefore, to dedicate to you the preſent performance. If the plan and the execution of it are honoured with your approbation, I ſhall be ſatisfied.

I have the honour to be,

With the moſt perfect reſpect,

SIR,

Your obliged

and devoted humble ſervant,

J. ELLIOT.

Great Marlborough-Street,
Sept. 28, 1785.

A 2

PREFACE.

THE utility of natural philoſophy to the medical practitioner muſt be ſufficiently obvious, when we conſider that the faculties of the human body are intimately connected with thoſe powers of nature which are in a more eſpecial manner the objects of that ſcience. Thus, viſion depends on light; health is in a great meaſure regulated by the ſtate of the atmoſphere, and life itſelf depends on the purity of the air we breathe.

The ſtudent who has had the advantage of a regular education, is taught to conſider philoſophy as an indiſpenſable branch of medical ſcience. 'Tis by this he is led to underſtand, and reaſon about, the *cauſes* of diſeaſes; and to form proper indications for the removal of them. By attending to the various ſtates of the atmoſphere, for example, he is enabled to account for and relieve a variety of ſymptoms that may chance to occur in the courſe of a diſeaſe, but which would puzzle and miſlead one unacquainted with theſe matters. It is this, chiefly, that diſtinguiſhes the ſcientific and regular practitioner from the empiric.

It is to be lamented however, that they who have not had ſuch an education are in general but little acquainted with the principles of natural philoſophy. For want of knowing what branches of it are neceſſary for their purpoſe, there are ſome who encounter the whole of the ſcience, and thus are either deterred by the formidable bulk of the matter, from entering on the ſtudy at all, or, conceiving it to be of little or no uſe in their profeſſion, conclude that the advantages to be derived from it will not compenſate for the time and trouble they muſt neceſſarily employ in acquiring it. The latter objection particularly affects ſtudents in the pharmaceutical line, who, having generally other employment, have but little leiſure for ſuch purſuits. If ſuch get acquainted with only the uſeful branches of philoſophy, it is as much as can be expected from them.

My deſign therefore in the following work is to treat of thoſe parts of philoſophy which are connected with phyſic; and I ſhall endeavour to diſcourſe of them in ſuch a manner as that thoſe for whom I write may not have much difficulty in underſtanding me. Even gentlemen who are deſigned for phyſicians, will, 'tis preſumed, find their advantage in the peruſal, as it will enable them the better to underſtand the lectures of their profeſſors, and prepare them for more learned treatiſes on theſe ſubjects.

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The work is divided into three parts.

The firſt treats of CHEMISTRY; the *practical* part of which however the reader is by no means to expect. At firſt it was intended merely to have given the doctrine of affinities. But it was afterwards judged proper to add the accounts in the preceding chapters. If the reader has not already ſome knowledge of the chemical operations, he would do well to conſult the writings of the celebrated M. Macquer; and M. Baumé's excellent manual of chemiſtry, in Engliſh, with Mr. Aikin's notes.

The ſecond part treats of OPTICS, ELECTRICITY, and ſuch other ſubjects as were judged neceſſary to the deſign of the work. But the ſuperfluous parts, even of theſe, are not entered upon. In the chapter on *optics*, for example, only ſo much of that ſcience is given as is neceſſary to the underſtanding of the doctrine of *viſion*.

In the laſt part it was only intended to give ſuch a ſketch of *phyſiology* as might be ſufficient for ſhewing the connection and application of the ſubjects previouſly treated of, to the human body. The reader is referred for further information in theſe matters to the authors who have profeſſedly written on this ſcience, on pathology, and the other branches of medical theory.

From this account of the work it will eafily be feen that it is intended rather as an *intro-duction to*, than a compleat treatife on the fubjects mentioned; and the Author's end will be an-fwered if it excites in the reader a *tafte* for this ufeful kind of ftudy. If the ftudent has leifure, and a laudable ambition, he will not only perfect himfelf in thefe matters from authors of a fupe-rior rank, but even acquire a knowledge of thofe parts of philofophy, which, not being fo imme-diately neceffary, are not here difcourfed of. For it need not be added, that an apothecary or fur-geon, as well as a phyfician, will be more con-fided in by his patients, and be more generally and juftly efteemed for his fkill in his profeffion, as his learning is more extenfive.

THE foregoing preface was prefixed to the firft edition. I fhall only add, that as the fpeedy fale of that impreffion has fufficiently proved the utility of the work, I have, in the prefent, made fuch alterations, and additions, as appeared on revifal to be neceffary.

Sept. 28, 1785

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INTRODUCTION.

BEFORE I enter on the ſubjects propoſed, it may be proper to premiſe the following particulars.

1.

All bodies, whether ſolid or fluid, are compoſed of particles too ſmall to be viſible to the naked eye. Thus, water is made up of ſuch particles. We can divide a given quantity of that fluid into ſeveral portions; thoſe again into others; each of which may again be ſubdivided, and ſo on till the portions ceaſe to be viſible. The leaſt portions into which it can be divided are called *the particles of water*. The like may be obſerved of other bodies.

2.

The particles of ſome bodies are mutually attractive. You may underſtand the manner of this, by obſerving what happens when two loadſtones are placed near to each, the north pole of one being turned

towards

towards the ſouth pole of the other; for they will draw, or attract one another, and by that means ſtick together, and it will require ſome force to ſeparate them. In like manner the particles of bodies, on account of their mutual attractions, ſtick or cohere. Some kinds of particles attract one another more powerfully than others. Thus, the particles of diamond cohere ſo ſtrongly that they cannot be ſeparated without a very great force. The particles of lead cohere leſs powerfully than thoſe of diamond, and therefore are more eaſily ſeparable. The particles of water cohere ſo weakly, that their ſeparation is very eaſily effected.

3.

The particles of ſome bodies do not attract, but are on the contrary mutually repulſive; that is, they drive each other away. You may have an idea of this by turning the north or ſouth pole of one magnet, to the ſame pole of the other; for you will find that inſtead of ruſhing together, as before, they fly further aſunder. The like is the caſe with particles of air, and of ſome other ſubſtances.

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The particles of ſome bodies attract thoſe of others, as the magnet attracts iron. Thus, particles of water attract thoſe of ſugar; hence water diſſolves ſugar. The particles of acids attract thoſe of alcalis, and hence they unite. Particles of different kinds attract each other with different degrees of force. Thus, particles of ſpirit of wine attract thoſe of eſſential oil; but they attract particles of water, more than they do thoſe of the oil. Alſo ſome kinds of diſſimilar particles repel each other; and there are other kinds which do not ſeem either to attract or repel.

5.

Bodies may exiſt in three different ſtates; at leaſt this ſeems to be the caſe with moſt ſubſtances. Thus, water with an heat ſufficiently gentle, is *ſolid*, as when it is frozen. With a greater heat it is *fluid*; which is the ſtate in which we moſt uſually obſerve it. But in an heat ſtill greater, it is turned into vapour, or becomes elaſtic like air. It may likewiſe be obſerved, that when water is in its *ſolid* ſtate, its particles attract each other moſt ſtrongly: when in its *fluid* ſtate, very little; and when in its *elaſtic* ſtate, they are, on the contrary, repulſive. The like may be obſerved of oil, of quickſilver, and many other ſubſtances. But different degrees of heat are required to produce theſe effects in different bodies, as will be more fully ſeen in the courſe of the work.

6.

Bodies gravitate, or tend towards the centre of the earth; and the force with which they gravitate, is in proportion to the quantity of matter which they contain. Thus, a quart of water contains twice as much matter as a pint of the ſame fluid, and therefore gravitates twice as much; or weighs twice as heavy: *gravity* and *weight* being ſynonymous terms.

7.

Different bodies, or ſubſtances, have different ſpecific gravities. Thus, a pint of ſpirit of wine weighs leſs than a pint of water, and therefore there is leſs matter in a pint of ſpirit, than in a pint of water. Hence ſpirit of wine is ſaid to have leſs ſpecific gravity than water.

On the contrary, a pint of quickſilver weighs heavier than a pint of water, and therefore contains more matter. Hence quickſilver is ſaid to have a greater ſpecific gravity than water.

To place it in another light, a pound of ſpirit of wine is greater in bulk than a pound of water; and a pound of water is greater in bulk than a pound of quickſilver. Or there is an equal quantity of matter in a pound of ſpirit of wine, a pound of water, and a pound of quickſilver; but it is contained under greater or leſs bulk in one of theſe ſubſtances, than another. Thus alſo, a pound of wool may be comprized in a greater or leſs bulk, according as it is more or leſs preſſed together; but whether the bulk be greater or leſs, the weight, or real quantity of the wool is the ſame.

8.

When the ſame quantity of matter is contained under a greater bulk, the body is ſaid to be *rare*; when in a leſſer, *denſe*. Thus, ſpirit of wine is rarer than water; but quickſilver denſer.

Bodies will keep above thoſe that are *denſer* than themſelves, provided the latter be be fluid; but ſink in ſuch as are *rarer*. Thus, a cork floats upon oil; but lead ſinks beneath it. Oil ſwims on the ſurface of water; quickſilver falls to the bottom.

9.

When a body is capable of being raiſed into vapour by heat, it is ſaid to be *volatile*: when it cannot be thus raiſed, it is ſaid to be *fixed*. Thus, ſpirit of wine is eaſily diſſipated in vapour, and thence is ſaid to be volatile: earth, not being capable of this, is ſaid to be fixed.

So ſpirit of wine is ſaid to be more volatile than water, becauſe it is diſſipated with leſs heat. Oil of vitriol is ſaid to be more fixed than water, becauſe a greater heat is required to raiſe it into vapour.

CHEMIS-

CHEMISTRY.

SECTION I.

IT has been cuſtomary with writers on this art to begin their diſcourſes with an account of the *chemical principles*. Of theſe principles, they ſay, all bodies are compoſed; and into them are capable of being again reſolved. The old chemiſts reckoned five principles, viz. ſpirit, ſalt, oil, water, and earth. Later authors have added air; and ſome others: and different writers have varied them, either according to their own fancies, or the philoſophy of the day. The doctrine of the four Ariſtotelian elements, earth, water, fire, and air, has of late years been revived, and admitted by very eminent chemiſts. Earth, in particular, has been conſidered as a principle by all writers on this ſubject. But ſalts and oils are known to be compounds of other principles; and probably the like holds good alſo with the reſt. For theſe, and other reaſons we ſhall not enter on the ſubject of *principles*; and in the following chapters it is merely intended to give the reader ideas of ſome of thoſe chemical ſubſtances with which he may be ſuppoſed not to be ſo well acquainted.

CHAPTER I.

OF WATER.

WATER is a ſubſtance ſo well known, and with many of the properties of which we are ſo well acquainted from common experience, that much will not be required to be ſaid concerning it.

It is tranſparent when pure, and without either taſte, ſmell, or colour.

With a certain degree of cold it is converted into an hard or ſolid ſubſtance called ice, and with ſufficient heat it is turned into vapour.

Water is a very general ſolvent. Salts of all kinds are diſſolved by it, ſome in greater, others in leſs proportion; ſome more readily, others more ſlowly; and with the aid of heat, the ſolution is not only effected in leſs time, but in greater portion than otherwiſe. Pure gums, and mucilages are likewiſe diſſolved by this liquid. Many ſubſtances which it cannot diſſolve entirely, it can yet diſſolve in part, as vegetable, animal, and many of the mineral ſubſtances.

Water cannot be compreſſed into leſſer dimenſions than it naturally occupies, or its compreſſibility is ſo very little, that it needs not be here conſidered, being as nothing when compared to the compreſſibility of air; neither does it, like air, expand when a force compreſſing it is removed.

Vegetable,

Vegetable, animal, and moſt of the mineral ſubſtances contain water when in their natural ſtates: by far the greater part of the blood and juices of the two former is mere water. In ſalts and many other ſubſtances, water is alſo contained as a neceſſary ingredient.

Water is likewiſe contained in moſt ſubſtances, not in its fluid form, but in a ſtate of combination, forming a ſolid body. What, for example, is more dry or ſolid than lignum vitæ? Yet if it be diſtilled, without any addition, in a retort, a vaſt quantity of water may be obtained. The like may be obſerved of the horns and bones of animals; of lime ſtones; and many other ſubſtances. The water being chemically combined with the other principles of theſe bodies, loſt its *fluid*, and aſſumed a *ſolid* form. But when the union between theſe ingredients was deſtroyed, the water reaſſumed its fluidity.

As the greateſt part of animal fluids is mere water, animal food muſt alſo contain this liquid in great proportion. Not to mention the liquids that we uſually drink, the ſtrongeſt of which are almoſt entirely water, the moſt ſolid of our aliment contains this principle in very great quantity, as is plain from what was ſaid above of the diſtillation of animal and vegetable ſubſtances, which make up almoſt the whole of our ſolid food.

Water cannot be obtained pure, becauſe it will neceſſarily diſſolve many particles of the various ſoils through which it paſſes. Hence the difference between river and ſpring waters, mineral waters, ſea waters, &c. The pureſt of all is rain water. But for nice chemical purpoſes water is diſtilled.

When water is ſufficiently heated it boils. The bubbles which then ariſe in it are water rendered elaſtic or turned into a kind of air, as will be ſhewn hereafter. If the preſſure of the air be leſſened or removed, the water boils with a leſs heat; but if the preſſure of the air be increaſed, a greater heat is required to make it boil than otherwiſe. It is remarkable, that after water boils, it cannot be rendered hotter by increaſing the heat. When water changes from a ſolid ſtate, or ice, to a liquid form, cold is generated; and the like happens when it changes from a fluid to an elaſtic, or vapoury ſtate; and heat is produced in the contrary caſes. What has been ſaid of water in this paragraph, holds good with oil, quickſilver, and other ſubſtances. But theſe things will be better underſtood after ſome other matters have been explained, wherefore I ſhall not at preſent enlarge on them.

Water has, till very lately, been conſidered as an element indeſtructible by any human means. But by ſome recent experiments, it appears that it is a compound of inflammable, and dephlogiſticated airs. For theſe uniting, compoſe water; and this water may again be reſolved into theſe

two

two ingredients, as may be ſhewn more fully in a future chapter.

CHAPTER II.

OF EARTH.

BY earth we do not mean, with the vulgar, ſoil, or dirt; theſe being mixtures of earth, water, oil, ſalts, and other matters. The earth of chemiſtry is that ſubſtance which remains after all the other principles are expelled from a body by heat.

If a leaf be carefully burnt, the ſalts, water, oil, and other principles of which it is compoſed, will be diſſipated. But the earth, reſiſting the force of fire, will remain behind, ſtill retaining the ſhape of the leaf; and therefore may alſo be ſaid to be the baſis of theſe other principles; by means of which they were the better enabled to ſuſtain the form into which they were contrived.

The general character of earth is, that it is fixed, or incapable of being raiſed into vapour by any heat that we can apply. Some earths cannot even be rendered fluid by our fires, but retain their dry form in the moſt intenſe heat. By heat they are capable of being turned into glaſs, either alone, or by fuſion with fixed alcalis.

Some philoſophers teach that there is but one kind of pure earth; which they therefore look upon as a principle; and call it *elementary earth.* All the various earths which we are acquainted with, they conſider only as pure earth adulterated with other principles; and imagine, that according to the ſubſtances with which it is alloyed, it forms earths of different kinds. Theſe alloys, they add, are ſo intimately combined with the earth, that they cannot be wholly ſeparated from it by any methods that we are yet acquainted with; and therefore the latter cannot be obtained pure.

It is, however, ſufficient for our purpoſe, to conſider earths in thoſe ſtates in which we uſually obtain them. For whether their differences be original, or accidental, they have diſtinct and ſpecific properties; and therefore ought to be conſidered as different ſubſtances.

1.

CRYSTALLINE EARTH.

CHEMISTS have given this name to diamonds, flints, cryſtal, and other hard, tranſparent, and infuſible ſtones; which are only earth in a ſolid or cryſtalline form. They are known from others by their property of ſtriking fire with ſteel. They are neither ſoluble in acids, nor fuſible by fire. When mixed with alcaline ſalts, and expoſed to an intenſe heat, they melt into glaſs. Could they be fuſed without ſuch addition, the glaſs which they would form, would be much harder than any that art has yet produced.

2.

CALCAREOUS EARTH.

QUICKLIME is pure calcareous earth. It is obtainable from lime-ſtones, chalk, the ſhells of animals, marble, and ſome other ſubſtances, by calcination, or expelling their other principles by heat. It is infuſible by our fires. In its natural ſtate (as in chalk, the common abſorbent or teſtaceous powders, &c.) it is combined with fixed air, and is then called *mild* calcareous earth. In its ſtate of quicklime, it is freed from fixed air, and is then ſaid to be *cauſtic*.

This earth is diſtinguiſhable from others, by its property of becoming quicklime on expelling its fixed air by fire, or other methods.

It is likewiſe ſoluble in water, in its cauſtic ſtate, and then forms lime-water. In its mild ſtate, it is not ſoluble.

It is diſſolved by acids, either in its mild or cauſtic ſtate. If in its mild ſtate, it *efferveſces*; the fixed air, which is ſet free by the acid, raiſing the liquid into a froth as it eſcapes. In its cauſtic ſtate it cannot efferveſce, becauſe it contains no air to be extricated by the acids: the ſolutions, therefore, are exactly the ſame, whether cauſtic, or mild calcareous earth be uſed; the air, which conſtituted the difference between them, being expelled and diſſipated when the mild earth is employed.

It neutralizes acids, and with vitriolic acid it forms ſelenite, or plaiſter of paris.

It expels volatile alcali from acids; and unites with ſulphur, forming a kind of hepar ſulphuris.

3.

MAGNESIA.

Like calcareous earth, it may be had either combined with, or free from fixed air. It may be obtained from Epſom, and ſome other ſalts, either by precipitation with an alcali, or by calcination, by which the acid is expelled.

It may be known from calcareous earth, by its forming ſal catharticus amarus, with vitriolic acid, which is eaſily ſoluble in water; whereas calcareous earth forms with the ſame acid ſelenite, which is inſoluble in water, or ſo little ſoluble as not in this caſe to be conſidered.

It may be precipitated from acids by volatile alcali.

It has leſs ſpecific gravity than calcareous earth, eſpecially when in powder.

4.

ARGILLACEOUS EARTH.

It is contained in clay, and may be extracted by the vitriolic acid, with which it forms allum.

It

It may alſo be precipitated from allum by fixt or volatile alcali; and as this is the method by which it is uſually obtained pure, it is alſo called *earth of allum*.

It is ſoluble in other acids: but its forming allum with the vitriolic is alone ſufficient to diſtinguiſh it from other earths.

5.

METALLIC EARTHS.

The ſubſtances remaining after the calcination of metals are called by this name. Thus, minium, ruſt of ſteel, and mercurius precipitatus, are metallic earths.

They have this remarkable and diſtinguiſhing property, that when fuſed with charcoal, or other inflammable matter, they become metals. Thus minium, treated in this manner, becomes lead; and mercury precipitate, quickſilver. This is called *reviving* them. By theſe means they may be known one from another, as well as in general from other earths. They may alſo be diſtinguiſhed by other methods. Thus,

CALX OF COPPER,

Combined with vitriolic acid, forms blue vitriol.

CALX OF IRON,

Combined with the ſame acid, forms green vitriol.

CALX OF LEAD,

Combined with vegetable acid, forms ſaccharum ſaturni. This calx is alſo ſoluble in oils.

CALX OF SILVER,

Combined with nitrous acid, forms lunar cryſtal, or lunar cauſtic.

CALX OF ZINC *,

Combined with vitriolic acid, forms white vitriol: and ſo of others. They may alſo be characterized by their colour, and other ſenſible qualities, but the reviving them is frequently the moſt eligible method of diſcovering them.

The metallic earths, or calces, uſually contain fixed or other air; which the phlogiſton, by which they are revived, expels.

ANIMAL AND VEGETABLE EARTHS,

Or the aſhes of animal and vegetable ſubſtances, freed from their alcaline ſalts.

Theſe are various, according to the nature of the ſubjects from which they are obtained. Thus ſome animal earths are calcareous; others not. Some are more eaſy of fuſion; others leſs; and the like is the caſe with vegetable earths.

It would take up too much room to enumerate their different kinds; and much more the various other ſpecies of earth, mentioned by chemical writers;

* Calamine, Tutty, &c. are calces of zinc.

writers; many of which are only compounds of thofe that have been mentioned. What has been faid on this fubject is amply fufficient to the purpofe of the prefent work.

CHAPTER III.

OF SALTS.

SALTS are fubftances having tafte, are foluble in water, and, for the moft part, incombuftible.

They are divided into acid, alcaline, and neutral; of each of which I fhall give a feparate account.

I.

OF ACID SALTS.

Thefe are known from other fubftances by their four tafte, and by their changing fyrup of violets, or other blue vegetable infufions red. When mixed either with one another, with alcaline falts, with metals which they can diffolve, or with water, they produce heat; with ice or fnow, cold. They coagulate animal fluids; they powerfully attract water, infomuch that in the pureft ftate in which we commonly ufe them they are combined with that fluid. Thus oil of vitriol is not pure vitriolic acid, but that acid and water. They have a ftrong tendency to unite with many other fubftances; as alcaline falts, earths, metals, animal and vegetable fubſtances, &c. For this reaſon they are never found pure, but combined with ſome of theſe ſubſtances, from which they are obtainable by art. Thus, oil of vitriol is obtained from copperas; and vinegar from fermented vegetables. They are volatile, and reſiſt putrefaction. They are uſually divided into four kinds.

I.

THE VITRIOLIC ACID,

Or that which is obtained from copperas by diſtillation, from ſulphur by burning, and from other ſubſtances. Thus, oil of vitriol, and ſpirit of ſulphur by the bell, are vitriolic acid, or rather that acid combined with water.

It is diſtinguiſhable from other acids by the following properties: it has a ſtronger affinity to alcaline ſalts and earths than the other three acids, and therefore diſlodges them from thoſe baſes, but is not uſually diſlodged by them.

When concentrated it excites a greater degree of heat with water, than any other acid.

It does not fume like the nitrous, or marine acids; nor has it either colour or ſmell, if pure.

With fixed vegetable alcali it forms vitriolated tartar; with foſſil alcali, Glauber's ſalt; with argillaceous earth, allum; with calx of iron, copper,

copper, or zinc, green, blue, or white vitriol; with calcareous earth, ſelenite; and with magneſia, Epſom ſalt. It is more fixed than the other three acids.

2.

NITROUS ACID,

Or that obtained from ſaltpetre. Thus Glauber's ſpirit of nitre, and aqua fortis, are nitrous acids, diſſolved in water.

It may be known by the red colour of its fumes when it yields them, and by the greater degree of cold which it generates with ice or ſnow, than the other acids. When concentrated, it produces flame being poured on certain oils. With fixed alcalis it forms nitres, which may be known from all other neutral ſalts, by their property of deflagrating with any inflammable matter, in a ſufficient degree of heat; and with volatile alcali, it forms a ſalt which detonates in a proper degree of heat without the addition of any inflammable matter. It is diſplaced from alcalis by the vitriolic, but not by the other two acids; but it attracts phlogiſton more ſtrongly than either of them. It is capable of exiſting in the form of air.

This acid may have its phlogiſton taken from it by proper ſubſtances: it is then quite colourleſs, and without any red fumes; and ſtronger than it was before.

3. MARINE,

3.

MARINE, or MURIATIC ACID.

Spirit of fea-falt is what we underftand by thefe terms; it is diftinguifhed by the following properties.

When concentrated it is lighter than the vitriolic or nitrous acids; of a yellow or ftraw-colour, and emits white fumes. It attracts metals more ftrongly than other acids. With the foffil alcali it forms common falt; and with volatile alcali, fal-ammoniac. It is diflodged from alcalis by the vitriolic and nitrous, but not by the vegetable acid. It is obtainable in a feparate ftate in the form of air.

This acid may be dephlogifticated like the nitrous. It is then quite colourlefs.

4.

VEGETABLE ACID.

Vinegar is moft commonly underftood by this term; it is obtained from vegetables by fermentation.

When concentrated, that is, when diftilled from verdegris, or from fal diureticus, or fugar of lead, by means of the vitriolic acid, or otherwife, it emits a moft pungent fmell.

It is diflodged from alcalis by all the three preceding acids. With fixed alcali, it forms diuretic

retic ſalt; with copper, cryſtals of Venus; and with lead, ſaccharum ſaturni.

Lemon-juice, cream of tartar, juice of ſorrel, and others, are alſo vegetable acids; they are for the moſt part weaker than vinegar, that is, are diſlodged by it from alcalis. Cream of tartar forms Rochelle ſalt with foſſil alcali, and ſoluble tartar with fixed vegetable alcali; neither of which can be obtained by uſing vinegar. Cream of tartar is alſo in a ſolid ſtate, contrary to moſt other acids; which attract water ſo powerfully as not to be uſually retained in this form.

Theſe are the acids uſually conſidered by chemiſts; but there are others: for example,

5.

THE VOLATILE VITRIOLIC ACID,

Or aqua ſulphurata of the London pharmacopœia, made by impregnating the vapours of ſpirit of vitriol with the fumes of ſome inflammable ſubſtance, or rather with phlogiſton.

It has a very ſuffocating ſmell, and is difficultly concentrated. It is diſlodged from alcalis by the vitriolic, nitrous, and marine acids; but the ſalts which it forms with thoſe alcalis may, by expoſing them to a gentle, but continued heat, be brought to the ſame ſtate as thoſe formed by the common vitriolic acid with the ſame alcalis; and the like is the caſe with the

acid

acid itſelf. The acid is capable of being obtained from the water by heat, in the form of a permanently elaſtic vapour, or air. It may be ſaid to be the vitriolic acid volatilized by phlogiſton.

6.

THE PHOSPHORIC ACID.

Phoſphorus is a compound of phlogiſton and an acid. If the phoſphorus be burnt, the acid remains behind, as is the caſe with ſulphur. It may alſo be obtained by diſtillation, from the fuſible ſalt of urine; and by other means.

It is the moſt fixed of any of the acids; for it may not only be evaporated to dryneſs, but will bear an heat capable of turning it into glaſs.

Diſtilled with charcoal, or other proper inflammable matter, it becomes phoſphorus.

7.

AQUA REGIA.

This is not a ſimple acid, but a compound of the nitrous, and marine; it is diſtinguiſhable from others by its property of diſſolving gold.

8.

SEDATIVE SALT,

Or the acid of borax, and which may be obtained from it by diſtillation with oil of vitriol.

It is ſolid, and vitrifiable; with the foſſil alcali it recompoſes borax.

The

The other acids are, the acid of amber, of ants, of animal fat, of the Swediſh fluor, of ſugar, and ſome others *. But thoſe already diſcourſed of are more than ſufficient to the purpoſe of this work. Fixed air is alſo juſtly reckoned by the ingenious Mr. Bewly and others, among the acids.

II.

OF ALCALINE SALTS.

The moſt diſtinguiſhing characteriſtics of alcalis are, their acrid urinous taſte; their turning blue vegetable infuſions green; and their uniting with, and deſtroying the ſour taſte of, acids. They are likewiſe capable of uniting with other ſubſtances: thus, with oil they form ſoap; and with ſulphur, hepar ſulphuris. When combined with fixed air, or in their *mild ſtate*, they cauſe effervеſcence with acids, and are capable of cryſtallization; but not in their *cauſtic one*. They are, like acids, obtainable by art from the ſubſtances which contain them. See alſo the cloſe of this article.

I. FIXED VEGETABLE ALCALI.

It is made by burning land plants to aſhes in an open fire, pouring water on the aſhes to diſſolve the ſalts, then filtering and evaporating the ſolution to dryneſs; the alcali remains behind. Thus, ſalt of tartar, ſalt of wormwood, pearl aſhes, and the like, are *fixed vegetable alcalis*.

* See Bergman's Tables.

It attracts acids ſtronger than volatile alcali, earths, or metals; it therefore diſplaces thoſe ſubſtances, but cannot be diſlodged by them.

It is capable of converting *earths, not otherwiſe fuſible,* into glaſs by heat; and promotes the fuſion and vitreſcency of others.

In its cauſtic ſtate it diſſolves vegetable and animal ſubſtances, and with expreſſed oil forms common ſoap. It is not volatile.

With vitriolic acid it forms vitriolated tartar; and with the nitrous acid, nitre.

It attracts water from the air, and thereby becomes liquid.

2. FIXED FOSSIL ALCALI,

Called alſo natron, and ſal ſodæ. It is obtained from ſea-plants, in the ſame manner as the other is from land ones. It may alſo be extracted from common ſalt, Glauber's ſalt, and borax; and in ſome parts is found in its natural ſtate. Kelp and barilla contain foſſil alcali.

It differs from the vegetable alcali in ſeveral reſpects: it does not liquify in the air; it forms different ſalts with acids: thus, with the vitriolic it forms, not vitriolated tartar, but Glauber's ſalt; with marine acid, it forms common or ſea ſalt; and with the nitrous, nitrum cubicum. It is not volatile.

3. VOLATILE ALCALI.

This is obtained, by diſtillation, from animal, and ſome vegetable ſubſtances, eſpecially when putrid; and likewiſe from ſal ammoniac, by the addition of fixed alcali, or calcareous earth. Volatile ſal ammoniac, and ſalt of hartſhorn, are volatile alcalis; ſpirit of hartſhorn, ſpirit of ſal ammoniac, ſpirit of urine, &c. are volatile alcalis diſſolved in water.

It differs in ſeveral reſpects from the fixed alcalis; it is diſplaced by them from acids, and alſo by calcareous earth.

It is volatile, and has a very ſtrong pungent ſmell. With nitrous acid it forms a ſalt which detonates by itſelf in a ſufficient degree of heat, called nitrous ſal ammoniac.

With marine acid it forms common ſal ammoniac. It precipitates magneſia, earth of alum, and metallic calces, from acids.

It may be obtained from the water with which it is combined, in the form of a permanently elaſtic air; and if water be preſented to this air, it preſently abſorbs it, and thereby becomes the ſame cauſtic liquid alcali as that obtained from ſal ammoniac with quicklime.

REMARKS ON ALCALIS.

All theſe alcalis, in their natural ſtate, are not pure, but mild, or combined with fixed air. Hence, when they are mixed with acids, they cauſe an effervefcence, which is nothing more than this air extricated from them by the acid, raiſing bubbles as it eſcapes through the liquid. If quicklime be mixed with them, it attracts the fixed air, and they then become cauſtic or pure. Thus, the lixivium ſaponarium is the cauſtic fixed alcali; and the ſpirit of ſal ammoniac, made with lime, is the cauſtic volatile alcali. Cauſtic alcalis violently attract water. Hence they are uſually in a liquid ſtate; but they may be obtained ſeparate from the water. Thus, lapis infernalis is the dry cauſtic fixed alcali; and alcaline air is the dry cauſtic volatile alcali. The cauſtic alcalis form the ſame neutral ſalts with acids as the mild ones; the air eſcaping when the latter are employed.

Volatile alcali contains more of the inflammable principle than the fixed. Hence it is, that it detonates with nitrous acid, when united in the form of nitrous ſal ammoniac.

III.

NEUTRAL SALTS.

They are formed by combining acids with alcalis or earths, as in the following Table:

ACIDS.

	Vitriolic Acid.	Nitrous Acid.	Marine Acid.	Vinegar.	Cream of Tartar.
Fixed Vegetable Alcali.	Tart. Vitriol	Nitre.	Sal Digeſtiv.	Sal Diuretic.	Tart. Solub.
Foſſil Alcali.	Sal Glaub.	Nitr. Cubic.	Sal Comm.		Sal Saignet.
Volatile Alcali.	Sal Amm. Vitriolic.	Sal Ammon. Nitros.	Sal Amm. Commun.	Sp. Minder.	
Calcareous Earth.	Selenitis.	Nitr. Calcar.	Liquidſhell.		
Magneſia.	Sal Cath. Amar.				
Argillaceous Earth.	Alum.				
Calx of Iron.	Green Vitr.				
Calx of Copper.	Blue Vitriol			Cryſ. Ven.	
Calx of Zinc.	White Vitr.				
Calx of Lead.				Sacc. Saturn.	
Calx of Mercury.			Merc. Corr. Sublim.	Keyſer's Mercury.	
Regulus of Antimony.					Tart. Emet.

Any neutral ſalt in the table is formed of the acid at the top of the column, and of the alcali or earth on the left hand. Thus, marine acid

 and

and foſſil alcali, form common ſalt; nitrous acid and fixed vegetable alcali, nitre; and ſo of others.

The alcali, or earth of a ſalt, is called its *baſis*: thus, volatile alcali is the baſis of ſal ammoniac; and magneſia is the baſis of Epſom ſalt.

The phoſphoric, and other acids, alſo form ſalts with alcalis and earths; but, as they are not in uſe, I have not inſerted them. Many of the ſpaces in the table are left vacant for the ſame reaſon; and ſome of thoſe that are ſet down might have been omitted.

Neutral ſalts are uſually divided into neutral, earthy, and metallic, according to their baſes.

From moſt of the two latter kinds the acids may be expelled by heat. But in thoſe with alcaline baſes this does not happen, or not ſo eaſily, becauſe their principles are held together by ſtronger attractions.

The ſalts with volatile alcaline baſes are volatile; at leaſt much more ſo than the others.

Neutral ſalts are for the moſt part capable of being cryſtallized; but the form of the cryſtals in each ſalt is different. In their cryſtalline ſtate they contain a portion of water, which indeed is neceſſary to their cryſtallization. Hence they are ſtronger when this water is evaporated, and they are alſo more difficult of fuſion.

1.

VITRIOLATED TARTAR.

It is composed of vitriolic acid and fixed vegetable alcali, remains dry in the air, and requires a great quantity of water to dissolve it. It decrepitates in the fire; is very difficult of fusion; is not soluble in spirit of wine; and its crystals are, for the most part, hexagonal prisms. Its taste is bitterish, and not very powerful. It cannot be decomposed by alcalis, nor, in the usual way, by acids. Fused with charcoal, it forms sulphur.

2.

GLAUBER'S SALT.

It is a compound of vitriolic acid and fossil alcali. It dries into a white powder in the air; is soluble in an equal weight of water, and is easily fusible. Its taste is somewhat like common salt, but more bitter, and its crystals are hexagonal. It is not capable of being decomposed by alcalis, or by acids in the usual way. It yields sulphur, being fused with charcoal.

3.

NITRE.

It is composed of nitrous acid, and fixed vegetable alcali. It deflagrates with inflammable matter in a sufficient degree of heat; is capable of being decomposed by vitriolic acid, when it emits red fumes; is easily fusible; has a sharp biting taste, and its crystals are hexagonal prisms.

4.

CUBIC NITRE.

It differs from common nitre chiefly in the figure of its cryſtals, which are quadrangular, or rhomboidal.

5.

COMMON SALT,

Is compoſed of marine acid, and foſſil alcali. It is capable of being decompoſed by vitriolic acid, when it emits white fumes. The nitrous acid likewiſe decompoſes it. It is ſoluble in about an equal quantity of water, which diſſolves as much of it when cold as by the aſſiſtance of heat. Its cryſtals are cubic, and very ſmall. It decrepitates in the fire, and is difficult of fuſion. Its taſte is well known. If pure it remains dry in the air.

6.

SAL DIGESTIVUS,

Differs but little from common ſalt. Its taſte is leſs agreeable; and with vitriolic acid, it forms vitriolated tartar; whereas common ſalt forms with the ſame acid, ſal Glauberi.

7.

SAL DIURETICUS.

It is compoſed of the acetous acid and fixed vegetable alcali.

It is ſoluble in ſpirit of wine, and very eaſily ſo in water. It may be decompoſed by heat, and by the vitriolic, nitrous, and marine acids, with

with which it forms tart. vitr. nitre, and digeſtive ſalt. It deliquiates in the air, and unites with gums and reſins.

8.

ROCHEL SALT,

Is compoſed of foſſil alcali, and cream of tartar. It is not deliquiſent like the preceding ſalt. It may be decompoſed by the mineral, and even vegetable acids; and if they are added to this ſalt, diſſolved in water, the cream of tartar will be precipitated.

9.

SOLUBLE TARTAR.

It is a compound of cream of tartar and fixed vegetable alcali. Beſides its being leſs ſubject to cryſtallize, and to remain dry in the air, it may be known from Rochel ſalt, by the ſalts which it forms with vitriolic and other acids. Thus the vitriolic acid forms vitriolated tartar with this ſalt, and ſal Glauberi with the Rochel.

10.

VITRIOLIC SAL AMMONIAC,

Is compoſed of vitriolic acid, and volatile alcali. It is decompoſed by fixed alcalis, and calcareous earths, which preſently diſcover its volatile alcaline baſis.

It is difficultly ſoluble in water, and not at all in ſpirit of wine.

11. NITROUS

11.

NITROUS SAL AMMONIAC.

It is a compound of nitrous acid and volatile alcali. It attracts water from the air; is soluble in spirit of wine, and may be decomposed by fixed alcalis and calcareous earth.

It may also be decomposed by vitriolic acid, when it emits red fumes.

It is easily fusible, and deflagrates in a sufficient heat, without any addition of inflammable matter.

12.

COMMON SAL AMMONIAC,

Is a compound of marine acid, and volatile alcali. Its basis may be detected by fixed alcalis, or calcareous earth, and its acid by oil of vitriol, in the form of white fumes.

It differs also from the vitriolic sal ammoniac in being soluble in spirit of wine.

Dissolved with common salt in water, it produces cold. It is volatile.

13.

VEGETABLE SAL AMMONIAC.

It is formed of volatile alcali, and vegetable acid. Thus spiritus Mindereri is this salt in a liquid form. But it may be obtained dry by proper methods.

Its alcali may be detected by fixed alcalis, and

calcareous

calcareous earths; and its acid by either of the mineral acids.

It eaſily deliquiates, and is copiouſly ſoluble in water, and in ſpirit of wine.

14.

SELENITE,

It is compoſed of vitriolic acid and calcareous earth, and is alſo called gypſum, and plaiſter of paris.

It is difficultly ſoluble in water, and requires a very large quantity for that purpoſe.

Its earthy baſis is precipitated by alcalis. But acids do not decompoſe it. Its acid, however, may be diſcovered by examining the ſalt formed by the added fixed alcali, which will be vitriolated tartar, or Glauber's ſalt, according as the vegetable, or mineral alcali is uſed.

15.

SAL CATHARTICUS AMARUS,

Is a compound of vitriolic acid, and magneſia. It is readily ſoluble in water, and in great quantity. But it is not fuſible.

Its baſis may be precipitated by volatile alcali, as well as by fixed.

Its acid may be detected by the vitriolated tartar which it forms with fixed alcali.

16.

ALUM.

It is formed of vitriolic acid, and argillaceous earth. It is eafily fufible, and diffolves in about four times its weight of water. It has an aftringent tafte, and its cryftals are eight-fided pyramids.

Its bafis may be precipitated by fixed or volatile alcali; and its acid may be known by the vitriolated tartar which it forms with fixed vegetable alcali.

17.

GREEN VITRIOL.

It is compofed of vitriolic acid and calx of iron; and is alfo called *falt of fteel*, and copperas.

Its cryftals are green, tranfparent, and rhomboidal. Its acid may be detected by the falt formed by the addition of fixed vegetable alcali, and the bafis precipitated thereby, may alfo be examined and difcovered. See earths.

18.

BLUE VITRIOL,

Is compofed of vitriolic acid, and calx of copper. Its cryftals are blue, and their tafte very acrid and ungrateful.

Its principles may be difcovered by the means directed in the laft article.

19.

WHITE VITRIOL.

It is a compound of vitriolic acid and calx of zinc. Its cryſtals are white and ſmall, reſembling ſugar in appearance. Their taſte aſtringent and ſweetiſh. Its principles may be detected as in green vitriol.

20.

SUGAR OF LEAD.

It is compoſed of acetous acid, and calx of lead.

It is eaſily ſoluble in water; of a ſweet aſtringent taſte; and its cryſtals are ſmall and white.

It may be decompoſed by either of the alcaline ſalts. Its acid forms diuretic ſalt with fixed vegetable alcali, and its precipitated baſis may be detected by referring to the chapter on earths.

21.

MERCURIUS CORROSIVUS SUBLIMATUS.

It is a compound of marine acid, and calx of mercury; it is ſoluble in ſpirit of wine; its taſte is nauſeous and braſſy, and it is volatile. Its cryſtals are ſmall and white.

Its principles may be detected by adding alcaline ſalt; examining the precipitated earth, and the neutral ſalt produced, as directed in the four preceding articles.

It

It would be tedious, and unneceſſary to the deſign of this work, to go through the whole number of neutral ſalts capable of being formed by acids, alcalis, and earths. Every ſolution of a metal or earth in an acid may be conſidered in this view; being only the ſalt formed by the acid and its baſis, diſſolved in water; and the number of acids and baſes is very great. Thoſe ſalts which have been conſidered, are ſufficient to give the reader an idea of neutral ſalts in general; and, together with what will be ſaid in the following chapters, will enable him to underſtand the nature, as well as to diſcover the compoſition, of others.

CHAPTER IV.

OF AIR.

AS the doctrine of air conſtitutes one of the moſt important branches of medical philoſophy, it will be neceſſary to enlarge on it.

Air is a fluid ſurrounding the globe of the earth to a very conſiderable height, forming what is called the *atmoſphere.*

In its uſual ſtate it does not diſcover itſelf to any of our ſenſes; and hence, with the vulgar, *air* and *nothing*, are ſynonimous. When it is in motion, it is perceptible to the feeling and hearing; and alſo (by its effects in moving light and flexible bodies) to the ſight, under the notion of *wind.*

If a bladder be filled with air, it may be rendered very obvious to the touch. For the hand will find it impoſſible to compreſs the bladder, as when in its empty ſtate. Alſo if you attempt to fill a veſſel with water, or any other ſubſtance, you will find it impracticable, unleſs at the ſame time you let out a proportionable quantity of air; as may be obſerved to great advantage in veſſels with narrow necks. Theſe are not only proofs of the *exiſtence* of air, but alſo of its *impenetrability*; or property, in common with water, and other bodies, of not ſuffering any other ſubſtance to poſſeſs the ſpace which it occupies, otherwiſe than by removing it from that ſpace.

If a bladder filled with air be weighed with a very nice pair of ſcales, and if it be weighed again after the air is forced out of it, it will be found lighter than before; and if the bladder be very large, the difference of weight will be ſeveral grains. From hence it appears, that air is alſo *heavy*; the only difference between water and it, in this reſpect is, that water is heavier than air; in the ſame manner that quickſilver is heavier than water.

If an almoſt empty bladder, carefully cloſed, be put into the receiver of an air-pump, and then the *air* be gradually withdrawn from the receiver, the bladder will begin to ſwell, and at length

length appear full blown. But if the air be again gradually let into the receiver, the bladder will lose its bulk by degrees till it appears empty as before.

From hence it appears, that the same quantity of air is capable of expanding itself into a greater bulk than that under which it usually exists. To understand the reason of this, it is to be observed, that the air naturally contained in the receiver pressed upon the bladder on every side, and thereby compressed it into its seemingly almost empty state. When part of the air in the receiver was pumped out, the compression of the bladder became less than before; and therefore the air within it was suffered to expand itself, and thereby swell the bladder. As more air was drawn out, and the pressure upon the bladder became less, the included air had still greater liberty to expand, till at last the bladder was perfectly distended. When the air was again let into the receiver, and the compression of the bladder began to be increased, the included air was forced into lesser bulk. As more air was let in, and the pressure became greater, the included air was forced into still less dimensions, till at length the bladder appeared as empty as before.

Air, therefore, naturally expands; and it is kept in its usual bulk or dimensions by the pressure of other air incumbent on it; and in

this

this view its elaſticity is alſo called *its ſpring*. A ſteel ſpring, for example, if bent by means of four pound weights, continues bent to the ſame degree as long as the weights remain on it. If one of thoſe weights be removed, the ſpring in part recovers itſelf, or becomes leſs bent. If another of the weights be removed, it recovers itſelf more; if a third weight be removed, it recovers itſelf ſtill further; and if the fourth be alſo removed, the ſpring will be quite unbent, or in its natural ſtate. But if the weights be afterwards added in the order that they were taken away, it will again be bent by the ſame degrees, till it returns to the ſtate it was in before; and will continue in that bent ſtate as long as the weights remain on it.

The air around us therefore is in a compreſſed ſtate, or forced into leſs ſpace than it would occupy if it was free. The cauſe of this compreſſion will be ſeen when we treat of the weight of the air. The fact alone is ſufficient for our preſent purpoſe.

Over the mouth of a baſon, or other proper veſſel, tie a piece of bladder or thin parchment, ſo that no air may paſs either to or from the veſſel; and let it be ſufficiently tight, yet ſo as that it may be bent. If you place a weight on this cover, you will find that it will be preſſed down into an hollow, or below the level of the brim of the veſſel; and if you add more weights, this will happen in a ſtill greater degree. But if the weights be removed, the cover will return to a level with the veſſel's brim, as at firſt.

From hence it appears, that air is capable of being compreſſed into leſſer dimenſion or ſpace than that which it uſually poſſeſſes; and that it returns to its wonted bulk, when the compreſſing cauſe is removed. Thus, if to the four weights, already compreſſing the ſpring in the laſt caſe, a fifth ſhould be added, the ſpring will be bent ſtill further than it was before; and if a ſixth be added, this will take place in a yet greater degree; but if the two additional weights be removed, the ſpring will return to the ſame ſtate as before they were added.

Air therefore when compreſſed endeavours, like a ſpring, to recover itſelf; and that endeavour is ſtronger, as the compreſſing force is greater. If a tube be ſtopt at both ends with wads of paper, and one of theſe be forced into the tube by a rammer, the air between the wads will be compreſſed; and in its endeavour to recover itſelf, will force out the paper at the farther end. So if a blown bladder be violently compreſſed, the air contained in it, by endeavouring to recover its former dimenſions, will burſt the bladder; and many other inſtances of the kind will occur. Thus the phænomena of the air-gun depends on this property of the air.

Squeeze almoſt all the air out of a bladder, and cloſe its neck with a ſtring; if the bladder be brought near the fire, it will ſwell; and, if the heat be ſufficient, will be puffed up like a bladder full blown. Remove the bladder to a cold place, it will continually contract in its bulk, till it appears as empty as before.

Alſo fill a bladder with air in a warm room, or in the ſummer, and remove it to a colder room, or keep it till winter, you will find that it is contracted in its dimenſions. Reſtore the bladder to the warm room, or keep it till ſummer, it will appear as bloated as before.

From hence it appears, that the ſame quantity of air is capable of being expanded, or increaſed in bulk by heat, and contracted, or leſſened in bulk by cold; or in other words, that its elaſticity or ſpring is increaſed by heat, and weakened by cold. It will be ſhewn hereafter, that the elaſticity of the air probably depends entirely on heat.

Having premiſed theſe properties of air, we may proceed to explain the general conſtruction of the atmoſphere.

Air is a fluid, reaching from the ſurface to many miles above the earth, and encompaſſing the whole globe, as hath been amply demonſtrated by philoſophers.

The upper part of this air is expanded into its utmoſt or natural bulk. The air next under this, is preſſed upon by the weight of that above it; and therefore is forced into leſſer dimenſions than it would have if not thus preſſed upon. The air next under theſe will be ſtill more preſſed, by reaſon of the weight of both the above-mentioned quantities of air on it, and therefore will be forced into a bulk ſtill leſs than that which is next above it; and in like manner we may imagine of the air beneath this; and ſo on continually, till we arrive at that which reſts upon the ſurface of the earth, which will be moſt compreſſed of all.

To obtain a clearer idea of this matter, take a quantity of wool, and place one lock or fleece of it upon the ground, that fleece will be of its natural bulk. If upon this fleece you lay another, the upper one will be of its natural bulk; but the under one will be compreſſed into leſſer dimenſions, by the weight of that which is upon it. If a third fleece be added, the under one will be compreſſed ſtill more, and the ſecond will be in the ſame ſtate as that was juſt before. By adding continually to the pile, the under-

moſt

moſt fleeces will be ſtill more preſſed upon by the increaſed weight of thoſe above, and therefore be forced into ſtill leſs dimenſions; and thoſe which are neareſt to the bottom, will of courſe ſuffer the greateſt compreſſion.

If now you remove theſe fleeces one by one, thoſe which ſucceſſively become uppermoſt will recover their natural bulk, and the preſſure upon the under ones will alſo become leſs in proportion. When they are all removed, that which was undermoſt will alſo recover its natural dimenſion, or return to the ſame ſtate as before the experiment.

The air above preſſes on that which is beneath, in like manner as hath been ſhewn with regard to the fleeces of wool. The uppermoſt air is expanded into its natural bulk, and that beneath is continually more and more compreſſed by the weight of that which is above, till we arrive at the earth's ſurface, where the compreſſion is greateſt of all.

From hence it appears, that if a bladder be filled with the air at the top of the atmoſphere, and brought down from thence towards the earth, it will, on account of the continual increaſe of compreſſion, be forced into leſs and leſs dimenſions; and the bladder will therefore appear to become more and more empty.

Alſo if a bladder almoſt empty of air, ſuch as it is at the bottom of the atmoſphere, be carried upwards, it will ſwell in proportion to the aſcent, becauſe a leſs weight is incumbent on it than before. You may prove both theſe caſes by carrying a bladder not full blown, from the bottom to the top of an high mountain, for it will be larger when you arrive at the top; and on the contrary, if you fill the bladder at the top of the mountain, it will appear to be partly empty when you deſcend to the bottom. Thus the bottom fleece of wool, if removed higher to the top, will enlarge its dimenſions; but if one of the middle fleeces be placed at the bottom, its dimenſions will become leſs.

If you weigh a bladder partly emptied of air, and then by means of heat, or the air-pump cauſe the air in it to ſwell or expand, it will not weigh heavier than it did before: for the quantity of air which the bladder contained, was the ſame when it appeared full as when it ſeemed partly empty. Thus, a fleece of wool in its natural ſtate does not weigh heavier than when ſqueezed or twiſted up into an hard ball, the quantity of wool being the ſame in both caſes.

From hence alſo it is plain, that if a bladder be filled with air as it is in its expanded ſtate at the top of the atmoſphere, it will not weigh ſo heavy

heavy as if filled with air at the bottom, becaufe in the latter cafe a greater quantity of air is contained in the fame bulk. Thus the fame bladder filled with wool put in lightly, will weigh lighter than if filled with wool in a compreffed ftate. Alfo if the bladder be filled with air, any where in the middle of the atmofphere, it will weigh heavier than if filled at the top, and lighter than if filled at the bottom; for reafons which will be obvious from what has been faid.

When the fame quantity of air is expanded into a greater bulk, it is faid to be *rare*, *rarefied*, *expanded*, or to have *a lefs fpecific* gravity. When compreffed into leffer dimenfions, it is faid to be *denfe*, *condenfed*, or to have *a greater fpecific gravity*, agreeable to what was faid on thefe points in the definitions.

From this general account of the ftructure of the atmofphere we may be enabled to reafon concerning its preffure.

I fhewed before that the air is *heavy*; and the compreffed ftate of the air near the earth has alfo been fhewn to be an effect of this property. Imagine a fquare to be drawn on the ground which meafures every way a foot, and fuppofe a column of air of the fame dimenfion with this fquare, reaching from the ground to the top of the atmofphere, it is demonftrated by philofophers that it would weigh

2000 pounds. The whole ſurface of the earth contains 5547800000000000 of ſuch ſquare feet, and therefore the preſſure or weight of the whole atmoſphere on the earth's ſurface is 11095600000000000000 pounds. The ſurface of the human body contains about 14 ſquare feet, the air therefore preſſes on it with a weight equal to 28000 pounds; and in like manner it preſſes on other bodies, according to the quantity of their ſurface. This preſſure however is not uſually ſenſible, becauſe the air contained in bodies, and compreſſed by that weight, equally reſiſts it by its elaſtic force. Thus, a ſteel ſpring bent with a four pound weight reſiſts any farther flexion by that weight. But if the ſpring ſhould happen to be weakened, the weight would then bend it more; if it ſhould be ſtrengthened, its flexion would on the contrary be leſs. In like manner, if the reſiſtance of the air contained in bodies, becomes either greater or leſs than the preſſure of the atmoſphere on them, the ſuperior or inferior force of that preſſure would then become manifeſt. We muſt however except thoſe bodies which are of ſo firm or rigid a texture as not to be influenced by theſe circumſtances. Thus air may be very much rarefied or condenſed in cloſe metallic or other veſſels; and theſe veſſels will not manifeſt any ſigns either of contraction or expanſion: tho' even theſe will be burſt by air, when ſufficiently condenſed in them.

In the veſſel covered with bladder, before deſcribed, we find that the internal and external air preſs equally againſt the bladder, and therefore its ſurface remains level with the brim of the veſſel. If the bottom of the veſſel be warmed, ſo as to heat the included air, and thereby increaſe its elaſticity, the bladder is driven upwards; which argues that the reſiſtance of the included air is become greater than the preſſure of the external.

On the contrary, if we place the veſſel in a mixture of ſalt and ſnow, ſo that the internal air may be cooled, and its ſpring weakened, the bladder will be driven downwards, a proof that the preſſure of the external is become greater than the reſiſtance of the internal air.

If this veſſel be put under an air-pump, and, by means of a hole properly contrived, the air which it contains be drawn out, there is ſaid to be a *vacuum* made in it, by reaſon that it is empty of all ſenſible matter. The reſiſtance within the veſſel, to the external air, is therefore entirely deſtroyed, and the preſſure of the latter will be ſeen to be ſo powerful, that it will break the bladder and ruſh into the veſſel with a great noiſe, in order to fill up the vacuum.

If part of the air be ſucked out from a vial, the reſiſtance of the internal air will be leſs than the

the preſſure of the external; or to ſpeak in the language of philoſophy, a partial, or imperfect vacuum will be made in it. The lip therefore will be preſſed into the vial by the external air, nor can they be ſeparated without ſome force, and then the air ruſhes in to fill up the vacuum.

If the piſton of a ſyringe be withdrawn, a partial vacuum will be made; and the air will ruſh in at the orifice of the pipe as faſt as poſſible, to reſtore the equilibrium; or if the pipe be placed in water, the preſſure of the air on the ſurface of that liquid will drive the water into the ſyringe.

But the preſſure of the air is in no inſtance more conſpicuous than in the barometer. If a ſlender glaſs tube, a yard in length, be filled with quickſilver, then turned upſide down, with the open end in a baſon of that metal, the quickſilver will run out of the tube into the baſon, till it has ſunk about five or ſix inches, but after that it ceaſes to flow. For it is ſupported at the height of about thirty inches by the preſſure of the air; and this is the method by which we know the exact weight of a column of air, reaching from the bottom to the top of the atmoſphere; for the quickſilver is ſupported in the tube, by the reſiſtance or preſſure of a column of air, equal in diameter to that of the quickſilver, and reaching from the mouth of the tube (or, which is the

ſame

ſame thing in effect, the ſurface of the mercury in the baſon) to the upper part of the atmoſphere, and therefore the weight of ſuch a column of air is exactly equal to the weight of the quickſilver in the tube, above the ſurface of that in the baſon, they preciſely balancing each other; and if the tube be a ſquare foot in width, the weight of the mercury, and in courſe that of the air, will be at leaſt two thouſand pounds, as mentioned before.

But the atmoſphere is not always of the ſame height in the ſame place; or, in other words, a column of air of the ſame diameter, does not always weigh exactly the ſame. For the atmoſphere, like the ſea, is ſubject to fluxes and perturbations, which will therefore cauſe it to be higher, and heavier at ſome parts of the earth than at others; and, at different times, in the ſame place. Thus, ſometimes the quickſilver is ſupported at the height of about thirty inches, at other times only at twenty-eight, and at others ſomewhere between theſe; and the uſe of the barometer is to ſhew, by the height of the quickſilver, the weight of the air. But another uſe of the barometer is, to ſhew the ſtate of the weather with reſpect to rain. When the air is heavier, it is alſo denſer in courſe; and therefore the clouds will be borne up higher, and prevented from falling; hence the weather is at thoſe times fair. But, when the atmoſphere is lighter, the clouds are ſuffered to deſcend to the earth, and then we have rain, ſnow, &c.

It may be proper to obſerve, that the air does not preſs directly downwards only, but every way alike. Thus, if a vacuum be made in a veſſel, and its mouth be held downwards, the air will preſs on, and ruſh into it as well as if its mouth were upwards. For every part of the air at the bottom being preſſed by that above, wherever there is a vacuity, the air around, in conſequence of the preſſure, will ruſh thither, and thereby reſtore the equilibrium.

The atmoſphere is always moiſt in a greater or leſs degree, from the quantity of aqueous vapour which it contains. Thus, if you expoſe ſalt of tartar to the air, it will in a little time attract ſo much water from it, as to make it liquid; and it will be diſſolved in greater or leſs time, according as the air happens to be more or leſs moiſt. The hygrometer, or inſtrument for meaſuring the moiſture of the air, is conſtructed on this principle. An oat beard, when the air is dry, is twiſted up, and therefore ſhorter; but when the air is moiſt, it is relaxed, or untwiſted, becauſe of its attracting that moiſture; and the length which it acquires in conſequence thereof, indicates the degree of the moiſture of the air. Several other methods have likewiſe been deviſed for meaſuring the moiſture of the air.

The air has alſo a power of diſſolving bodies in the manner of a menſtruum, according to the preſent philoſophy. If a ſalt of any kind be put into water, the water will diſſolve it; and the ſolution will be haſtened by agitation and heat. In like manner, if water be expoſed to air, the air diſſolves it, and if the air be hot, and the water agitated by wind, or any other cauſe, the ſolution takes place the ſooner. Water when hot will diſſolve a greater quantity of a ſalt than it can retain when cold; and hence it cryſtallizes. In like manner air, in a hot ſummer's day, diſſolves a large quantity of water, which it depoſits in the night, or when cold, in the form of dew. Vegetable, animal, and moſt other ſubſtances, are likewiſe capable of being diſſolved by air. Thus, the fleſh of a dead animal, expoſed to the air, will, in time, entirely diſappear *.

For theſe reaſons, and alſo on account of the ſteams and exhalations which are continually riſing

* Some philoſophers deny this ſolvent power of the air. But I have found that, by ſhaking air with water, ſo that part of the water may be mixed with the air, *cold* is produced; which, as will be ſeen in a future chapter, is a ſign of the air having *diſſolved* part of the water: for the caſe is the ſame when ſalts diſſolve in water. I tried the ſame with ſpirit of wine; and cold was produced in the air, though leſs than when water was employed. Moiſt air is likewiſe rarer than dry, which is another ſign of the *ſolution* of the water in the air. Water, however, is alſo diffuſed through air without a proper ſolution of it. Some chemical ſolutions cauſe heat: ſo does that of phlogiſton in air. Theſe facts ſhew that ſolutions in air, are perfectly analogous to chemical ſolutions in liquids.

rifing into the atmofphere, from the bowels of the earth, it is plain that air, any more than water or earth, cannot be obtained pure; and it is alfo evident, that on account of the various natures of thefe exhalations, and of the winds which bring them from different parts, the air will be adulterated in a different manner, not only at different parts of the earth, according to the nature of the foil, but likewife, at different times, in the fame part.

When air is rarefied in any particular part of the atmofphere, by heat, or otherwife, the air around will flow towards that part, to reftore the equilibrium; and this motion or flux of the air we call wind.

The effects of air, in its different ftates, on the body, will be confidered in a future and more proper place.

CHAPTER

CHAPTER V.

OF THE DIFFERENT KINDS OF AIR.

TILL within theſe few years paſt, philoſophers had no idea of any more than one kind of air. They conſidered it as an element; and whatever differences they found in air, in different circumſtances, they imputed entirely to the admixture of foreign matters, from which the air was capable of being obtained in the ſame pure ſtate as before. They reaſoned about air then in the ſame manner as we do now concerning water. The induſtry of philoſophers, however, has ſet us right in theſe matters.

I.

OF COMMON AIR.

There are certain proceſſes in chemiſtry, which the later writers on that art term *phlogiſtic*. Thus, *combuſtion*, or the burning of bodies, is a phlogiſtic proceſs; ſo likewiſe are reſpiration, and ſome others. The theory of theſe proceſſes will be explained more at large in a future chapter. The effect only, will be ſufficient to illuſtrate the ſubject in hand.

If a candle be burnt, or an animal breathes, in a given quantity of air, it is well known that the one will ſoon be extinguiſhed, and the other die.

die. Thefe effects will happen fooner, according as the quantity of air is lefs. The facts may eafily be proved, by putting the candle, and the animal, in glafs veffels, of proper fizes, filled with common air.

The effect which thefe proceffes have on air, is to diminifh it in bulk. If we fix a lighted candle into an inverted glafs receiver, and immediately place its mouth in water, we find, that when the candle is extinguifhed, and the air in the receiver cool, the water will rife up into the neck of the veffel, higher than it did at the beginning of the procefs, and therefore the air is diminifhed.

If an animal be put into the veffel, and fuffered to remain there till it expires, the air will be ftill further diminifhed, than by the burning candle. But when the diminution of air, by thefe proceffes has proceeded to a certain degree, it cannot be carried any farther.

The caufe of this diminution is *phlogifton*; which is imparted to the air by the candle, and the animal, in thofe proceffes. The air attracts the phlogifton by means of a fuperior affinity, as will hereafter be fhewn; and on this principle combuftion, &c. depend. When air becomes faturated with phlogifton, it is incapable of imbibing more. It can therefore be no farther diminifhed;

diminiſhed; and is no longer fit for ſupporting animal life, or for other phlogiſtic proceſſes.

From hence it appears, that with reſpect to reſpiration, &c. air may be conſidered as better, or more pure, in proportion as it is freer from phlogiſton. We ſhall conſider this ſubject again, under the article of *dephlogiſticated air*.

2.

OF PHLOGISTICATED AIR.

Air which has been injured by reſpiration, combuſtion, &c. in the manner already deſcribed, is thus called. If air be fully ſaturated with phlogiſton by thoſe proceſſes, it is ſaid to be completely *noxious*. A candle is inſtantly extinguiſhed, and animals preſently die in this air. But we ſhall have occaſion to ſpeak of it further in the following article.

3.

OF DEPHLOGISTICATED AIR.

It has long been known that nitre is capable of maintaining the combuſtion of inflammable bodies, as well as air.

If lighted charcoal be placed in proper expoſure to air, it will continue to burn till the whole is reduced to aſhes.

If nitre be mixed with charcoal, and the powder, already kindled, be put into a cloſe veſſel, the combuſtion will be as complete as if the charcoal had been expoſed to the open air: though without the aſſiſtance of the nitre, the charcoal would preſently have been extinguiſhed in that confined ſituation. Nitre, therefore, has the ſame effect in this proceſs as air.

The reaſon of this was not known till lately. But Dr. Prieſtley has found that by means of heat, air may be expelled from nitre, of the ſame nature with that of the atmoſphere, but much more pure. A candle will burn, and animals live in it, four or five times as long: and therefore it is freer from phlogiſton than common air.

When nitre is burnt with a combuſtible body, a quantity of air is ſet at liberty, and reſumes its elaſtic or expanſive ſtate. This is the dephlogiſticated air above ſpoken of, combined with the phlogiſton of the inflammable ſubſtance. The exploſions of gunpowder, and other nitrous mixtures, depend on this air.

Nitre is not the only ſubſtance from which dephlogiſticated air may be extracted. It may be obtained from many other bodies, merely by heat. But different ſubſtances yield it in different proportions; and it is alſo more pure, when obtained from ſome bodies than from others.

After minium has yielded as much of this air as it will by heat, if ſpirit of nitre be added, a freſh quantity may be procured. If more ſpirit of nitre be added to the remaining calx, there will be a ſtill further yield; and the operation may be continued, with the like reſult, as long as any of the minium remains. And there is no earthy ſubſtance from which this kind of air may not be obtained by a like treatment.

But the vitriolic acid anſwers this purpoſe as well as the nitrous; and from every earthy ſubſtance on which that acid can act, dephlogiſticated air may be obtained.

As this air is ſo much purer than common air, there is reaſon to hope that great benefit will accrue to mankind by the medicinal uſe of it, in diſorders where the phlogiſtic principle abounds in the conſtitution, by breathing it inſtead of common air. It has already been preſcribed in thoſe caſes, with good effect. In combuſtion alſo, it may be employed to advantage. If a fire be blown with this air, the heat is prodigiouſly more intenſe than when common air is employed.

It appears by ſome late diſcoveries, that the common air of the atmoſphere is compoſed of dephlogiſticated and phlogiſticated airs mixed together, the latter being in by far the greateſt proportion. When phlogiſton is added to air, it is combined only with the dephlogiſticated part, which it converts either into fixed air, or water, according to circumſtances. And as both fixed air, and water, are denſer than the air of the atmoſphere, hence the dimininution of air by phlogiſtication. Common air therefore, in reſpect to purity, may be conſidered as in a mean between phlogiſticated, and dephlogiſticated airs.

As the atmoſphere is conſtantly expoſed to animal reſpiration, combuſtion, putrefaction, and a variety of other phlogiſtic proceſſes, it muſt be continually receiving injury; and therefore if there were no contrivance in nature for purifying it, it would long before now have been rendered unfit for theſe proceſſes. Animals could not live, nor could fires exiſt in it. But Dr. Prieſtley has diſcovered, that air thus rendered noxious, is purified by vegetables growing in it. And by proſecuting that diſcovery, he has found that they perform that ſalutary effect by means of the *ſun's light.* If a plant grows in the ſhade, it rather injures the air; but if it be placed in the light of the ſun, it purifies the air in a ſurpriſing degree, mending it out of all proportion beyond the injury it does to it in the ſhade *.

Animals and vegetables therefore counteract each other's effects in this particular; and hence is diſcovered

* See alſo Dr. Ingenhouſz's treatiſe on this curious ſubject.

discovered to us an use of the vegetable creation, which mere reason could never have led us to suspect.

4.

OF NITROUS AIR.

If spirit of nitre be added to iron, or any other phlogisticated substance which it can dissolve, there will fly off from it, during the solution, an elastic vapour; which being caught in proper vessels, is what is usually called *nitrous air*.

If this air be mixed with common air, a considerable degree of heat succeeds, together with a turbid redness, and *diminution of their bulk*. The latter circumstance has been happily applied by Dr. Priestley to a very useful and important purpose.

He found that the diminution was greater, in proportion to the purity of the common air employed; and hence has established a test of the goodness of air, or the degree in which it is proper for respiration, &c. Instruments are now used for this purpose, as thermometers are for discovering the temperature of bodies; they are called *eudiometers*.

If common air be diminished as far as it is capable of, or rendered perfectly noxious, nitrous air has no effect on it; neither does it diminish any other kind of air, but common air not completely phlogisticated.

Nitrous air conſiſts of nitrous acid, and phlogiſton. The air takes the latter ingredient from the acid, and thereby becomes diminiſhed, in the ſame manner as when it is phlogiſticated by the proceſſes of combuſtion and reſpiration; the manner of which has already been deſcribed. The turbid redneſs is owing to the nitrous acid, now ſeparated from the phlogiſton, and appearing in its uſual form of red fumes.

Nitrous air has alſo the property of preſerving ſubſtances kept in it from putrefaction; but it is totally unfit for reſpiration, animals preſently dying in it.

5.

OF INFLAMMABLE AIR.

If iron be diſſolved in the vitriolic or marine acids, an elaſtic vapour ariſes, which being mixed with common air, takes fire at the flame of a candle, and therefore is called *inflammable* air.

This kind of air may likewiſe be produced by putrefaction, and a variety of other methods; and is ſometimes found ready formed. Thus, when coal mines take fire, it is owing to a quantity of inflammable air exhaled from the mineral ſubſtances, and mixing with the common air in the mine. It is unfit for reſpiration, &c. and is

ſuppoſed

ſuppoſed by Mr. KIRWAN, to be phlogiſton in an elaſtic ſtate.

6.

OF ALCALINE AIR.

If heat be applied to the cauſtic ſpirit of ſal ammoniac, the volatile alcali will be expelled from the water with which it was combined, and fly off in the form of a permanently elaſtic vapour. This may be proved by the following elegant experiment.

Fix a ſlender glaſs tube properly bent, into a vial containing the ſpirit; then fill a large vial with quickſilver, which let an aſſiſtant hold inverted in a baſon of the ſame metal. Let the tube paſs through the mouth of this inverted vial; apply the flame of a candle to the vial containing the alcali, the vapour will paſs through the tube into the inverted vial, and be collected in its upper part; driving the quickſilver downwards, in proportion as it accumulates. The vapour, however, will not condenſe into a liquid, but remain in an elaſtic ſtate, like common air.

Quickſilver has no action on this air, which is the reaſon that it is employed in the experiment. But if water be introduced, the air is preſently abſorbed by it; and in conſequence

 thereof,

thereof, the quickſilver riſes in the vial, and nothing is to be ſeen but quickſilver and water. The water thus impregnated becomes *ſpirit of ſal ammoniac.*

By impregnating water with this ſpecies of air, a cauſtic liquid volatile alcali may be formed, as ſtrong as that diſtilled from ſal ammoniac with quicklime; ſo that the latter preparation is nothing but water impregnated with *alcaline air.*

Other particulars of this air may be collected from the following articles.

The *fixed alcali* cannot be expelled in a permanently elaſtic form.

7.

OF MARINE ACID AIR.

The acid of ſpirit of ſalt may be obtained ſeparate from the water, in the form of air, in the ſame manner as was ſhewn with regard to the volatile alcali, and by the ſame means. It is alſo as readily abſorbed by water.

But it is remarkable, that the marine acid, in the form of air, is much ſtronger than in its uſual ſtate of combination with water. For whereas before it was the weakeſt, it is now the ſtrongeſt of the three mineral acids; for it diſengages both

both the nitrous and vitriolic, from their refpective bafes.

Water fully impregnated with this air, forms likewife a fpirit of falt ftronger than that obtained by diftillation; and an aqua regia much more powerful than the common, may be made by a proper admixture of this air with fpirit of nitre.

If this air, and the alcaline air before defcribed, be mixed, an union is immediately formed between them; they lofe their elaftic, or airy form, and condenfe into white powder; which if collected, will fcarce occupy the thoufandth part of the fpace which the ingredients poffeffed before. This powder is common *fal ammoniac.*

8.

VITRIOLIC ACID AIR.

The volatile vitriolic acid may be feparated from the water with which it is combined, and exhibited in the form of air, like the marine acid, and volatile alcali. And water impregnated with this air appears to be the fame with the common aqua fulphurata.

9.

OF SULPHUREOUS AIR.

If an acid be added to liver of fulphur, a kind of air will arife, which may be called *fulphureous air.*

By

By impregnating water with this air, the ſulphureous waters may be imitated, in the ſame manner as the acidulous ones may by impregnating water with fixed air.

10.

OF FIXED AIR, OF AËRIAL ACID.

If lemon juice be added to ſalt of wormwood, it is well known that an efferveſcence happens, becauſe there is extricated from the ſalt a large quantity of air.

This air, before the addition of the acid, was combined with the alcali; that is, the particles of air were attracted by thoſe of the alcali ſo ſtrongly, that they ſtuck firmly together. In this caſe, therefore, the air appeared to have entirely loſt its elaſticity, and exiſted in a ſolid or *fixed* ſtate, whence it came to be called *fixed air*. The term, however, is equally applicable to the other kinds of air already ſpoken of, and for the ſame reaſons. But as this happened to be the firſt in which this property was diſcovered, the appellation was applied to it; and has been continued ever ſince. Experiments ſhew, that as much air was contained in the alcali in this fixed or coherent form, as would occupy a ſpace

ſome

ſome hundreds of times greater, when reſtored to its elaſticity.

The acid has the property of freeing this air from its combination with the alcali. For the alcali attracting it ſtill more powerfully than it does the air, unites therewith; letting go the latter ingredient, which then immediately reſumes its elaſtic or expanſive ſtate. In its eſcape through the liquid, it cauſeth the effervеſcence, or bubbling, in like manner as would be occaſioned by air blown through ſlender tubes, inſerted in the bottom of the veſſel.

This air may alſo be obtained by mixing any acid with any mild alcali, or abſorbent earth. And it may likewiſe be expelled from the laſt-mentioned ſubſtances by heat: thus, quicklime is chalk, or lime-ſtone, deprived of its fixed air.

A large quantity of this air is extricated from vinous liquids, and other ſubſtances, while in a ſtate of fermentation.

When vegetable and ſome other ſubſtances are diſtilled, a great quantity of fixed air is expelled merely by heat, with the water, and other volatile principles of thoſe bodies. This part of the product had not uſually been conſidered by chemiſts; whereas now, it appears to be an important principle of bodies.

Almoſt

Almoſt half the weight of marble, for example, is fixed air. The other ingredient is calcareous earth, or quicklime. By means of this air the particles of the earth are, by means of a little water, united into that firm ſubſtance; for when deprived of that principle, it crumbles into duſt.

When we firſt ſee hartſhorn diſtilled, we are aſtoniſhed at the quantity of liquid obtained from ſo dry a ſubſtance. It was partly by means of the fixed air that this water, with the other principles, were united into that firm body. Vegetable, and animal ſubſtances, deprived of this air, are more diſpoſed to putrify; their other principles becoming more eaſily diſſipable.

If fixed air be mixed with alcaline air, they form the mild volatile alcali. Without the fixed air, the volatile alcali cannot be obtained in a ſolid form.

Lime-water impregnated with this air, immediately becomes turbid; and a white powder precipitates. Hence it is uſed as a teſt to diſcover the preſence of this kind of air. The air uniting with the lime, renders it mild, and no longer ſoluble in the water.

Water imbibes this air; and thereby becomes artificial *Pyrmont water*. Water, thus impregnated,

nated, is capable of diſſolving iron, camphire, and ſome other ſubſtances, which it could not do before.

Fixed air has been ſucceſsfully applied to medical purpoſes, as an antiſeptic; and in ſome other intentions. For though it will not ſerve for reſpiration, it is not hurtful when taken into the ſyſtem; on the contrary, experience proves it to be very ſalutary.

Fixed air acts on alcalis as an acid of the weakeſt kind, and thence is juſtly called by the ingenious Mr. Bewly, and Profeſſor Bergman, an acid. Hence mild alcalis may be conſidered as a kind of neutral ſalts.

For many other curious particulars reſpecting the different kinds of air, the reader is referred to Dr. Prieſtley's juſtly admired publications on theſe ſubjects. To that philoſopher the world is indebted for almoſt the whole of what is known concerning them.

Theſe are the principal ſubſtances, yet known, capable of exiſting in a permanently elaſtic ſtate, in the common temperature of the atmoſphere. But it may be obſerved, that many other bodies are capable of being turned into air by a ſufficient heat. Thus, the bubbles of boiling water are water converted into an elaſtic fluid, which may

may therefore be called *aqueous air*. But this, when the heat ſufficiently abates, loſes its elaſtic ſtate, and returns into the form of water. The like may be obſerved of ſpirit of wine, oil, quickſilver, &c. In the Introduction, it was obſerved, that bodies may, for the moſt part, exiſt in three different ſtates; a ſolid, fluid, and an elaſtic one: but that bodies of various kinds require different degrees of heat for theſe purpoſes. Thus, an heat leſs than the loweſt degree that we can produce, is ſufficient for the formation of common air. Water requires a greater heat for that purpoſe than the uſual temperature of the atmoſphere; and earths cannot be made ſo by the moſt violent of our fires.

CHAPTER VI.

OF PHLOGISTON, AND ITS COMBINATIONS.

THIS principle has a very extenſive uſe in nature, and ſeems to be of the utmoſt importance. We cannot indeed obtain it in a ſeparate groſs or denſe form, like alcalis and earths *; but we can transfer it from one body to another, which is ſufficient for chemical purpoſes. Thus, if powdered charcoal be mixed with the calx of lead, and placed in a proper veſſel, over a fire ſufficiently ſtrong, the phlogiſton will quit the charcoal, to combine with the calx, by which it is more powerfully attracted; and which will thereby be formed into lead.

Thus again, phoſphorus is a combination of phlogiſton with the phoſphoric acid. But if the phoſphorus be expoſed to the air, its phlogiſton will leave the acid, and combine with the dephlogiſticated part of the air, by which it is more ſtrongly attracted.

The

* Inflammable air is thought to be either phlogiſton alone, or phlogiſton combined with water.

The fuſibility of bodies is promoted by their combination with this principle. Thus, minium is very difficult of fuſion; but lead melts with much leſs heat. It alſo cauſeth bodies to be more ductile or malleable than before.

I ſhall have occaſion to ſpeak of this principle in future; and at preſent ſhall only conſider thoſe bodies of which it forms a conſtituent part.

I.

OF METALS.

Metals are divided into perfect, imperfect, and ſemi-metals. The perfect metals are, gold, ſilver, and platina. They are ſo termed, becauſe they remain unaltered in the fire. The only effect that the heat of our furnaces has on them is, to render them fluid. When the heat is removed, they return to their ſolid ſtate, without having ſuffered any change either in their properties, or weight.

The imperfect metals are, copper, iron, lead, tin, and quickſilver *. They differ from the perfect metals in being calcinable by heat; or in being

* Quickſilver has lately been thought to be a perfect metal; the *mercurius calcinatus* being reduced by heat alone.

being changed thereby from metals, into mere calces or earths.

The ſemi-metals are zinc, regulus of antimony, nickel, &c.

In the calcination of metals, one of the ingredients, the *phlogiſton*, is taken from them by the air; in lieu of which, they uſually attract fixed air, or ſome other, from the atmoſphere; and hence the calx is found to be heavier than the metal before calcination.

Metals are alſo converted into calces by thoſe acids which are capable of diſſolving them. For their phlogiſton eſcapes, and only the calces remain with the acids.

The calces of metals are, like other earths, convertible into glaſs. But this is not the caſe with the metals themſelves. Metals are the moſt ponderous of all known bodies.

The phlogiſton of all metals is exactly the ſame; and therefore the difference in them is owing entirely to the nature of their calces: thoſe differences are ſufficient to diſtinguiſh the metals from each other. Thus, phlogiſton, united with the calx of

GOLD,

Forms a metal whoſe ſpecific gravity is nineteen times greater than that of water; and the only acid in which it can be diſſolved, is aqua regia. Its colour is yellow, and it is unalterable by the heat of our furnaces. With the calx of

PLATINA,

It compoſes a metal which reſembles gold in its ſpecific gravity, perfectneſs, and ſolubility in aqua regia: but differs from it in colour, and in being infuſible by the fires of our furnaces; whereas gold is fuſible. With the calx of

SILVER,

It forms a metal, which, like gold, is indeſtructible by the heat of our fires, but has much leſs ſpecific gravity, and is ſoluble in the nitrous acid. With the calx of

COPPER,

It forms a metal calcinable by heat; of a reddiſh colour; not fuſible but in a great heat; and ſoluble in all the acids. With calx of

LEAD,

A metal is formed by it, fusible in a moderate heat, and not difficultly calcinable. It is the softest of all metals, and also the heaviest, excepting gold, platina, and quicksilver. With calx of

IRON,

A metal is formed capable of being attracted by the load-stone; which requires the most intense heat to fuse it; is soluble in all acids and alcalis; is the least malleable, and most elastic of all metals; and which rusts on exposure to moist air. With calx of

TIN,

It forms a metal the lightest of all others, and the most fusible except mercury; the softest next to lead; and which, when pure, crackles on being bent. With calx of

MERCURY,

It forms a metal the heaviest of all the imperfect ones; volatile by heat; and which remains fluid in the common temperature of the atmosphere. With calx of

ZINC,

A ſemi-metal is compoſed ſoluble in all acids, and which may be ſublimed in the form of flowers. Its colour is a blueiſh-white, and is commonly named *tutenag*. With calx of

ANTIMONY,

It forms a ſemi-metal, ſoluble in aqua regia, but not in other acids, or difficultly and imperfectly. It ſublimes into flowers; and when combined with ſulphur forms *antimony*.

The other ſemi-metals are alſo formed of phlogiſton, and the reſpective calces. But different calces require different proportions of that principle, in order to their metallization.

II.

OF SULPHURS.

Phlogiſton properly combined with the vitriolic acid, becomes

I.

BRIMSTONE,

Or *common ſulphur*. If vitriolated tartar, Glauber's ſalt, or other ſubſtance containing vitriolic acid, be fuſed with charcoal, the acid of the former and the phlogiſton of the latter, will unite and form ſulphur.

This

This ſubſtance eaſily melts. It is neither ſoluble in acids, water, nor ſpirit of wine; but may be united with oils, and ſome of the metals; and alſo with alcaline ſalts and quicklime, forming *hepar ſulphuris*.

It is kindled with leſs heat than almoſt any other inflammable ſubſtance; burns with a blue flame, and ſuffocating ſmell. In this proceſs its phlogiſton is attracted by the air, leaving the acid behind in the form of vapour; and which is the cauſe of the ſmell juſt mentioned. This again ſhews that phlogiſton and the vitriolic acid are the principles of which it is compoſed.

2.

PHOSPHORUS.

It is compoſed of phlogiſton and the phoſphoric acid, in the ſame manner as brimſtone is compoſed of phlogiſton and the vitriolic acid; and therefore muſt be conſidered as a *ſulphur*.

Its principles ſeem to be leſs ſtrongly united than thoſe of brimſtone; for the latter ſubſtance requires to be heated in order to make it inflame; but phoſphorus parts with its phlogiſton to air, without the aſſiſtance of heat; and hence it is that it kindles on being expoſed to the air.

After combuſtion, its acid remains behind in a ſolid ſtate; in which reſpect likewiſe it differs from brimſtone. A ſmell of garlic is perceived while it is burning.

Nitrous air may alſo be conſidered as a *nitrous ſulphur*.

III.

OF COAL.

By *coal* is meant any oily ſubſtance burnt to blackneſs: as the coal of wood, charcoal, and the like. It may be conſidered as a combination of phlogiſton, with either animal or vegetable earth. If it be deprived of the former ingredient by combuſtion, the earth remains behind. When much heated, and then left to cool, it abſorbs air.

IV.

OF OILS.

Oil, ſimply conſidered, is probably a combination of phlogiſton, with an acid, earth, and water.

Oils are inflammable, and burn with a ſoot, leaving alſo a coaly matter behind, unleſs it be carried off in the vapour. They are not uſually miſcible in water; but either ſwim above it, or ſink to the bottom, according to their ſpecific gravity.

gravity. The ſubſtances with which they are accidentally combined make a conſiderable variety in them. And, as their properties are different, we ſhall, as in the caſe of earths, conſider them as diſtinct ſubſtances.

1.

EXPRESSED VEGETABLE OILS,

As oils of almonds, olives, &c. When pure they have little or no taſte or ſmell, and are ſoft and bland; they neither mix with water, nor ſpirit of wine.

With cauſtic fixed alcaline ſalts they form common ſoap; they diſſolve ſulphur, and calx of lead; and unite with eſſential oils. They alſo ſwim in water.

2.

ESSENTIAL VEGETABLE OILS,

Or thoſe obtained by diſtilling vegetables; as lavender-flowers, caraway-ſeeds, &c. with water.

They diſſolve in ſpirit of wine, and produce cold thereby. They unite with water by diſtillation; and hence the ſmell and other properties of diſtilled ſimple waters. They have the ſmell and taſte of the ſubjects from which they were drawn.

They form volatile *ſoaps* with the volatile, and thoſe called *philoſophical* with fixed alcalis. When they are in a dry or ſolid ſtate, they are called

3.

RESINS.

Thus, reſin of jalap, of guaiacum, &c. may be conſidered in this light; as may alſo camphire. They agree with eſſential oils, in their being ſoluble in ſpirit of wine, not in water; and in ſeveral other properties.

4.

ANIMAL FATS.

Their properties are very ſimilar to thoſe of expreſſed vegetable oils. They differ from them chiefly in being uſually in a ſolid ſtate; whereas the others are moſt commonly fluid.

There are other diverſities in oils; as the empyreumatic oils of animals and vegetables; ariſing from their being partly decompoſed by the fire; foſſil oils; and the ſubſtances reſin, wax, &c. But for accounts of theſe, authors on the materia medica, and practical chemiſtry, may be conſulted, a particular enumeration of them not being neceſſary to a work of this nature.

V.

VINOUS SPIRIT.

It ſeems to be compoſed of acid, phlogiſton, and water. It burns without ſoot, or coal.

It mixes with water. It diſſolves eſſential, but not expreſſed oils; reſins are alſo diſſolved by it.

It is eaſily inflammable; and its capacity for containing fire is greater than that of oils. It alſo burns with a weaker flame.

It coagulates animal fluids; is very volatile; and, excepting æther, is one of the lighteſt of liquids.

VI.

ÆTHER.

It is produced by diſtilling pure vinous ſpirit with a concentrated acid.

It is the lighteſt of all known liquids. It neither unites with vinous ſpirit, acid, nor alcali, but diſſolves eſſential oils and reſins. It unites, in a very ſmall proportion, with water.

Beſides the ſubſtances already mentioned, phlogiſton enters more or leſs into the compoſition of all bodies, though in leſs proportion, or elſe in a leſs obvious manner than in thoſe ſpecified. But theſe are ſufficient to ſhew the great importance of this principle, and in ſome meaſure its nature. For it is abſolutely neceſſary to the formation of inflammable matters; and of courſe to vegetable, animal, and other bodies, into the compoſition of which inflammable ſubſtances are known to enter. It alſo ſeems neceſſary to the formation of *air*, and to many other important purpoſes in nature, which it is not neceſſary at preſent to conſider.

CHAPTER VII.

OF FIRE.

FIRE is that ſubtile principle which cauſeth heat. As heat is the moſt obvious effect of fire, I ſhall firſt diſcourſe of it.

If the heat or warmth of any ſubſtance be greater than that of the part of an animal body to which it is applied, it cauſeth the ſenſation of heat in that part; if contrariwiſe, cold; but if the heats be equal, neither of theſe ſenſations are cauſed. Thus, if water be hotter than the hand, it feels warm; if colder, cold; but if it be of an equal heat with the hand, it neither feels hot nor cold. The hand however is no certain meaſure of heat; for if one hand be hotter than the other, the ſame water may at the ſame time feel hot to one hand, and cold to the other. And, at different times, water of the ſame warmth may feel hot and cold even to the ſame hand.

Philoſophers therefore have another, and more accurate method of meaſuring heat, which is by the thermometer. When a body is hotter, the fluid in the thermometer applied to it riſes higher; and when colder, the fluid ſinks lower, and a graduated ſcale is affixed to the tube to mark the degrees. A body therefore is not ſaid to be hot, or cold; but only more or leſs hot *. Ice, for example, has a leſs degree of heat than boiling water. The heat of a body is alſo called its *temperature*.

The moſt general effect of heat on bodies, is to expand them into greater dimenſions: there is not a body yet known but what is thus affected by heat. If a ſmall quantity of air be contained in a bladder, the application of heat will expand it into ſo great a bulk, that the bladder will be completely diſtended. If ſpirit of wine be put into a long ſlender tube, and then made hot, it will very conſiderably expand; and if a rod of iron, which can juſt enter a ring when cold, be made red hot, it cannot then enter that ring, becauſe it is expanded in bulk by heat. All bodies therefore are expanded by heat; and the only difference is, that ſome are more expanded than others, for reaſons which will appear in the ſequel.

On

* Bodies, though they do not appear hot to the ſenſe, are in reality very conſiderably ſo. It has been found, for example, that they are capable of being cooled above 100 degrees below the uſual heat of the hand. If therefore the uſual heat of the hand were at that point, and a body which does not now feel warm were applied to it, the heat would be almoſt equal to that which is now felt on putting the hand into boiling water. A very conſiderable quantity of fire therefore is contained in bodies, when at the common temperature of the atmoſphere.

On this principle the thermometer is formed. A glaſs tube is made, with a bulb at the bottom, capable of holding a ſufficient quantity of quickſilver, or ſpirit of wine. When heat is applied, the fluid in the bulb is expanded, and for want of room makes its way up into the tube, ſo that the ſurface riſes higher. When a leſs degree of heat is applied, the fluid in the bulb is contracted, and therefore part of that which is in the tube will ſink down into the bulb, its ſurface becoming lower than before. The graduated ſcale indicates the difference, and therefore meaſures the degree of heat.

If bodies are heated leſs than a certain degree, they are ſolid; if they are heated beyond that, they are fluid; and if they are heated beyond a certain greater degree, they are rendered elaſtic, or turned into vapour or air, as was mentioned before. Water, for example, when it has only 32 degrees of heat, by Farenheit's thermometer, is ſolid; and it is ſolid in all degrees of heat below 32. When the heat is greater, it melts, or becomes fluid. And when the heat is boiling and beyond, it loſes its fluid form and is turned into vapour, or elſe rendered elaſtic like air. The like happens to quickſilver, with this difference, that quickſilver loſes its ſolid form in a leſs degree of heat than water; and yet does not become elaſtic, but with a greater heat. Lead does not become fluid,

fluid, but with an heat greater than that which would turn water into vapour; yet there is a leſs number of degrees between its ſolid and elaſtic ſtate, than in water. Gold does not become fluid but with a very intenſe heat; and the ſtrongeſt of our fires cannot turn it into vapour; and ſome earths cannot even be rendered fluid with the greateſt heat that our furnaces can give. On the other hand, ſpirit of wine cannot be rendered ſolid; and air cannot even be brought to a fluid ſtate, by the moſt intenſe cold that we have yet been able to produce. Yet a ſolid, fluid, and elaſtic ſtate, are with reaſon concluded to be proper to all thoſe bodies, provided they were in the degrees of heat requiſite for theſe purpoſes. The only difference between bodies in this reſpect ſeems to be, that no two of them have their ſolid, fluid, and elaſtic points at the ſame degrees of heat.

When bodies which differ in theſe reſpects are mixed together, they may therefore be ſeparated from each other by proper applications of heat, provided their particles do not too ſtrongly cohere; but of this, and of the other chemical uſes of heat, more will be ſaid on a future occaſion.

Fire has a tendency to diffuſe itſelf over all bodies, till they are of an equal degree of heat or warmth; and this equality of heat is called the

the *common temperature*. Thus, if a red hot bullet be placed upon three others which are cold, the former will be continually loſing heat, and the latter gaining; but all of them will be continually loſing heat to the bodies around, till they are all of the ſame temperature.

If a pound of hot water be mixed with a pound of cold, the heat of the water, after mixture, will be in the mean between the heats of the two portions before the mixture; the cold water will be heated half way to that of the hot, and the hot water will be cooled half way to the temperature of the cold.

If a pound of hot water, however, be mixed with a pound of cold linſeed oil, the heat of the mixture will be greater than the mean of their two heats before mixture; and if, on the contrary, the water be cold, and the oil hot, the heat will be leſs than that mean. This is a very curious difference; and the cauſe of it may be underſtood from what follows.

If a pound of water be placed in a veſſel in a certain degree of heat, and another pound in a ſimilar veſſel in the ſame heat, the heats which they gain or loſe in the ſame times will be equal.

But if in one of the veſſels be a pound of water, and in the other a pound of linſeed oil, the

the oil will acquire a greater degree of heat, in a given time, than the water; and the like difference is obſervable in their cooling. In other words, the ſame quantity of fire will heat the oil more than the water; and the ſame quantity of fire taken from the oil, and from the water, will cool the water leſs than the oil.

Half the fire contained in the hot water therefore, heated the oil more than it cooled the water, and the heat after the mixture was more than the mean. On the contrary, half the fire contained in the hot oil heated the water leſs than it cooled the oil, and of courſe the heat after mixture was leſs than the mean. And, as in the caſes of expanſion, &c. ſo in this, there are perhaps no two ſubſtances exactly alike in this reſpect.

Different bodies therefore have different powers, or capacities for containing fire; and hence when they are at a common temperature, or equally hot to the ſenſe and the thermometer, the proportions of that principle which they contain, are unequal. The capacity of linſeed oil, for example, is leſs than that of water; and therefore when equally hot to the ſenſe, and the thermometer, contains leſs fire. An equal proportion of that principle added to, or ſubtracted from, the water and the oil, ought

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in courſe to affect the temperature of the latter, more than the former.

The ingenious Dr. Irvine (to whom, in conjunction with the celebrated Dr. Black, we are indebted for this doctrine) has diſcovered a method by which the capacities of bodies may be determined by experiment. If, for example, I would know the proportion of the capacities of two liquids, I heat one of them, and pour it on an equal weight of the other while cold, having previouſly noticed the difference of their temperatures. If the capacities are equal, the heat of the mixture will be in the mean between the temperature of the two liquids before mixture; as was before obſerved to happen, when water is mixed with water. But if their capacities are unequal, the heat of the mixture will vary from the mean in proportion to that difference, as was obſerved to be the caſe on mixing water with linſeed oil; the capacities of which are to one another very nearly in the proportion of 2 to 1. To theſe experiments however, it is neceſſary that the ſubſtances ſhould have no chemical action on each other: that is, they ſhould produce neither heat nor cold, when mixed together at like temperatures.

Not only different bodies have different capacities, but even that of the ſame body is variable according to the ſtate which it happens to be in. When water freezes, its capacity becomes *leſs* than it was during the fluid ſtate; and on the contrary *greater*, when it is turned into vapour. The ſame rule holds good with other ſubſtances.

When the capacity of a body happens to be altered, it is evident that its temperature will be affected in proportion thereto. Thus, if the capacity be ſuddenly increaſed, the body will become colder than before; and if diminiſhed, hotter. Accordingly we find, that heat is generated by the congelation of fluids; and cold, by their evaporation. Cold is a conſequence of the tranſition from a ſolid to a fluid ſtate; and heat of the condenſation of vapour.

When water is mixed with oil of vitriol, a great degree of heat is produced. The capacity of the mixture becomes leſs than the ſum of the capacities of the ingredients before mixture; of courſe the fire which they contained, muſt occaſion the temperature of the mixture to be higher.

On the contrary, when ſnow is mixed with ſpirit of nitre, the capacity of the ſolution becomes greater than the ſum of the capacities of the ingredients before mixture. The quantity of fire which they contained becoming now too little, the temperature muſt ſink in proportion thereto. The like may be obſerved of the other inſtances of heat and cold generated by chemical mixtures.

The difference of the capacities of bodies may depend on different arrangements of their particles, or on other circumſtances, with which we are not yet properly acquainted. But by obſervations related in a book*, publiſhed by the author of this work, but more particularly by the experiments of the ingenious Dr. Crawford, it appears that, in ſome caſes, *phlogiſton* cauſeth this difference in bodies. Bodies which are freeſt from that principle have (at leaſt in many inſtances) their capacities greater than thoſe which contain it in greater proportion. Thus oil contains more phlogiſton than water, and its capacity is found to be leſs. The like may be obſerved of metals, and their calces; of ſulphur, and the vitriolic acid; and in other caſes of phlogiſticated and dephlogiſticated bodies.

Hence if the phlogiſton be ſuppoſed to be ſuddenly taken from oil, its capacity will be in-
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* Philoſophical Obſervations.

creaſed. The quantity of fire which it contained will no longer be ſufficient to keep it at the ſame temperature as before. It will therefore become colder; and of courſe will imbibe fire from the ſubſtances around, till it returns to an equal temperature with thoſe ſubſtances.

On the contrary, if the phlogiſton be ſuppoſed to be ſuddenly reſtored, the capacity will be leſſened. The fire which it contains, will raiſe it to an higher temperature than before; and therefore it will communicate heat to the ſurrounding bodies, till an equality of temperature between them again obtains.

The ſame quantity of phlogiſton combined with different bodies, affects their capacities in different proportions. Thus, if the phlogiſton of *oil* be transferred to *air*, the capacity of the latter will be more diminiſhed than that of the former is increaſed. The heat generated by the combination therefore, will be greater than the cold produced by the decompoſition; and on this principle we account for the heat in the combuſtion of oil, and other ſubſtances.

The elaſticity of air depends on heat. For if the heat be increaſed, the elaſticity is increaſed. If the heat is diminiſhed, ſo is likewiſe the elaſticity. If therefore air were ſufficiently deprived of heat, its particles would probably become coherent, like thoſe of water, and other ſubſtances.

The effect of fire on the particles of bodies therefore, is to give them a repulſive power. Thus, if two or more particles be in contact, cohering with each other, and heat be applied, the repulſive force which they acquire in conſequence thereof, will oblige them to quit each other. Hence the expanſion of bodies by heat. The particles while within their ſpheres of coheſion will reſiſt the action of heat more, as their attractive or cohering forces are ſtronger. But when the heat becomes ſo great as to urge them beyond thoſe ſpheres, they will become elaſtic like air; the repulſive force which they acquire from the heat, overpowering that of their attraction. This is the reaſon that particles are ſeparated from each other, or *volatilized* by heat. See alſo what was ſaid of the three ſtates of bodies in the former part of this chapter. But independently of their cohering forces, the particles of bodies ſeem to be ſome more, and others leſs, capable of being made repulſive by heat. Thus different kinds of air are capable of being differently expanded by equal degrees of heat, though the particles in this caſe are without the ſpheres of their cohering forces.

The uſes and effects of fire, or heat, in chemical operations, will be conſidered in the next ſection.

SECTION II.

HAVING given an account of ſuch chemical ſubſtances and agents as required explanation, we may proceed to the ſubject of chemical operations: and it will be moſt proper and natural to conſider thoſe firſt which depend merely on heat.

It muſt however be remembered, that I do not make it my buſineſs in this work to treat of the *practical* part of chemiſtry; the *philoſophy* of that ſcience was all that I propoſed; and even no more of that than might be ſufficient to enable the reader to enter, in a MORE GENERAL MANNER, into theſe uſeful and entertaining ſtudies.

CHAPTER I.

OF VOLATILIZATION.

BY this term we underſtand that part of chemiſtry, which treats of the ſeparation of volatile from fixed ſubſtances; that is, the decompoſition of bodies, by heat alone.

If a volatile ſubſtance, as water, be combined with a fixed one, ſuppoſe fixed alcali, they may be ſeparated by putting the mixture into a proper diſtilling veſſel, and applying a ſufficient heat. For the water will be raiſed into vapour and diſtil into the receiver, leaving the alkali at the bottom.

A greater heat however will be required than if the water had been diſtilled alone, becauſe the water is attracted by the ſalt; and the heat in theſe caſes is required to be greater according as the attraction is ſtronger, ſo as to overcome that attraction.

You will find by the 3d chapter of the former ſection, that green vitriol is a compound of vitriolic acid and iron. But a proper degree of heat forces over the acid (together with ſome water which the vitriol alſo contains) in the form of ſpirit of vitriol, the iron remaining in the form of colcothar behind,

Hartſhorn is a combination of animal earth, volatile alcali, oil, water, fixed air, *&c.* Heat forces over all the volatile ingredients, leaving the earth at the bottom of the retort.

So guaiacum wood is a combination of vegetable earth, ſalt, acid, water, air, and oil. By the application of a ſufficient degree of heat, the latter ingredients being volatile, are ſeparated in vapours; the earth with the fixed alcaline ſalt remaining behind. The like may be

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obſerved of other animal and vegetable, and of many of the mineral ſubſtances alſo.

In caſes however where the attraction of the ingredients is very ſtrong, this decompoſition cannot be effected by our fires. For example, vitriolated tartar is a combination of the vitriolic acid with fixed alcali. The acid, though volatile, cannot be ſeparated from the alcali by the utmoſt force of the furnaces, becauſe it is too ſtrongly attracted by the alcali. The like may be obſerved of ſome other ſubſtances.

In the inſtances laſt mentioned, the power of the fixed ingredient fixes alſo the volatile one. There are others, in which the volatile one volatilizes alſo the fixed. Thus, ſedative ſalt of Homberg is fixed. But if it be combined with water, the water carries it up with itſelf in vapour. Iron is, in like manner, volatilized by ſal ammoniac.

If ſubſtances of different volatility be mixed together, which have but little or no attraction for each other, the moſt volatile may be driven over in diſtillation; leaving the other, or others, behind; provided only ſuch a degree of heat be applied, as is juſt ſufficient to raiſe the former in vapours, but not the latter. Thus, if water and ſpirit of wine be mixed together, both which

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are volatile, the ſpirit will riſe firſt, the water not till the heat becomes greater. In like manner, water may be raiſed from ſpirit of vitriol; the acid, being more fixed, remaining concentrated behind. So volatile alcali may be ſeparated from water; eſſential oils from thoſe of a more fixed nature: And hence alſo, the matters obtained by diſtilling hartſhorn, guaiacum, and other ſubſtances, may be ſeparated from one another, as you find by their proceſſes in chemical books.

But in caſes where the principles ſtrongly attract each other, they will not be ſeparated, but both riſe together in their combined ſtate. Thus, the marine acid and volatile alcali, are both volatile; but the latter more ſo than the former. Yet heat does not ſeparate them, as in the caſes laſt mentioned, but they both riſe together in the form of ſal ammoniac. So ſulphur and quickſilver riſe together in the form of cinnabar; and the like happens in many other inſtances.

If in a ſubſtance to be diſtilled, oil and water are contained, they may both be driven over into the receiver; and as they will not mix, the oil will either float at top, or ſink to the bottom, according as its ſpecific gravity is greater or leſs; and therefore they may be ſeparated by filtration, or other *mechanical methods* contrived for

for that purpose. Hence essential oils are obtained by distillation. And the like may be observed of other matters, which will not mix; as of quicksilver and water, water and phosphorus, *&c.* Hence though the matters may be of different volatility, yet the necessity of the mode of separating them by heat, is, in these cases, superseded.

It should be observed, that *air* has some share in the business of volatilization. Thus, water placed *in vacuo*, evaporates with much greater difficulty than when the vessel contains air, or when in open exposure to that element. The air in this case acts as a *menstruum*, or *solvent.* See also what was said on this subject, in the chapter on Air.

CHAP-

CHAPTER II.

OF MENSTRUUMS.

ONE of the moſt uſeful branches of chemiſtry depends on menſtrua. The extracting of tinctures, decoctions and infuſions depends on this principle.

In order to effect ſolution, one of the ſubſtances at leaſt muſt be fluid. The fluid ſubſtance is called the ſolvent or menſtruum.

There are ſome bodies which diſſolve intirely in certain menſtrua. Thus ſugar wholly diſſolves in water; camphire is totally diſſolved by ſpirit of wine; wax diſſolves intirely in oil; and quickſilver in ſpirit of nitre. In many inſtances, theſe ſolutions may be made in the uſual temperature of the atmoſphere. Others require heat to diſſolve them; but in all theſe caſes, agitation greatly facilitates the ſolution, as by it the unſaturated parts of the menſtruum are applied to the ſubſtance to be diſſolved. This operation depends on the principle of attraction already ſpoken of. Thus ſpirit of wine diſſolves camphire, becauſe there is a mutual attraction between the particles of theſe ingredients. But camphire is not diſſolvable by water, for want

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of ſuch mutual attraction. Spirit of wine therefore is a menſtruum for camphire, water not.

In moſt caſes, however, only part of the principles of which a body is compoſed are ſoluble in any one menſtruum; for example, aloes conſiſts of two different ſubſtances or principles, a reſin and a gum. Spirit of wine diſſolves reſinous ſubſtances, but will not touch gummy ones. If, therefore, it be required to extract the reſin from the aloes, it muſt be digeſted in ſpirit of wine. The reſin will be diſſolved, the gum remaining behind. But gummy ſubſtances are diſſolved by water. Hence, if it be required to extract the gummy part from the aloes, water muſt be uſed. When therefore tinctures are extracted from ſubſtances with pure ſpirit of wine, it is with a view of obtaining their more oily or reſinous parts. Hence, the tinctures of aſſafœtida, guaiacum, balſam of Tolu, and the like.

On the contrary, when water is employed, whether in the way of infuſion or decoction, it is with deſign to extract the ſaline, gummy, gelatinous and mucilaginous parts; of all which water is a ſolvent.

By treating any ſubſtance therefore, firſt with ſpirit of wine, and afterwards with water, or firſt with water, and afterwards with ſpirit of wine, we extract from it both its reſinous and ſaline

and

and gummy parts. If the ſubſtance contains no other than theſe (as is the caſe with aloes, aſſafœtida, &c.) it will be totally diſſolved. But if it alſo contains earthy, or other matters, not ſoluble in thoſe menſtrua, thoſe parts will remain undiſſolved.

If, however, water and ſpirit of wine be mixed together, they will not always diſſolve thoſe ſubſtances which are wholly ſoluble by them when applied ſucceſſively, becauſe they then weaken each other's attractive or ſolvent virtues. Thus, water and ſpirit of wine will not diſſolve aloes, aſſafœtida, &c. The tincture, however, which is extracted by this mixture, partakes both of gummy and ſaline, and of reſinous parts, though in a leſs degree than when employed ſeparate.

For the ſame reaſon, if the tinctures drawn by thoſe menſtrua ſeparately, be mixed together, they will not incorporate into a clear tincture; but becauſe the forces of the menſtrua are mutually weakened, they each let go part of what it before retained; the mixture in courſe becomes muddy, and a precipitation enſues.

Heat increaſes the diſſolving power of menſtrua, and in ſome caſes gives that power where it did not before appear. Hence many ſpirituous tinctures

tinctures are directed to be drawn with heat; and watery ones are most generally made either with hot water, or by actual boiling.

In many cases, the part of the substance dissolved carries with it into the tincture, infusion, or decoction, many particles of the substance, not naturally soluble in that menstruum. Thus, wine extracts part of the resin from opium, which it lets go again in time. Hot water draws out not only the saline and gummy, but also great part of the resinous, and even woody parts from bark; but lets them fall to the bottom, in great measure, after standing a sufficient time. Thus also water dissolves gum ammoniac, assafœtida, &c. into milky, or otherwise turbid liquors. The turbidness shews the tincture to be imperfect; and ariseth from the resinous parts still held by the others, which the water dissolves, and which, therefore, is rather a mixture than a tincture, and will, in time, separate. Oil is in like manner mixed imperfectly with water, by means of an alcali; the water dissolving the alcali, and that still retaining the oil. Hence the turbidness or milky appearance of that mixture.

In common distillation, the water used for distilling simple waters, and the spirit of wine employed in the distillation of spirituous ones, act also as menstrua. In the former case, the saline parts of the vegetable substance are dissolved

ſolved in, and carried over by, the vapour of the water: in the latter, the reſinous, or thoſe depending on the eſſential oil, are in like manner extracted and carried over by the vinous ſpirit. Theſe therefore may alſo be conſidered in the light of infuſions or decoctions, and tinctures; the only material difference being, that in ordinary decoctions and tinctures, the more fixed parts of the ſubſtance are alſo retained by the menſtruum; in diſtillation, only the volatile parts.

Any other fluid that acts on, and diſſolves the whole, or any part of a ſubſtance, may alſo be conſidered as a menſtruum. Thus, oils are menſtrua to many ſubſtances which water and ſpirit of wine will not touch. Acids are menſtrua to metals, earths, &c. Air is a menſtruum to water, and other matters; by which means their volatilization is alſo facilitated, as hath been obſerved. Subſtances reduced to vapour, or air, even act more powerfully than in a fluid form. Thus, ſpirit of ſalt and ſpirit of wine will not form ether, unleſs mixed together in a vapoury ſtate; and there are other inſtances of a like nature.

From hence it appears, that the decompoſition of bodies by means of menſtrua, forms an extenſive branch of chemiſtry; and it has this excellence, that the virtues of animal and vege-

table

table ſubſtances may be extracted, at leaſt by water and ſpirit of wine, without alteration, which is not commonly the caſe with operations by the retort. For example, by the retort all vegetables yield nearly the ſame principles, viz. oil, an acid, water, fixed alcali, and earth; and the like may be obſerved of the diſtillation of animal ſubſtances by the ſame method. But by means of water, and ſpirit of wine, as above, their reſpective virtues may be obtained unaltered. The like holds good with extracts, as will be ſeen in the next chapter.

CHAPTER III.

OF EXTRACTS.

THE theory of this part of Pharmacy depends on the two preceding heads of volatilization and menſtrua.

Extracts may be divided into ſpirituous, watery, &c. according to the nature of the menſtruum employed, and of the extract to be made.

A reſinous extract is drawn by means of vinous ſpirit. For example, if I would extract the reſinous part of aloes, bark, or any other ſubſtance, I bruiſe the ingredient and infuſe it in rectified ſpirit, with a proper degree of heat, agreeable to what was delivered in the laſt chapter. I then decant, or filter the liquid; and as the ſpirit is more volatile than the reſin, it may be raiſed from it by evaporation, or by diſtillation, as may be underſtood from what was delivered in the 9th chapter; the reſin remaining at the bottom.

If I would extract the ſaline or gummy matter from a ſubſtance, I boil or infuſe it in water, and afterwards diſtil or evaporate the water by a proper degree of heat; the extract, being leſs volatile, remaining behind.

As ſpirit of wine evaporates with leſs heat than water, extracts made by the former contain more of the volatile parts of the ſubſtance, than thoſe made by the latter. For though you may obſerve, that in an extract or reſin, only the more fixed parts of the ſubſtance can be retained, the volatile ones flying off in evaporation; yet the more of thoſe volatile parts that can be retained, the more of the virtue of the ſubſtance will the medicine contain. Hence the ſlower the evaporation proceeds, the better will the extract be.

In order that it may contain as much as poſſible of the virtue of a ſubſtance, the gummy and ſaline, and the reſinous parts, are, in ſome caſes, directed to be ſeverally drawn with water, and ſpirit of wine. Thus, in ſome recipes, a tincture is directed to be drawn from bark with ſpirit of wine, in order to extract the reſin, and the bark to be afterwards boiled in water, to get out the other principles. Theſe tinctures, or rather the extracts made from them when nearly reduced, are then directed to be mixed together. Such an extract therefore contains both the reſinous and ſaline-mucilaginous principles; or, in other words, the whole virtue of the bark.

By proper management an extract ſimilar to the above may be drawn with water alone. Thus, a ſmall quantity of water is added to opium, only ſufficient to make it into a pulp; the gummy and ſaline parts are hereby ſufficiently diſſolved. At the ſame time the reſin is melted by the heat; and as the mixture is thick, does not ſeparate, but is entangled by and blended with the other parts, ſo as to paſs the ſtrainer together. A due degree of heat afterwards reduces it to its proper conſiſtence.

Any liquid ſubſtance, vegetable juice, &c. properly evaporated, may alſo be called an extract. Thus the juice of elder-berries evaporated, called rob of elder, is an extract. Sugar of lead, extracted from ceruſe, or litharge by vinegar, and then evaporated, is an extract; and ſo of others.

CHAP-

CHAPTER IV.

OF FERMENTATION.

VEGETABLE and animal ſubſtances only are ſubject to this proceſs. There are ſeveral ſtages of it; all of which vegetable, but not animal ſubſtances, may undergo.

By fermentation, the particles of the compound ſuffer a new arrangement; ſo that the properties of the ſubſtance become different from what they were before.

If a vegetable juice (of grapes, for example) be fermented, it will yield on diſtillation, inflammable ſpirit, which the *muſt* did not yield before fermentation. This is called the *vinous* fermentation.

If the ſame liquid be farther fermented, it yields vinegar, which could not be obtained from the liquid before, either in its original or vinous ſtate. This therefore is called the *acetous* fermentation.

The third ſtage of fermentation, is *putrefaction*; by which the ſubſtance is converted firſt into a mucilage, and afterwards into calcareous earth, marine, and other acids, and volatile alcali; which eſcaping with a portion of oily matter, occaſions the diſagreeable ſmell ariſing from putrifying ſubſtances.

Animal ſubſtances can only paſs through the latter ſtage.

A quantity of *fixed* air eſcapes from the fermenting ſubſtances during their firſt ſtages; but in putrefaction, *inflammable* air alſo ariſeth. In all fermentations therefore, not only new arrangements of the particles take place, but part of them are ſeparated, and fly off.

Fermentation is the means employed by nature for the deſtruction of thoſe bodies which are produced by vegetation and animalization; or for reſolving them, as far as is neceſſary, into the principles of which they were originally compoſed.

SECTION III.

BEFORE we enter on the ſubject of this ſection, it may not be improper to premiſe the following, taken from the writings of the ingenious Dr. Fordyce; to which we are alſo indebted for part of the chapter on fermentation.

COMBINATION IS OF TWO KINDS; MECHANICAL AND CHEMICAL.

Mechanical combination is alſo of two kinds. Firſt, *Mixture*; when the particles of one of the bodies attract one another ſtronger than they do thoſe of the other. In this caſe, if they be both fluid, the one which is leaſt in quantity, is broke down into ſpheres; as oil is when mixed with water.

Secondly, *Diffuſion*; when the particles of one of the bodies attract thoſe of the other. In this caſe they intermix equally. Thus, ſolution of blue vitriol mixes uniformly with water.

In mechanical combination, the properties of the elements remain exactly the ſame as before the mixture; and the properties of the compound depend on them.

When the bodies are of different ſpecific gravity, they remain mixed from friction; and the attraction of the particles of the one in the largeſt quantity, to one another.

But in chemical combination, the ſubſtances unite by an attraction which takes place between themſelves, without any external power.

A particle of each element unite together ſo as to form but one particle, conſidered mechanically. Thus nitrous acid, and fixed vegetable alcali, form nitre; which is to be conſidered mechanically as one ſimple ſubſtance.

The properties of the compound do not depend on the properties of the elements.

No mechanical power can ſeparate the ſubſtances ſo combined.

A compound may become an element. Thus, vitriolic acid and phlogiſton form ſulphur. But ſulphur with fixed alcali, forms hepar ſulphuris; ſo that in this caſe the ſulphur, though a compound of two other principles, is only an element of the hepar.

Elements remain combined from the attraction which takes place between them.

A TABLE OF ELECTIVE ATTRACTIONS.

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1. VITRIOLIC ACID.

Phlogiſton	Sulphur
Fixed Alcali	Tart. Vitriolat.
Volatile Alcali	Sal Ammon. Vitriolic
Magneſia	Sal Cath. Amar.
Zinc	Vitriol Alb.
Iron	——— Virid.
Copper	——— Cærul.
Water	Spirit. Vitrioli

2. NITROUS ACID.

Phlogiſton	Nitrous Air
Fixed Alcali	Nitre
Volatile Alcali	Sal Ammon. Nitros
Iron	
Copper	
Silver	Lunar Chryſtals
Water	Sp. Nitri

3. MARINE ACID.

Fixed Foſſil Alcali	Common Salt
Calcareous Earth	Liquid ſhell
Volatile Alcali	Sal Ammoniac
Regulus of Antimony	Butter of Antimony
Silver	Luna Cornea
Mercury	Merc. Corroſ. Subl.
Lead	Plumbum Corneum
Water	Spirit of Salt

4. ACETOUS ACID.

Fixed Alcali	Sal Diuretic.
Volatile Alcali	Spirit. Mindereri
Magneſia	
Lead	Sacc. Saturn.
Copper	Cryſtal. Veneris
Water	Vinegar

5. FIXED VEGETABLE ALCALI.

Vitriolic Acid	Tartar Vitriolat.
Nitrous Acid	Nitre
Marine Acid	Sal Digeſtivus
Acetous Acid	Sal Diuretic.
Fixed Air	Mild Fixed Vegetable Alcali

6. FIXED FOSSIL ALCALI.

Vitriolic Acid	Sal Glauberi
Nitrous Acid	Nitrum Cubicum
Marine Acid	Common Salt
Vegetable Acid	
Fixed Air	Mild Foſſil Alcali

7. VOLATILE ALCALI.

Vitriolic Acid	Sal Ammon. Vitriolic
Nitrous Acid	——— Nitrous
Marine Acid	——— Commun.
Vegetable Acid	——— Vegetabil.
Fixed Air	Mild Volatile Alcali

8. CALCAREOUS EARTH.

Vitriolic Acid	Selenite
Nitrous Acid	——— Nitrous
Marine Acid	Liquid ſhell
Vegetable Acid	
Fixed Air	Quick Lime
Water	Lime Water

9. EARTH OF MAGNESIA.

Vitriolic Acid	Epſom Salt
Nitrous Acid	
Marine Acid	
Vegetable Acid	
Fixed Air	Magneſia

10. METALS.

Marine Acid	
Vitriolic Acid	
Nitrous Acid	
Acetous Acid	

11. PHLOGISTON.

Air	
Vitriolic Acid	Sulphur
Phoſphoric Acid	Phoſphorus
Metallic Calces	Metals
Veget. & Anim. Earth	Coal

12. SULPHUR.

Fixed Alcali	Hepar Sulphuris
Abſorb. Earth	
Volatile Alcali	
Iron	
Reg. of Antim.	Antimony
Mercury	Cinnabar

13. SPIRIT OF WINE.

Water	Spirit. Vin. ten.
Eſſential Oils	Eſſences

14. WATER.

Spirit of Wine	
Volatile Alcali	Sp. of Sal Ammoniac

15. FIXED AIR.

Calcareous Earth	Chalk
Earth of Magneſia	Magneſia
Fixed Alcali	Mild Fixed Alcali
Volatile Alcali	Mild Volatile Alcali

16. PURE AIR.

Phlogiſton	
Fire ?	

OF CHEMICAL COMBINATION AND DECOMPOSITION.

The later writers on chemiſtry have comprized almoſt the whole of this branch of the ſcience into a brief ſynopſis, which they call the Table of Affinities, or *Elective Attractions*; wherein the ſeveral ſubſtances are diſpoſed according to the relations, or attractions which they have to each other, and on which the operations of chemiſtry for the moſt part depend. The annexed ſcheme contains as much of theſe tables as was judged neceſſary to the preſent purpoſe. To underſtand this table, you muſt obſerve, that the ſubſtance at the top of any column, combined with either of the ſubſtances beneath it, form the compound wrote againſt the latter on the right hand. Thus vitriolic acid, and fixed vegetable alcali, form vitriolated tartar. And you are farther to obſerve, that the ſubſtance at the top of a column is capable of attracting and combining with any of the ſubſtances underneath it; but that the combination is weakeſt with thoſe ſubſtances which are at the greateſt diſtance. Alſo when any one of the ſubſtances in a column is combined with that at the top of that column, any of the ſubſtances above it will, by means of a ſuperior attraction, unite with the latter, and expel the former.

For

For example; it will be ſeen by the thirteenth column, that ſpirit of wine will unite with eſſential oil. Thus, oil of peppermint, mixed with ſpirit of wine, forms eſſence of peppermint. But water is above eſſential oil in the column, which ſhews, that there is a ſtronger attraction between ſpirit of wine and water, than between that ſpirit and oil. If therefore water be added to eſſence of peppermint, the ſpirit will let go the oil, to combine with the water. Hence we find, that when eſſence of peppermint is mixed with water, a milky appearance enſues, occaſioned by the ſeparated oil; which, after a while, riſes to the ſurface, leaving the liquid beneath it clear.

Having thus given a general idea of the table, and doctrine of affinities, or elective attractions, I ſhall proceed to the ſubject propoſed. In each proceſs, I ſhall mention, as far as may be neceſſary, the circumſtances or conditions requiſite to be obſerved; and as vitriolated tartar is one of the moſt obvious inſtances of chemical combination, I ſhall begin with it.

This neutral ſalt is compoſed of vitriolic acid, and cauſtic fixed vegetable alcali, as you will find by the table, in the columns for thoſe principles. But vitriolic acid is not to be met with pure. The moſt ſimple that we have, is combined with water, in the form of ſpirit of vitriol; the alcali however, may be had pure. Thus, the

the lapis ſepticus, or potential cautery, is the pure fixed vegetable alcali. If this alcali be added to the ſpirit of vitriol, it will attract the acid from the water, or in other words, the particles of the acid, being more powerfully attracted by the particles of the alcali than by thoſe of the water, will quit the latter to combine with the former. If only juſt as much alcali be added as is ſufficient to ſaturate the acid, the mixture will contain nothing but vitriolated tartar, and water; the water may be evaporated by heat, and the neutral ſalt will remain behind; or if it be required in cryſtals, the evaporation may be only carried on in part, and then the mixture ſet in a cool place, for the cryſtals to ſhoot, as directed in books of practical chemiſtry.

When theſe ingredients are mixed in ſuch proportions as perfectly to ſaturate each other, the acid will have loſt its ſour taſte, and the alcali its acrid one. This mutual loſs of taſte, is a very remarkable circumſtance. Oil of vitriol is the moſt cauſtic of all acids, and has perhaps, the ſtrongeſt taſte of any other known ſubſtance. The taſte and cauſticity of the alcali are almoſt as great. Both of them pain and burn the fleſh in a manner almoſt ſimilar to fire. Yet when theſe two principles are combined, they form a ſubſtance which has hardly any taſte, or none reſembling that of either of the ingredients. This loſs of taſte is generally proportional to the force with which the ingredients combine. Thus vitriolic acid and water, or oil of vitriol, has a very ſtrong taſte. If it be combined with volatile alcali, its taſte is weaker, becauſe it attracts that ſubſtance more powerfully than it does water, or exhauſts on it more of its attracting force. If it be combined with fixed alcali, as above, the taſte is ſtill leſs; and if with phlogiſton, as in ſulphur, its taſte is entirely loſt. Its attraction to phlogiſton is ſo ſtrong, that it ſeems to exert its whole attractive power on it, and therefore with its loſs of attraction, loſes its taſte; for taſte being cauſed by the attraction between the tongue and the ſubſtance applied to it, if the ſubſtance has no attractive force remaining, it can have no taſte.

So again, the cauſtic fixed alcali has a very powerful taſte. When it is combined with fixed air, as in the mild vegetable alcali, the taſte is leſs. When with the muriatic acid, as in common ſalt, it is ſtill weaker, and when with vitriolic acid, as above, leaſt of all; its taſte being leſs as the force of its attraction is more exhauſted. This rule may be applied to other acids, alcalis, and earths. There are, however, ſome exceptions to it, which yet perhaps may depend on other cauſes. Thus nitre has a ſtronger taſte than ſoluble tartar, and tart. vitriolat. than ſelenite, though the attractions of their reſpective ingredients are the reverſe; as may be ſeen by the table.

Vitriolated

Vitriolated tartar may be made, not only in the manner deſcribed above, but with many ſubſtances which contain the two ingredients of which it is compoſed; and the ſalt may afterwards be extracted from the mixture by chemical art. For example,

Mild fixed alcali is a combination of the pure fixed alcali with fixed air. If this be uſed inſtead of the pure, the alcali will quit the fixable air with which it is combined, and unite with the acid, by which it is more powerfully attracted. The air thus let go by the alcali, reſumes its elaſtic ſtate, and by its flight cauſeth an effervеſcence in the liquid. What remains is the ſame mixture of vitriolated tartar and water as in the former proceſs, and the ſalt may be obtained from it in the ſame manner.

Green vitriol is a combination of vitriolic acid with iron. If cauſtic fixed alcali be added to this compound, the acid quits the iron to unite with the alcali, by which it is more powerfully attracted; the iron will ſettle at the bottom in form of a powder, from which the clear liquor may be poured off, and the ſalt may be ſeparated from the water in the manner already deſcribed. The like may be obſerved of the other vitriols, of alum, and of Epſom ſalt.

But it is worthy of remark, that if this laſt ſubſtance, and mild fixed alcali be uſed, the fixable air of the latter will not fly off in its elaſtic ſtate in the manner deſcribed above, but unite with the magneſia ſeparated from the Epſom ſalt by the alcali, ſo that there will be two new compounds formed. The Epſom ſalt is vitriolic acid combined with magneſia; the acid, uniting with the alcali, forms vitriolated tartar; and the magneſia, uniting with the fixable air, forms the common or uncalcined magneſia; for it muſt be obſerved, that the *calcined*, is the pure magneſia, the *common* is magneſia combined with fixable air, like the mild alcali. The ſame double decompoſition takes place when ſelenite and mild alcali are uſed, and in many other caſes; and this is called *double affinity*, or *double elective attraction*, as the former is termed *ſingle*, becauſe there are two new compounds produced in the latter caſe, and only one in the former.

Again, nitre is a combination of fixed vegetable alcali with nitrous acid, as you will find by the table. But if oil of vitriol be added, the alcali will quit the nitrous acid to unite with the vitriolic, by which it is more powerfully attracted, and the nitrous acid will unite with the water; ſo that here alſo we have a double affinity. The mixture therefore is now vitriolated tartar, and ſpirit of nitre. The latter may be diſtilled over

with

with a ſufficient degree of heat, leaving the former behind.

Vitriolated tartar may be obtained in like manner from ſal digeſtivus, and from regenerated tartar, by adding to them the vitriolic acid, with this only difference, that ſpirit of ſalt and vegetable acid are reſpectively obtained inſtead of ſpirit of nitre.

What has been ſaid of vitriolated tartar may be applied in great meaſure to nitre and ſea ſalt.

Thus, by mixing ſpirit of nitre with pure vegetable alcali, nitre may be obtained in like manner as tart. vitriol. was from the ſame alcali and ſpirit of vitriol. If nitrous acid be combined with ſome other ſubſtance, to which it has a weaker attraction than to the vegetable alcali, nitre may be formed, as tart. vitriolat. was with green vitriol, and alcali. Alſo, if the fixed vegetable alcali be combined with any ſubſtance, by which it is leſs ſtrongly attracted than by the nitrous acid, nitre may be made by adding the nitrous acid, as vitriolated tartar was made by adding ſpirit of vitriol to nitre, ſal digeſtivus, or regenerated tartar.

So ſea ſalt may be formed by adding ſpirit of ſalt to natron; or with ſpirit of ſalt and ſal Rochel: or with natron and ſal ammoniac, butter

ter of antimony, or corrofive fublimate of mercury.

So likewife diuretic falt may be formed with fixed alcali and vegetable acid; with fixed alcali and fugar of lead; with fixed alcali and fpiritus Mindereri; and the like; all which require no explanation, as they will be eafily underftood from what has been faid of vitriolated tartar. Yet, to render the doctrine of chemical compofition ftill more clear, I fhall give another inftance in *fal ammoniac*.

If fpirit of falt (which is a combination of marine acid with water) be mixed with fp. fal. ammoniac cum calce (which is the cauftic volatile alcali, alfo combined with water) to the point of faturation, the mixture will be common fal ammoniac, and water. The water may be feparated from the falt by evaporation, or cryftallization, as fhewn before; or the falt may be fublimed, or formed into a cake, like the fal ammoniac of the fhops. For the ingredients being both volatile, and ftrongly attracting each other, they will rife in vapour in their combined form, as hath already been fhewn *.

In this cafe the volatile alcali entirely lofeth its very powerful fmell, its particles being attracted

* A mixture of alcaline, with marine acid air, forms this falt, as was fhewn in a former chapter.

tracted, and as it were, fixed by thoſe of the acid. The taſte alſo is nothing comparable to that of the acid, or even of the alcali in ſtrength, for reaſons already given.

If the mild volatile alcali be employed, the fixed air will be expelled, and fly off, (hence the violent effervecſcence;) and therefore the mixture will be ſal ammoniac and water, as when the cauſtic alcali was uſed.

If the acid be combined with another ſubſtance to which it has a weaker attraction than to the volatile alcali, it will quit its union with that ſubſtance to unite with the alcali. Thus, if merc. corr. ſubl. be mixed with the volatile alcali, the acid will leave the mercury, and form ſal ammoniac with the ſalt. The mercury thus diſengaged, will fall to the bottom in the form of a powder, and the ſal ammoniac may be obtained from the clear water in the manner already deſcribed.

Alſo if the volatile alcali be combined with a ſubſtance to which it has a leſs affinity than to the marine acid, the alcali will quit that ſubſtance, and form ſal ammoniac with the acid. Thus, ſpiritus Mindereri is this alcali combined with the vegetable acid. But ſpirit of ſalt being added, the alcali will leave the vegetable, to form ſal ammoniac with the marine acid. The ſalt may be ſeparated from the liquor by cryſtallization, or by other means.

Theſe inſtances will be ſufficient to give you an idea of chemical combination. I ſhall now give a few examples of decompoſition.

We may decompoſe a compound chemically, by knowing its ingredients, and duly applying a principle to which one of the ingredients has a ſtronger attraction than to that with which it is already combined. The table of affinities affords a variety of ſuch inſtances.

Let it be required, for example, to decompoſe ſal ammoniac, ſo as to obtain its volatile alcali. By examining the table, I find that ſal ammoniac is a combination of the volatile alcali with marine acid. In the column for that acid I find, that natron, among other ſubſtances, is above the volatile alcali. Marine acid therefore has a ſtronger attraction to the foſſil than to the volatile alcali, and therefore will leave the latter to unite with the former. The mixture will be the volatile alcali, and common ſalt. As a proof of this, as ſoon as the ingredients touch each other, though before they were deſtitute of odour, yet now a very ſtrong ſmell of volatile alcali is perceived: and as the alcali is volatile, the ſalt fixed, we have only to put the mixture into a retort, and a due degree of heat will force over the alcali, leaving the ſea-ſalt behind.

It

It may be obſerved, that if the cauſtic foſſil alcali be uſed, the volatile alcali obtained will alſo be cauſtic. But this is always in a fluid ſtate, as before obſerved. To obtain a ſolid, and therefore mild ſalt, the natron muſt be uſed in its mild ſtate. The fixed air of which is transferred to the volatile alcali, as the natron is to the acid; ſo that here again is a double affinity, a double decompoſition, and two new combinations *.

The volatile alcali may likewiſe be obtained from ſal ammoniac, by uſing calcareous earth, or fixed vegetable alcali, inſtead of natron; and it may alſo be had either cauſtic or mild, according to the ſtate in which theſe ſubſtances are uſed.

To decompoſe ſal ammoniac ſo as to obtain its acid. In the column for volatile alcali, above marine acid you find, among others, the vitriolic. If you mix oil of vitriol with ſal ammoniac, the volatile alcali will quit the marine acid, and form, with the vitriolic, ſal ammon. vitriolic. The mixture therefore will be this ſalt, and the marine acid combined with the water of the oil of vitriol, which may be obtained from the ſalt by diſtillation, as being more volatile.

This may alſo be done by uſing the nitrous acid. But practitioners prefer the vitriolic, be-

* The mild alcali may alſo be compoſed directly, by mixing fixed, with alcaline air. See the chapter on different kinds of air.

caufe part of the nitrous is apt to pafs over with the marine in diftillation; fo that inftead of the pure fpirit of falt, you have aqua regia, or a compound of the fpirits of nitre and of falt.

Subftances containing the vitriolic acid may likewife be ufed, and the nitrous and vegetable fal ammoniacs may be decompofed by methods fimilar to thofe above defcribed.

Thefe inftances will be fufficient to give an idea of chemical combination and decompofition, and enable you to underftand not only the other inftances in the table, but alfo the reafon of many proceffes which you meet with in difpenfatories, and books of practical chemiftry. But thefe points will be further elucidated by what follows to the end of this chapter.

In the fourth chapter, I gave a fynopfis of the neutral falts, and fhewed that each of them was a compound of a particular acid with fome alcali. From what has been faid of vitriolated tartar, and fal ammoniac, you will underftand in general the manner in which thefe falts are obtainable from their refpective principles. The like may be obferved of the metallic and earthy falts in the fame chapter.

Thefe falts may likewife be decompofed on the fame principle as hath been fhewn of fal ammoniac.

It

It muſt, however, be obſerved, that the circumſtances attending the proceſſes require to be varied in ſome particular caſes, though the principles on which thoſe proceſſes depend are the ſame; and hence the particular directions for conducting thoſe different proceſſes, to be met with in books of practical chemiſtry. I ſhall give a few inſtances by way of illuſtration.

Green vitriol is a combination of the vitriolic acid with iron. But if you add iron to oil of vitriol, this ſalt cannot be made. For in order to the ſolution of the iron, the oil of vitriol muſt be previouſly diluted with water.

Corroſive ſublimate is a compound of marine acid and mercury. Mercury, however, cannot be diſſolved by that acid in a liquid form. In order to their combination, they muſt be raiſed into fume, and in this ſtate the ingredients unite, though they could not in their coherent form. Hence in this proceſs, vitriol and common ſalt are employed. The acid of the vitriol diſengages that of the ſalt, which iſſuing forth in vapours, attracts the mercury from the nitrous acid, with which it had before been purpoſely combined, and by their union ſublimate is formed.

So in decompoſition, if green vitriol be mixed with nitre, the acid of the vitriol muſt be expelled by the force of heat before it can act on the nitre ſo as to diſengage its acid. Without this circumſtance no nitrous acid is obtained.

But further to illuſtrate this ſubject, I will run through the whole of one of the columns for ſalts, together with certain other proceſſes, proper for our purpoſe, noting the circumſtances requiſite to be obſerved towards forming the ſeveral decompoſitions and combinations.

Spirit of vitriol is a combination of vitriolic acid with water. If to this compound you add thin plates of copper, and give a due degree of heat, the copper will be diſſolved. The mixture therefore will now be blue vitriol and water, which might eaſily be ſeparated by the methods already deſcribed. If to this ſolution you add plates of iron, the acid will leave the copper and unite with the iron. As the latter diſſolves, and the former is let go by the acid, it depoſits itſelf upon the ſurfaces of the iron plates, ſo that they look like copper. But when the iron is all diſſolved, the copper will fall to the bottom in form of a powder. The clear liquor being decanted, will therefore be a mixture of water and green vitriol. If to this ſolution zinc be added, the acid will leave the iron by degrees, and unite with the zinc, and the iron will fall to the bottom in form of a powder, as the copper did before. The clear liquor being decanted, will be a ſolution of white vitriol in water. Add volatile

alcali

alcali to this ſolution, the acid will leave the zinc to unite with the ſalt; the zinc will fall to the bottom in form of a powder, and the clear liquid being decanted, will be vitriolic ſal ammoniac and water. Add fixed alcali to this liquid, the acid will unite with it, letting go the volatile, and the mixture will be vitriolated tartar, and ſpirit of ſal ammoniac. The latter may be obtained by diſtillation, the former remaining behind. Mix this ſalt with an equal quantity of fixed alcali, and add powdered charcoal equal to about a fourth part of the weight of the whole. The charcoal, you will obſerve, contains phlogiſton combined with a vegetable earth, and the alcali is added to make the vitriolated tartar melt, which it will not eaſily do without ſuch addition. Put theſe ingredients into a crucible, covered, and apply a ſudden and ſtrong heat for a ſhort time, the vitriolic acid will leave the fixed alcali to unite with the phlogiſton of the charcoal. The mixture therefore is now common ſulphur, fixed alcali, and vegetable earth, that is, it is an impure *liver of ſulphur*. Diſſolve the maſs in water, the earth will ſubſide, and the clear liquid will be a ſolution of liver of ſulphur and alcali, in water. Decant, or filter this liquid; and to obtain the ſulphur, look in the table for fixed alcali, you will find above ſulphur ſeveral acids, add a ſufficient quantity of either of theſe, the alcali will quit the ſulphur to unite with the acid, and the ſulphur will fall in a powder to the bottom, which you may ſeparate from the liquid, and melt into a roll. And thus will you have had ſucceſſively ſpirit of vitriol, blue vitriol, green vitriol, white vitriol, vitriolic ſal ammoniac, vitriolated tartar, and ſulphur, each of which might have been eaſily obtained in their uſual forms.

In the column for ſulphur, you find that ſulphur and mercury form cinnabar. There is, however, no method of combining theſe ingredients into that form, either by dry-mixture or liquefaction. If they are mixed in either of theſe ways they form not cinnabar, but Æthiops mineral. To combine them into the form required, they muſt be raiſed in vapour. If they be firſt mixed into an Æthiops, and then ſublimed, *cinnabar* will be the ſublimed ſubſtance.

To decompoſe this compound ſo as to obtain the mercury, look in the column for ſulphur, and you will find, above mercury, iron. By mixing iron-filings with the cinnabar, and diſtilling them in a retort, the ſulphur is attracted by the iron from the mercury, which riſes pure into the receiver, (filled with water to condenſe the fumes,) the ſulphur and iron remaining behind.

Sulphur and fixed alcali form liver of ſulphur. This, however, they do not do by mere mixture;

mixture; they are to be placed on the fire ſo as juſt to melt the ſulphur, and the mixture is to be continually ſtirred, till the combination is formed. If the mild alcali is uſed, it will not unite with the ſulphur till its fixed air is expelled. You may obtain the ſulphur from the alcali again by ſublimation; but the better way is to add ſome acid to attract the alcali from it, the ſulphur will then be precipitated in form of a white powder. By waſhing and melting, it may be reſtored to its priſtine form.

In the column for water you will find mild volatile alcali, which forms ſpirit of ſal ammoniac. Imagine this as ſtrong as it can be made. Above volatile alcali you will find ſpirit of wine, which you muſt likewiſe ſuppoſe to be as ſtrong as poſſible. If theſe are mixed, the ſpirit of wine will attract the water from the ſalt, which will therefore be inſtantly reſtored to its ſolid ſtate, forming that beautiful experiment of Van Helmont, of the *offa alba*.

In the column of fixable air, (for the philoſophy of which, in this view, we are indebted to the learned and ingenious Dr. Black,) you will find that the volatile alcali and this principle form the mild volatile alcali. Fixed alcali is above the volatile in the column. If to the pure fixed alcali, diſſolved in water, you add the mild volatile alcali, the fixed air will be attracted by the

the former from the the latter, which, with the water, may be diſtilled over in the form of cauſtic volatile alcali; the fixed alcali, now rendered mild, remaining behind.

If to this alcali, diſſolved in water, you add pure magneſia, the latter will attract the fixed air from the former, and the magneſia and cauſtic fixed alcali may be obtained ſeparate by filtration, &c.

If to the magneſia, mixed with a due quantity of water, quicklime be added, the fixed air will leave the magneſia to unite with the lime, forming common calcareous earth. It is obſervable that calcareous earth is ſoluble in water when in its cauſtic ſtate, forming what we call lime-water; but mild calcareous earth is not ſoluble in that liquid. It is alſo obſervable that any of theſe ſubſtances will become mild by being expoſed to the fixable air eſcaping from an effervеſcent mixture, which it will attract or abſorb. And they will do the ſame in time if expoſed to common air, becauſe there are always many particles of fixable air floating in the atmoſphere, which theſe ſubſtances imbibe. Hence if lime-water be expoſed to the air, a white cruſt forms upon its ſurface, which is nothing but the lime now become no longer ſoluble on account of its combination with fixed air. And if fixable air be mixed with lime-water, the lime, which before remained diſſolved, will be precipitated in form of a white powder, for the ſame reaſon. Hence it is that lime-water is a teſt of the preſence of fixed air, as mentioned in a former chapter. Theſe proceſſes contain ſuch a variety of combinations and decompoſitions, with the circumſtances relating to them, that to a perſon of common capacity, nothing farther needs be ſaid on the ſubject.

I ſhall conclude this account with the rationale of ſome proceſſes depending on *phlogiſton*, the moſt extraordinary perhaps, of all the chemical principles.

Metals are combinations of their reſpective earths or calces, with this ſubtil principle.

If an acid be applied to a metal which it can diſſolve, the calx, having a greater affinity to the acid than to the phlogiſton, quits the latter to unite with the former. The phlogiſton uſually flies off in the form of inflammable air.

Metallic ſalts, and ſolutions therefore are not combinations of acids with metals, but only with their calces.

If a metal diſſolved in an acid be precipitated by any metallic calx, or by any other ſubſtances

beſides

befides a real metal, the precipitate will not be a metal, but a calx. Thus if copper be diffolved in vitriolic acid, the folution only contains the calx of the copper, the phlogifton having efcaped. If calx of iron, fixed alcali, or the like be added, the acid will unite with thefe, letting go the calx of copper, which therefore will fall to the bottom only in the form of a calx.

But if to this folution of copper, iron or zinc be added in their metallic ftate, or as they are combined with phlogifton, a double affinity takes place. The calx of the added metal unites with the acid, and its phlogifton with the precipitated calx; fo that the powder at the bottom is now not calx of copper, but copper itfelf. And this is the cafe in all metallic folutions, when the precipitation is made with a metal.

Charcoal is a combination of vegetable earth with phlogifton, as you will find by the table. If calamine ftone be properly treated with charcoal, the calx will attract away its phlogifton and be formed by it into a metal. This metal is zinc. If the phofphoric acid be added to this metal, and they be diftilled in a retort, with a fufficient heat, the phlogifton will quit the metal to unite with the acid, and the phofphorus formed by their union, will diftil over into the receiver (which muft be filled with water to condenfe and

and quench the vapours) the calx remaining behind. This compound is the famous ſubſtance known by its property of ſhining in the dark, and burning in the ordinary heat of the atmoſphere. It is uſually obtained, by a very laborious proceſs from urine. In the urine is a particular kind of ſalt, called by chemiſts the fuſible ſalt of urine. It conſiſts of the poſphoric acid united to an alcali, like other neutral ſalts. In the courſe of the proceſs, the acid quits the alcali and unites with the phlogiſton of the urine into phoſphorus, in the ſame manner as in the proceſs of making ſulphur with charcoal and vitriolated tartar, or Glauber's ſalt. But if this ſalt be extracted from the urine by cryſtallization, and then mixed with charcoal, or other proper phlogiſticated ſubſtance, and diſtilled with a ſufficient heat, the ſame phoſphorus will be formed. Phoſphorus therefore is only a particular kind of ſulphur, burning with leſs heat than common ſulphur. If *pure* vitriolic acid and this ſubſtance were mixed together, and diſtilled, the phlogiſton would quit the phoſphoric to unite with the vitriolic acid. The ſulphur formed by their union would be ſublimed by a proper degree of heat, leaving the phoſphoric acid behind. If this ſulphur be mixed with, or expoſed to the action of air, and a proper degree of heat be applied, the phlogiſton will quit the vitriolic acid to unite with the air, by which it is more powerfully attracted, and the acid remain alone in vapours, which

which may be caught and condenſed, by means of the ſteam of water, into common ſpirit of vitriol, or ſpiritus ſulphuris per campanam.

Other bodies containing phlogiſton not too ſtrongly combined may be decompoſed by air as well as ſulphur. The air decompoſes phoſphorus in the uſual heat of the atmoſphere; but moſt other bodies require heat for that purpoſe. Thus oils and fats require a greater heat than ſulphur; and metals are not decompoſed by air without an intenſe degree. The heat enables the air to act on the body and attract from it its phlogiſton, which it could not do before. Thus alſo it has been ſeen that many decompoſitions of other kinds can be effected without heat, but that there are others of them to which heat is neceſſary.

The decompoſition of phlogiſticated bodies by air, I had occaſion to treat of in the chapter on different kinds of air; and in the chapter on fire was given the preſent theory of the heat attending ſome of theſe proceſſes. To account for the heat in combuſtion, let it be ſuppoſed that a great quantity of fire is contained in air, in a fixed, or latent ſtate. In combuſtion, the phlogiſton of the inflammable body is transferred to the air; the fire is ſet at liberty becauſe it has a weaker attraction, and by uniting with the ſubſtances around, produces the great degree of heat obſervable on theſe occaſions. (See the table, column 16.)

The

The more rapidly the decompofition proceeds, that is, the greater the quantity of it which takes place in a given time, the greater will be the heat. Hence bellows, blow-pipes, and currents of air, by applying frefh particles of air to the body, are fuccefsfully employed for that purpofe. Alfo the heat will be greater according as the air is more pure. Hence with dephlogifticated air, the heat is much greater than when common air is employed.

Bodies containing phlogifton in the manner above defcribed, are called *combuftible bodies*, and their decompofition by air is called *combuftion* or burning, on acccount of the heat attending it. But the combuftion of bodies may be effected by means of nitrous acid as well as by air. Nitre contains a quantity of pure air in a ftate of combination, as fixed air is contained in marble, &c. when nitre therefore is mixed with a combuftible body, and a due degree of heat is applied, the phlogifton and air mutually attract each other from the fubftances with which they were before combined, and unite; and heat is generated on the principle already explained. See alfo the chapters on fire, and the different kinds of air.

CONCLUSION.

WHAT has been ſaid will, it is preſumed, be ſufficient to give the reader a general idea of chemical elective attraction, and enable him to reaſon on the operations which depend on it. With a few remarks on what has been ſaid, I ſhall cloſe this part of my ſubject. Theſe remarks however, will be ſuch as would, at leaſt for the moſt part, naturally occur to a reader of tolerable capacity after having gone through the preceding chapters.

1.

Bodies cannot act on one another, unleſs one of them at leaſt be in a fluid, or vapoury ſtate. In theſe ſtates the particles of one body are free to exert their action on thoſe of another, which, in a ſolid ſtate they cannot do, becauſe of the great attraction which takes place among themſelves.

2.

In many caſes heat is neceſſary to the action of bodies on each other. Thus mild fixed alcali and ſulphur will not form hepar ſulphuris without heat: and calces with inflammable ſubſtances will not become metals but by means of the ſame agent. In thoſe caſes wherein bodies act on each other in the uſual temperature of the atmoſphere, heat uſually very much promotes the effect. Thus, cold water will diſſolve ſugar; but if heat be applied, the ſolution takes place more ſpeedily, and alſo in greater proportion. Heat is alſo the agent in the preceding remark. If ice cannot diſſolve ſugar, it is only for want of ſufficient heat to render the former ingredient fluid. If ſpirit of ſalt cannot form corroſive ſublimate with mercury, it is only becauſe there is not a ſufficient heat to reduce it into vapour.

3.

In explaining the table of affinities, I have ſometimes mentioned a compound only in the light of a principle, or ingredient. Thus, at the head of one of the columns is ſulphur, which yet in another column is given as a compound of the vitriolic acid, and phlogiſton. But with reſpect to the ſubſtances underneath it in the column, it is a principle; thoſe ſubſtances not decompoſing, but uniting with it as it is ſulphur. Thus, mercury and ſulphur are the proper conſtituent principles of cinnabar; and ſo of others.

Alſo many of thoſe which appear to be principles are in fact only compounds. Thus, alcaline ſalts are combinations of earth, acid, and phlogiſton. So likewiſe acids, &c. are only compounds of other and more ſimple principles.

4.

In many caſes the union of bodies, according to the courſe of their affinities, will not take place but under particular circumſtances. Thus, phlogiſton will not decompoſe vitriolated tartar, but in a violent degree of heat. Mercury and the marine acid will not combine but in the form of vapour; and ſo of others. It may alſo be obſerved, that a combination cannot be effected in ſome caſes, but by previouſly uniting the ſubſtance with another, to which it has a weaker attraction. For example, æther will not diſſolve gold, yet if gold be diſſolved in aqua regia, and then the æther be added, the latter will attract the gold from the former; and chemiſtry furniſhes other inſtances of a like kind.

5.

In ſome caſes two principles which will not unite, may yet be made to do ſo, by means of a third principle, which has an attraction for both. Thus, ſulphur will not unite with water, but if the ſulphur be previouſly combined with an alcali, the water, by reaſon that it ſtrongly attracts the ſalt, retains alſo the ſulphur, which the alcali, on its union with the water, does not let go. So likewiſe oil and water will not mix; but if an alcali, which attracts both, be added, their mixture will, by means of this intermedium, be effected.

6. From

6.

From what has been ſaid concerning the table of affinities, the reader will be enabled, with a little attention, to underſtand many particulars of the philoſophy of chemiſtry, not there diſcourſed of. For example, he will now be capable of comprehending the reaſonings of chemical writers, when treating of the theory of their art, or giving the rationale of any particular proceſs; which was what was chiefly intended by theſe elements: and I ſhould hope that he will alſo be able to diſcover the theory of many of thoſe proceſſes, even without ſuch aid. For exerciſe in theſe particulars I would refer him to the operations concerning metals; to the ſeveral proceſſes for making the æthers; and to others, which I have not touched upon; examples of which he will find in abundance in chemical and pharmaceutical writings.

7.

He will alſo be enabled to comprehend the reaſon of the ſeveral general operations of chemiſtry. For inſtance,

PRECIPITATION,

Or the diſplacing or expelling of one principle from another by means of a third, on account of a ſuperior affinity. Thus, if ſulphur be diſſolved in an alcaline liquor, and an acid be added, the alcali unites with the acid, letting go the ſulphur, which therefore falls to the bottom, in form of a powder, called from hence, *sulphur precipitatum*. Thus likewise, if an essential oil be dissolved in spirit of wine, and water be added, the spirit of wine unites with the water, and lets go the oil, which rises in the liquid, and floats on the surface; this is likewise called precipitation; and fixed air, when disengaged by an acid, and flies off from the liquid, is also said to be *precipitated*.

CRYSTALLIZATION,

Which happens when particles of salt are suspended in too small a quantity of liquid, or in a liquid not sufficiently hot; for the particles running together, form themselves into those regular, transparent clusters, or masses, which we call crystals. As some salts require a greater quantity of water than others to keep them dissolved, if more than one sort is dissolved in any liquid, that which requires the greatest quantity of water to keep it dissolved, will crystallize before the other; and hence the art of obtaining the several salts dissolved in any liquid separate; hence also several kinds of salts when mixed together, may be separated on this principle. Common salt, for example, dissolves in less water than nitre: hence if nitre and common salt be dissolved in the same liquid, the nitre will crystallize soonest, and therefore may, by a proper management of the evaporation, be obtained before

fore

fore the common salt begins to shoot. As nitre when first made contains a large quantity of common salt, it is purified from it by this method.

DISTILLATION,

Or the raising of any volatile substance by heat into vapour, and making it pass over into a proper receiver, where it is condensed. Similar to which is

SUBLIMATION,

Or the raising of certain volatile matters in dry fumes which form themselves into a powder, or hard solid mass in the upper part of the vessel, or in a receiver.

CALCINATION,

Which is of two kinds. 1. Where the volatile matters are driven from the fixed, by means of fire in open vessels, or in the open fire, as is the case with magnesia, quicklime, and some other substances; and, 2. When the phlogiston is to be taken from a substance by a like exposure to heat; this is more properly called combustion. Thus, lead, antimony, &c. are reduced to calces, that is, are deprived of their phlogiston by calcination in open vessels; the air attracting their phlogiston in like manner as was shewn of the combustion of sulphur, and other bodies; but the decomposition in these cases, proceeding but very slowly, a degree of heat is not generated sufficient for the continuance of the combustion as happens in thofe bodies, and therefore the application of extraneous heat is alfo neceffary. There are other calcinations which partake of both thefe kinds.

CONCENTRATION,

Or the reducing of any principle not obtainable in a feparate ftate, into as fmall a compafs, or in other words, making it as ftrong, as poffible. Thus, oil of vitriol is concentrated by evaporating its fuperfluous water; the ftronger and lefs volatile acid remaining behind. Spirit of wine is concentrated by diftilling it with a very gentle heat, fo that as little water may rife with it as may be: which concentration is effected in a direct contrary manner to the other, the fpirit being more volatile than the water; the water more volatile than the acid. There are alfo other methods of concentration: thus, vinegar may be concentrated by freezing; the watery part only congealing, which may therefore be taken out in the form of ice, the remaining acid being fo much the ftronger. Hot, dry falt of tartar added to rectified fpirit of wine, attracts water from it, after no more can be obtained by diftillation. Vinegar again may be faturated with an alcali, and thereby formed into a neutral falt. To this falt made dry, concentrated oil of vitriol being added, the vinegar is expelled by means of a fuperior affinity, as was fhewn in the diftillation of fpirit of nitre and fpirit of falt, by which means

the

the vinegar receives the higheſt poſſible degree of concentration; and other inſtances of concentration may be met with in chemical writers.

8.

An acquaintance with chemical theory will alſo enable him to analyſe compounds, ſo as to diſcover their ingredients. If, for example, I would know the compoſition of a neutral ſalt, preſented to me for that purpoſe; I diſſolve part of the ſalt in water, and add a fixed alcali. As there is no turbidneſs, I conclude, that the baſis of the ſalt is neither earthy nor metallic. I apply my noſtrils to the liquid, and find that it ſmells ſtrongly of the volatile alcali, which therefore I conclude to be the alcaline baſis of the ſalt.

I pour on the ſalt a little oil of vitriol, and immediately perceive fumes to ariſe. I therefore conclude that the acid of the ſalt is not the vitriolic. On examining the colour of the fumes, I find it to be red. The ſalt therefore is probably a combination of nitrous acid with volatile alcali; that is, the nitrous ſal ammoniac.

To be further ſatisfied of this I grind a little of it with ſpirit of wine, and find that it totally diſſolves therein. I place another quantity of it in a ſhovel over the fire, without any mixture of inflammable ſubſtance, and it explodes. From all theſe circumſtances I ſafely conclude that the ſalt is the nitrous ammoniac, as I before conjectured. For no other anſwers to that deſcription; and in particular it is the property of this neutral ſalt alone to detonate without addition.

If there be preſented to me a ſolution of two different ſalts in water, and I am required to diſcover them, I add to a little of the liquid, ſome fixed alcali, and find a turbidneſs, together with a ſmell of volatile alcali. One of the ſalts therefore is ammoniacal, the other either earthy or metallic. I collect, and waſh the precipitated powder, and find that it is perfectly white, that it readily diſſolves in the vitriolic acid, with efferveſcence, and is precipitated from it by volatile alcali. It is therefore probably magneſia. I evaporate and cryſtallize this latter ſolution, the ſalt ſhoots into long ſlender cryſtals, and appears like the ſal catharticus amarus, another argument that the baſis is magneſia.

To diſcover the acids, I evaporate a ſufficient quantity of the original liquid, and on part of the cryſtals firſt obtained, pour a little oil of vitriol; a white fume ariſes, which ſhews that the acid of thoſe cryſtals is the marine. To another part of them I add fixed alcali, and find a ſmell of volatile alcali; from whence I conclue that one of the ſalts is the common ſal ammoniac.

As the baſis of the other was magneſia, I add to the liquor from which I obtained the cryſtals of of ſal ammoniac, a ſufficient quantity of fixed alcali to precipitate the whole of the powder. I evaporate the clear liquid, and pour on part of the firſt cryſtals obtained ſome vitriolic acid. But no fume whatever ariſes. The ſalt therefore is probably vitriolated tartar. I expoſe it to the fire, and it crackles like that ſalt; it does not fuſe; it is difficultly ſoluble in water. Theſe characteriſtics, together with its taſte, and the form of its cryſtals, leave no doubt of its being vitriolated tartar, as I before imagined. The two ſalts in the original ſolution therefore were ſal ammoniac, and ſal catharticus amarus.

By knowing the properties of ſaline ſubſtances, and the doctrine of chemical affinities, ſophiſtications may be detected. If for example the ſal catharticus amarus be impoſed on me for the true Glauber's ſalt, which it may be made to reſemble in the form of its cryſtals; by adding a little fixed alcali to a ſolution of the ſalt in water, the cloudineſs occaſioned by the precipitation of the magneſia, diſcovers the fraud.

If I would examine the purity of a powder ſold me for magneſia, I pour on it vitriolic acid; if the ſolution is perfectly tranſparent, I may pretty ſafely conclude, that the powder is genuine, eſpecially if by evaporating and cryſtallizing the liquid, a true ſal catharticus amarus is obtained.

tained. But if the ſolution depoſited a ſediment, or any other than Epſom ſalt is obtained from it, the magneſia may be concluded to be impure.

The reader who has a genius for chemiſtry, will be readily enabled to extend theſe hints to other chemical ſubſtances; and I would recommend this kind of analyſis to him, as the moſt likely means of improving him in this branch of ſcience.

POST-

POSTSCRIPT.

SINCE the preceding sections were written, the tables of the celebrated Professor Bergman have fallen into my hands. As these admirable tables are not yet published in any English work, and are not generally known, I have subjoined them to the *chemical* part of this treatise, by way of exercise to the student. They will also be useful to proficients in chemistry; as they contain, in a manner, all that has yet been discovered in that art.

The first of these tables is that of *simple elective attractions*. It is divided into two parts. The upper respects the *humid*, the lower the *dry* way of chemical combination.

This division is very proper. For attraction will sometimes take place in one of these cases, though it will not at all, or in a different manner, in the other. The vitriolic acid, for example, will not unite with phlogiston, so as to form sulphur in the *humid* way, or with water: yet in the *dry* way, phlogiston takes place of ponderous earth, which, in the humid way, stands immediately under that acid.

In

In former tables, the vegetable acids were considered as the ſame. In this they have their ſeparate columns; and their attractions appear to be ſcarce leſs different from one another, than from the other acids. Former tables alſo reckoned but three mineral acids. In this, more than double that number will be found, with equal variety of attractions.

The mineral and vegetable fixed alcalis were thought to have the ſame attractive force to acids: by this table it will be ſeen that the attraction of the vegetable alcali is ſtronger than that of the mineral.

Subſtances, with their elective attractions, are alſo to be met with in this table, which are not to be found in thoſe of Geoffroy or Gellert; as the ponderous earth, manganeſe, acid of ſpar, and others.

The reader who has attended to the directions for the former table, will find no difficulty in underſtanding this, after having learnt the characters.

The ſecond of theſe tables relates to double elective attractions, and chemical operations.

By the character of *water* in the middle of ſome of them, the *humid way* is meant. By the character of *air*, the *dry way*.

In

In theſe figures, the effects of mixing different bodies are ſhewn. Always one, and often both of the bodies whoſe mixture theſe diagrams repreſent are compounded; and the chemical character expreſſing the compound is placed on one ſide of an *upright* circumflex or bracket, (thus {) with the characters expreſſing its ingredients on the other. In the 21ſt figure, for example, the effects of mixing vitriolated tartar with fixed ammoniac is repreſented, both which are compounds. On the left is placed the character of the tart. vitriol. alſo ſeparated by an *upright* bracket from the characters of its two ingredients. On the right ſtands the mark of the fixed ammoniac, ſeparated in like manner from the ingredients of which it is compoſed.

Where the original compounds are decompoſed, and new ones produced, the new compoſition is ſignified by a bracket or circumflex drawn *horizontally*; the character of the compound being placed on the outſide, and the ingredients of which it is compoſed within. Thus, fig. 3. repreſents the mixture of fixed alcali with ſea-ſalt. The ſea-ſalt, which is a compound, is decompoſed, and a new compound is formed: the marine acid quitting the mineral, and uniting with the vegetable alcali, forming ſal digeſtivus. Where the mixture is neither accompanied with the production of a new compound,

pound, nor with the decompoſition of the old one, the horizontal circumflex is omitted. An inſtance of this occurs in fig. 2. where lime is added to tart. vitriol. without any effect being produced.

The darts which are to be ſeen in theſe ſchemes point out the relative force of the attractions of the reſpective ingredients. In fig. 21. the dart directed to vitriolic acid from calx, ſhews that it is as capable of decompoſing the fixed ammoniac; and the dart directed to vegetable alcali from acid of ſalt, ſhews that it is capable of effecting the ſame decompoſition, by uniting with the marine acid. The dart directed to vitriolic acid from vegetable alcali, ſhews that that acid is capable of decompoſing the ſal digeſtivus by combining with its alcali. The calx not being able to decompoſe the ſal digeſtivus, nor the marine acid the ſelenite, no darts are directed towards them.

In many caſes, the mixture of bodies is accompanied with precipitation. When the new compound is a precipitate, its precipitation is denoted by turning the apex of the circumflex *downward*; as is the caſe with ſelenite in the 21ſt fig. When the precipitate is not a new compound, but an ingredient of one of the old ones, it is repreſented by a *half circumflex*, the extremity

extremity of which, pointing to the right hand, is turned downwards, as is the caſe with lime in the fourth figure. Whenever the apex either of the whole or half horizontal bracket is not thus turned downwards, it ſhews that the compound or ingredient remains diſſolved in the liquid.

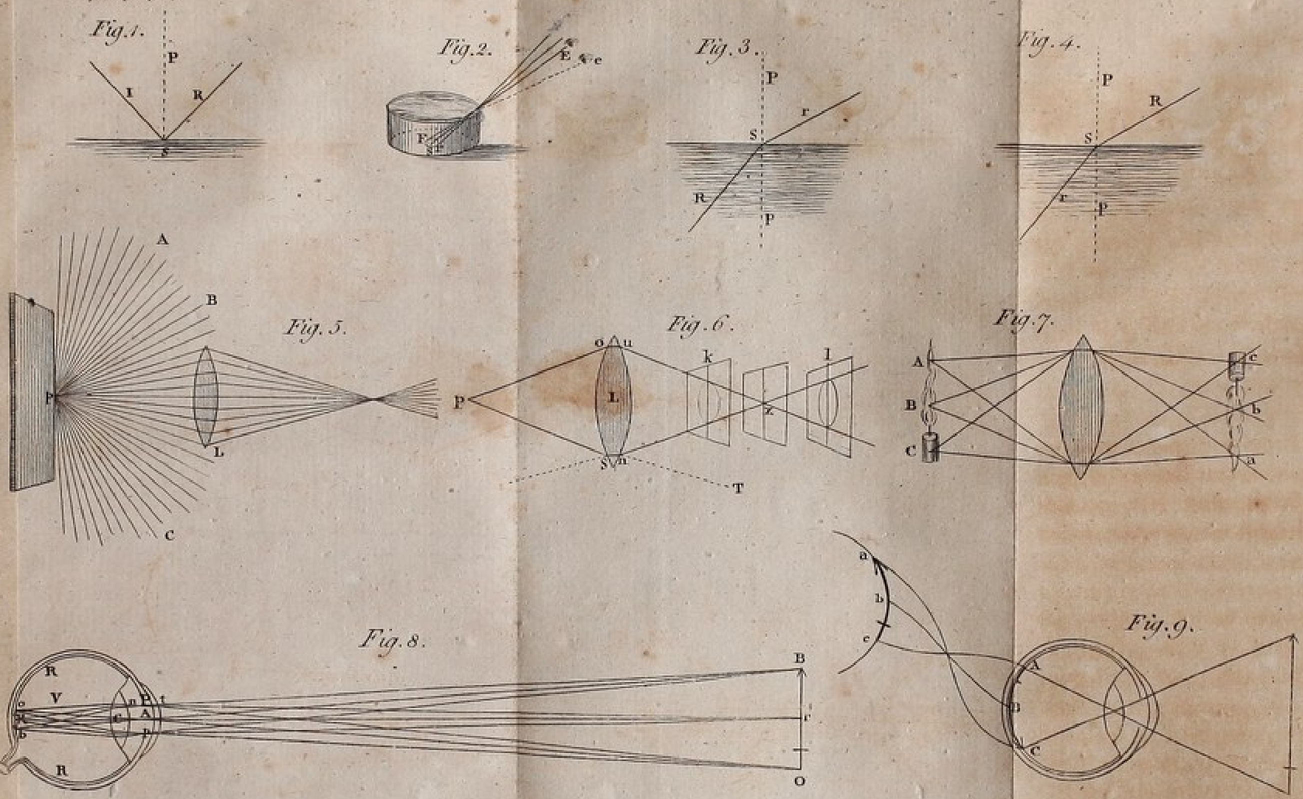
The ſchemes from 1 to 20, and from 40 to 55, repreſent ſimple elective attractions. In the others the attractions are double. Double elective attraction is elegantly explained by fig. 65.

On the left hand are the ingredients forming vitriolated tartar. On the right, the ſalt formed by the union of nitrous acid, and calx of ſilver. Neither the nitrous acid, nor calx of ſilver, can decompoſe vitriolated tartar, yet both of them acting together, can do it eaſily. Thus, if vegetable alcali and vitriolic acid attract each other with the force 9, and the nitrous acid, and calx of ſilver only with the force 2, then if the nitrous acid attracts the vegetable alcali with the force 8, and the calx of ſilver, the vitriolic acid with the force 4; 8 and 4 is greater than 9 and 2; a decompoſition therefore will be effected, and two new compounds formed; the one, of the vegetable alcali with the nitrous acid, and the other, of vitriolic acid with the calx of ſilver.

Theſe explanations will be ſufficient to render the tables intelligible, after what has been already ſaid on the ſubject; and the farther ſtudy of them is left for the exerciſe of the ſtudent's ingenuity, as well as for his information.

N. B. In the table of ſimple elective attractions, the compounds formed by the two ingredients are not mentioned, as is done in the table in page 105. Spaces, or intervals are alſo found between ſome of the ingredients in Bergman's columns, which imply that there is a greater difference between the attractions of the two ingredients with the principal, than when they immediately follow each other. The mark of calx joined with that of a metal ſignifies *the calx of that metal.*

Plate I. to face p. 145.



PART II.

CHAPTER I.

OF

OPTICS.

AS the doctrine of *viſion* conſtitutes a very important branch of phyſiology, I ſhall next proceed to inſtruct the reader in ſo much of the ſcience of optics as may be neceſſary to his underſtanding it.

Bodies become viſible by means of *light*; for without light they cannot be ſeen. This is ſo well known, that a proof need not be entered on.

Let a room be made quite dark, then let a ſmall hole be made in the upper part of the window-ſhutter, ſo that the ſun may ſhine through it, and let the light that enters at this hole from the ſun, paſs on to the wall oppoſite. Faſten one end of a thread at the hole, and the other end at the place where the light falls on the wall, and draw it tight, ſo that it may be perfectly ſtrait. If a piece of paper be held any where in the ſtrait line occupied by the thread, the ſun's light will fall upon it; but if the paper be removed out of that line, this will not happen. Alſo, if the eye be placed any where in that line, the ſun will be ſeen; but if it be removed from that line, the ſun is no longer viſible. Light therefore moves on in a right line, when no obſtacle hinders, and this muſt be remembered as a fundamental principle in optics.

Take a flat looking-glaſs, (Opticians call it a *plane mirror*,) drill a ſmall hole through its middle, and paſs through it three threads. Suſpend the mirror from the ceiling, or otherwiſe, by one of them, and let it down flat upon a table, in ſuch a manner as that the light from the window-ſhutter may fall upon the middle of the glaſs, the hole being in the center of the luminous ſpot. Faſten the glaſs to the table in this ſituation, the light will be reflected from the glaſs to the oppoſite wall. Let one of the remaining threads be fixed to the hole in the ſhutter, the other at the ſpot on the wall, both of them, as well as the perpendicular one, being drawn perfectly ſtrait. All things being thus ordered, you may obſerve that the perpendicular thread is exactly in the middle between the two others; or in other words, the angle which the thread from the window makes with

the

the perpendicular one, is exactly equal to that which is made with it by the thread which goes to the ſpot on the wall. For if you place a graduated ruler againſt the three ſtrings, parallel with the table, you will find that the perpendicular one falls exactly in the middle between the others. See figure 1ſt.

The light comes in a right line from the window to the glaſs, and goes in another right line from the glaſs to the wall. The ſtrings therefore being ſtrait, repreſent thoſe beams of light. The light which comes from the window to the glaſs is called the *incident light*; and that which goes from the glaſs to the wall, is called the *reflected light*. The angle which the incident ray (IS) (ſee the figure) makes with a line (PS) perpendicular to the point of the ſurface whereon they fall, (as the perpendicular thread in this caſe) is called *the angle of incidence*. That which the reflected ray (SR) makes with the ſame perpendicular, is called *the angle of reflection*. And it is an invariable rule in optics, *that the angle of reflection is equal to the angle of incidence*. If the angle of incidence be great, the angle of reflection will be great; if ſmall, the angle of reflection will alſo be ſmall: and if the angle of incidence be nothing, the angle of reflection will be nothing, ſo that the ray will be reflected back in the ſame line that it came.

Whenever therefore a ray of light falls on a body, we are to imagine a line perpendicular to the point of the ſurface whereon the ray falls; and by knowing the angle which the ray makes with that perpendicular, we alſo know the angle of reflection.

This rule holds good, not only in flat, but in all other kinds of ſurfaces, of whatever figure they be. And it may likewiſe be noted, that if the reflected ray be again reflected, and if the reflection of it be repeated to any number of times, the ſame rule obtains. We have only to conſider, that if a reflected ray is to be again reflected, it is to be conſidered as an incident ray; ſo that nothing in philoſophy is more eaſy to be conceived than the reflection of light.

Before I proceed to explain the *refraction* of light, I muſt acquaint the reader, that whatever light paſſes through, is called by opticians a *medium*. Thus, air is a medium; water, and glaſs are mediums, and ſo of other tranſparent ſubſtances. An optician has only to conſider bodies as mediums of greater or leſs refractive denſity. Thus air is a rare medium, and refracts but little; water a denſer, and refracts more; and glaſs is a medium, ſtill denſer.

While

While a ray of light paſſes through a medium of the ſame denſity, it goes on in a ſtrait line. But if it paſſes obliquely out of that medium into another, whoſe refractive denſity is greater or leſs, it takes a new direction, or is bent into an angle, as will preſently be ſeen.

Into any ſhallow upright veſſel put a ſhilling; and retire to ſuch a diſtance, as that you can juſt ſee the farther edge of the ſhilling, but no more. Let the veſſel, the ſhilling, and your eye, remain in the ſame ſituation, while an aſſiſtant fills up the veſſel with water, and the whole ſhilling will now become viſible. The reaſon of this will be ſhewn by the following ſcheme. (Figure 2.)

Let V repreſent the veſſel, S the Shilling, and E the eye. R E will be the only one of the three rays, coming from three different points of the ſhilling, which will reach the eye while the veſſel is empty, and therefore only the outermoſt edge of the ſhilling can be ſeen: the rays in this caſe coming in a right line from the ſhilling to the eye.

Let now the veſſel be filled with water, and let r N be a ray, coming from the innermoſt edge of the ſhilling, it will paſs on in a right line to the ſurface of the water. But on its entrance into the air it will not continue its courſe in a right line, but will be bent or refracted, ſo as to arrive at the eye (e) in the direction of the dotted line N e; and hence you have the reaſon why the whole ſhilling was ſeen in the latter caſe, and not in the former; for if the inner edge is ſeen, the whole ſhilling muſt in courſe be viſible. So likewiſe a ſtrait ſtick put partly into water appears to be bent. And objects appear through a priſm higher or lower than they really are.

I ſhewed before, that the angle of reflection is equal to the angle of incidence. But with regard to refraction, the caſe is otherwiſe, as will appear by the two following rules.

1. When the refraction is made out of a denſer into a rarer medium, the angle of refraction is *greater* than the angle of incidence; that is, the ray is refracted *from* the perpendicular.

2. But when the refraction is made out of a rarer medium into a denſer, the angle of refraction is leſs than the angle of incidence; or the ray is refracted *towards* the perpendicular.

To explain the firſt of theſe laws, let R S (fig. 3.) be a ray paſſing through the water in a right line, till it arrives at S, draw P p perpendicular to that point of the ſurface; and as the refraction is out of water, a denſer medium, into air, a rarer, it muſt be *from* the perpendicular. The ray therefore, inſtead of going on in a right line R S, will be bent into the direction S r, and therefore the angle of refraction r S P is *greater* than the angle of incidence R S p.

To explain the ſecond law, let R S (fig. 4.) be a ray paſſing through air in a right line to S. P p is the perpendicular to that point of the ſurface. And as the refraction is to be made out of air, a rarer, into water, a denſer medium, it will be *towards* the perpendicular. The ray therefore, inſtead of paſſing on in a right line R S, will be turned into the direction S r, ſo that the angle of refraction r S p will be leſs than the angle of incidence R S P.

Theſe caſes, being only the reverſe of each other, are perfectly eaſy to be conceived. And the rules hold good, as in reflection, whatever be the figure of the medium's ſurface. When therefore the angle of incidence is great, the angle of refraction will alſo be great; when ſmall, the angle of refraction will likewiſe be ſmall. And when the angle of incidence is nothing (that is, when the ray moves on to the ſurface of the body in the direction of the perpendicular) the angle of refraction will be nothing; that is, the ray will continue to paſs on in a right line, as if in the ſame medium: in like manner as when in reflection, the angle of incidence is nothing, the ray is reflected back into the line of its incidence.

As in reflection, the angle is always equal to that of incidence, ſo there is a conſtant or invariable proportion between the angles of incidence and refraction, with the ſame mediums; or between the ſines of thoſe angles. For an angle may be meaſured by letting fall a perpendicular from a given point in one of the lines, by which it is formed upon the other: this perpendicular line is called the ſine of the angle; and in order to determine the ratio between the ſines of different angles, no other caution is neceſſary than that the aſſumed points from which the perpendiculars are let fall be equally diſtant from the center or point of incidence. Thus it is found, that the ſine of the angle of refraction out of air into water is to the ſine of the angle of incidence always as three to four. But in different mediums the proportions are different, according to their refractive denſity. For example, the proportion of the ſines of the angles of incidence and refraction out of air into glaſs, is as ſeventeen to eleven; and other mediums have other fixed proportions.

Having

Having thus explained the laws of reflection and refraction of light, I shall now proceed to the application of them; and alſo to the conſideration of ſuch other particulars as may be neceſſary to the underſtanding of the doctrine of viſion.

Whatever is ſeen or beheld by the eye, is called by opticians an *object*. Thus, an arrow is an object; a bird is an object; a wall, the ſky, the ground, &c. are objects.

The ſurface of an object is conſidered by opticians as made up of a vaſt number of very minute points placed cloſe to each other; from every one of which points rays of light iſſue in every direction. If you ſingle out one of theſe points, and imagine it to remain alone; or if you ſuppoſe that point only to be illuminated by the rays of light, it may be repreſented by figure 5th. p is the point, and the lines proceeding from it are rays of light. Of courſe, in whatever poſition the eye be placed, whether at A, B, C, &c. the point will be viſible, rays being alike reflected from it to every part.

Let L repreſent a convex lens, or common burning-glaſs. Let it be placed before the point p, and as the glaſs is tranſparent, the rays

rays will paſs out of the air into the glaſs, and out of the glaſs again into the air beyond it, and then ſtrait on. But as glaſs is a denſer medium than air, it will refract the rays at their entrance into it, and the air beyond will again refract them in a contrary manner, in their paſſage into it from the other ſide of the glaſs, as may be gathered from what has been ſaid of refraction. To repreſent this the more clearly, let p in the 6th figure be the point, L the lens, and p S one of the outermoſt rays that falls on that lens. P S will be the perpendicular to the point of the ſurface on which the ray falls. As glaſs is a denſer medium than air, the angle of refraction will be leſs than the angle of incidence, and therefore the ray will be turned out of its right-lined direction, and go on in a ſtrait line to n. It is now to paſs out of the glaſs into the air. T n is the perpendicular to that point of the ſurface; and as the refraction is to be out of a denſer into a rarer medium, the angle of refraction muſt be greater than the angle of incidence, and therefore the ray will be turned from T, and of courſe it will go on in the direction of n x. Now it is obvious, that the ray p O muſt be refracted in the ſame manner as the ray p S. The two rays will therefore meet at x; and if we ſuppoſe a number of intermediate rays iſſuing from the point p, they will all be refracted

by

by the glaſs in ſuch a manner, as that their angles of incidence ſhall be to the angles of refraction, as ſeventeen to eleven, and they will all be again refracted by the air in paſſing out of the glaſs, in ſuch a manner as that their angles of incidence ſhall be to their angles of refraction as eleven to ſeventeen, ſo that they will all meet at the point x; they will croſs each other at that point, and then go ſtrait on, forming the angle n x u.

Now, if a paper be placed at x, ſo that the rays may fall on it, they will paint the image or picture of the point p on that paper.

Inſtead of one, imagine three points, A, B, C, at a convenient diſtance from each other, and let the lens be placed before them, as repreſented in the ſeventh figure. The rays flowing from each point, will, after refraction in the manner before deſcribed, form each their reſpective images c, b, a, on a paper placed behind the lens, as you may alſo prove by experiment; but the images you ſee are inverted, or in a contrary order to that of their originals, the image of A, which is uppermoſt, being below, and the image of C, which is undermoſt, being above.

To make this more plain, place the convex lens before a candle, and at a proper diſtance on the other ſide, hold a piece of paper; you will find the image of the candle very exactly painted on this latter, but in an inverted poſition, or upſide down, juſt as is repreſented in the figures; and if you imagine the whole ſurface of the candle to be made up of luminous points, and the rays from each point to be refracted in the manner of thoſe three which are here delineated, you will have the whole experiment, with its very curious reaſons, clearly before you.

But this is not the principal inference which was meant to be drawn from this experiment. You will find, that by holding the paper nearer to the lens, the image of the candle becomes leſs clear or diſtinct, till at length its figure is quite loſt; and the like happens by removing the paper beyond the proper diſtance. If you look in figure 6, you will perceive that the image of the point p can only be painted in its proper dimenſions, where the rays meet at x. If the paper be held nearer, or removed further from the lens, as at k or l, not a point, but a ſpot will be painted on it by the rays; and the ſpot will be greater according as the paper is removed either way from the point; the

the point or place where the rays meet and crofs is called the *focus*. So in figure 7, when the paper is in the focus of the rays, each point of the candle is painted in its proper fize and fituation with refpect to the others, as in the original; and therefore the whole image formed of thofe points appears diftinct, or rightly defined. But if the paper be fuppofed to be removed out of that focus, either towards or from the glafs, the images of the points of the object will be enlarged, and run into one another, the picture formed of them will of courfe become indiftinct or confufed, and that fo much the more as the paper is further removed from the focus, till at length it is no longer diftinguifhable.

Thus much being premifed concerning the images of objects, we may proceed to the doctrine of vifion.

In the eye are contained three humours, the aqueous, cryftalline, and vitreous, feperated from each other by proper coats or membranes. A (fig. 8.) reprefents the aqueous, or foremoft, C the cryftalline, which is in the middle, and V the vitreous, which is behind, and fills up all the back part of the eye; p p is the pupil or hole through which the rays pafs, and R, R, R, is the retina, placed behind all the humours, and which is the proper organ of vifion. For the

rays

rays of light, by ſtriking againſt that membrane cauſe viſion, in like manner as any thing ſtruck againſt the ſkin cauſeth feeling. Thus alſo, if you ſtrike the corner of either eye with your finger, you ſee a ſpot of light; the ſtroke of the finger being conveyed by the humours of the eye to the retina. Alſo, if the eye be violently ſtruck, light is ſeen, as pain is felt from ſtriking any part of the body, in which is the ſenſe of feeling.

The three humours of the eye are to be conſidered as ſo many mediums. The aqueous is the rareſt, the cryſtalline the denſeſt, and the vitreous between both.

If a ray of light, as r R, falls perpendicularly on the eye, it paſſes ſtrait on the retina, without refraction; for reaſons which have been already given.

But if a ray enters the eye in any other direction, it will be refracted by the ſeveral humours, in the following manner.

Let R t be a ray paſſing through the air to the eye, ſo as to fall on the cornea at t; and as the aqueous humour is denſer than air, the refraction muſt be made towards the perpendicular, as has already been explained; the ray therefore will paſs on to the ſurface of the cryſtalline humour

mour in the direction of t n. The cryſtalline is denſer than the aqueous and vitreous humours, and therefore the ray will, by the refraction, be deflected towards the axis of the cryſtalline, upon the principle of convex lenſes, and will at length fall at R on the retina.

Other rays may be imagined iſſuing from the ſame point with the ray r R, ſo as to occupy the whole width of the pupil p, p, and then they will all be refracted in like manner, ſo as to meet in the ſame point of the retina; and the image of the point r, from whence the rays flow, will then be painted on the retina, in the ſame manner as the image of the point p in figure 6 was painted on the paper by means of the lens.

Imagine three ſuch points, viz. O, r, B, with rays proceeding from each of them to the eye, analogous to what was before deſcribed with reſpect to the lens. The rays after refraction will meet on the retina, in three points, b, R, o, in an inverted ſituation with reſpect to their originals, the image of the upper one being loweſt, and that of the lower one higheſt; and by the ſame reaſon, if you place an arrow before the eye, the image thereof will be painted in an inverted poſition with reſpect to the arrow itſelf, as was ſhewn of the lens. From hence you will

will alſo underſtand, that the images of all objects ſeen by the eye are painted on the retina in a direct contrary poſition to the objects themſelves; the upper parts of thoſe objects being painted lowermoſt in the retina, their right ſides on the left in the retina, and the like of other parts.

It may be aſked, "How comes it that objects are ſeen in their proper poſition, ſeeing that their images are inverted in the eye?" To this it may be anſwered, that it is not the eye itſelf that ſees, but the fibres of the optic nerve which are expanded into, and form the eſſential part of the retina, convey the impreſſion which they receive from the impulſe of the rays, to the ſenſory or ſeat of the mind, at the origin of thoſe nerves in the brain. As a proof of this, if the optic nerve be compreſſed, ſo that its communication with the brain is hindered, objects are not ſeen, though their images are painted on the retina as uſual. Thus alſo, if by leaning the head on the hand, with the elbow reſting on a table, or by throwing one leg over another, certain nerves are compreſſed, the parts which they ſerve loſe their ſenſe of feeling, as every one muſt have obſerved; which alſo ſhows, that it is not the organ of ſenſe, but the mind ſeated at the origin of the nerves in the brain, that perceives. The

fibres

Plate II. to face p. 161.

Fig. 10.

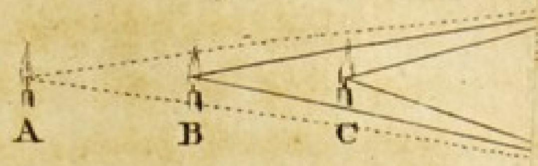
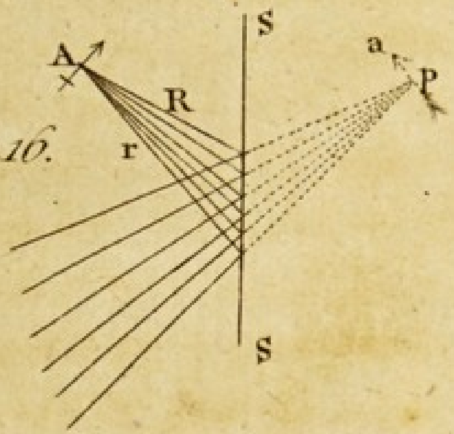


Fig. 12.

Fig. 16.



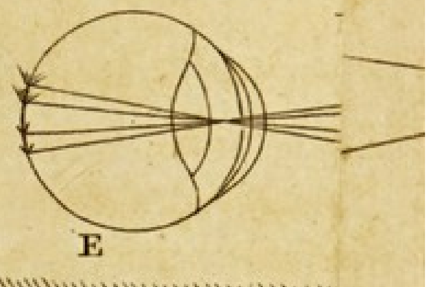


Fig. 24.

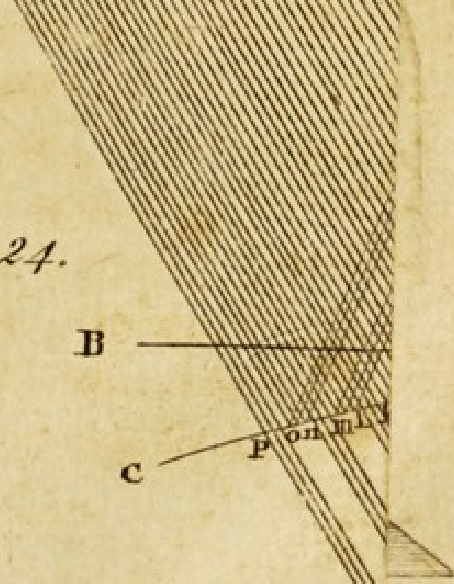
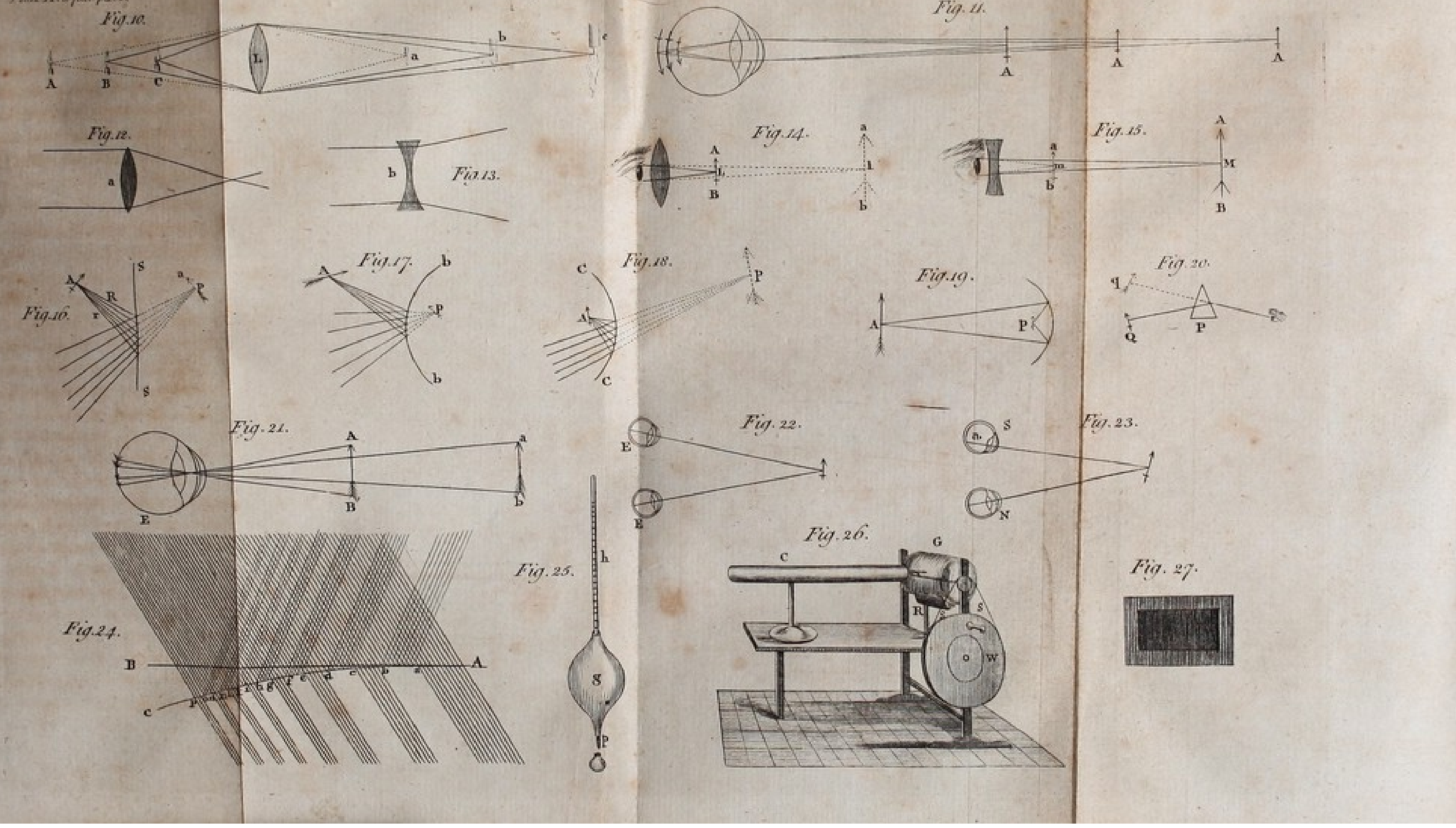


Plate II. to face p.161.



fibres of the optic nerve, when they arrive at the ſenſory, are diſpoſed in a contrary ſituation to what they are in the eye, thoſe fibres that are on any one ſide of the retina going to the contrary ſide of the ſenſory; and hence objects are painted in the ſenſory in their true poſition.

You may form a crude idea of it by the 9th figure, where A, B, C, repreſents the retina of the eye, c, b, a, that of the ſenſory, the fibres A c, B b, C a, of the optic nerve, and of courſe the arrow a, b, c, being in a contrary poſition to what they are in the ſenſory; and even the figure of the retina is alſo inverted; for its concavity is outwards in the eye, but inwards in the ſenſory; and the concavity is *towards*, not *from* the perceiving principle, as I have elſewhere ſhewn *; for, by preſſing the centre of the eye, ſo as to excite the whole retina, I found that the luminous appearance cauſed thereby was concave, but that the concavity looked *towards* me, which again proves that it is not in the eye, but in the ſenſory that the images of objects are perceived; for the concavity of the retina of the eye looks the direct contrary way. There being an inſenſible ſpot in the retina, and no dark ſpot in an object viewed anſwerable thereto, is another argument that it is not the

M eye,

* In Philoſophical Obſervations on the Senſes, &c.

eye, but the mind at the end of the nerves in the brain that fees the object.

But to return to our fubject. It was fhewn before that the image of the candle refracted by the convex lens was not diftinct, except the paper was held at a certain diftance from the lens; and that the reafon was, that the paper muft be held in the focus of the rays, or juft where the rays meet in points, or pencils, if I may fo call them, before they crofs each other: for, that if the paper was removed from that focus either way, the image became confufed. The caufe of this confufion I alfo fully explained; but, previous to the application of it to vifion, it will be neceffary to purfue the fubject a little farther.

If the lens be held at a certain diftance from the candle, and the paper at a certain diftance from the lens, the image on the paper will be diftinct. If now you keep the paper at the fame diftance from the lens, and bring the candle nearer, its image on the paper will begin to be lefs diftinct, and its confufion will be greater as the candle is brought nearer to the lens. Alfo, if the candle be returned to its firft diftance, and then removed the contrary way, or farther from the lens, the image will become more and more confufed, in like manner as when it was brought nearer. The reafon of this is, that

that when the candle is nearer to the lens, the focus falls at a greater diſtance than when it is removed farther off. Let L be the lens (fig. 10.) and A, B, C, the candle at three different diſtances from it; the focus, in theſe caſes, will fall at a, b, and c, reſpectively, as you will find by tracing the refractions of the rays from theſe ſeveral diſtances, according to the foregoing rules; and conſequently the diſtance of the paper from the lens, in order that the image may be painted diſtinct, muſt be varied, according to the diſtance of the object from the lens. If you look on the figure, you will alſo find that the angle which the rays make with the lens, is greater according as the diſtance of the object is leſs, and the focus of the rays is nearer to the lens according as that angle is leſs. The diſtance of the focus therefore depends on the angle which the rays, iſſuing from a point of an object, make with the lens.

For the ſame reaſon that the focus varied its diſtance from the lens, according to the diſtance of the candle from it, the focus of the rays refracted by the eye muſt alſo be nearer to, or farther from, the cryſtalline humour (which is likewiſe called a lens) according to the diſtance of the object from the eye: for when the object is at a greater diſtance, the focus muſt be nearer; and when the object is leſs remote, the focus muſt be more diſtant. But yet in order to ſee objects diſtinctly or clearly, the retina as well as the paper in the above experiments, muſt be exactly in the focus of the rays; for if this does not happen, it is obvious that the pictures of thoſe objects cannot be formed on it diſtinct; and yet diſtinct viſion depends on the perfection of the images of the objects looked at, on the retina. But if the arrow A, fig. 11, be moved nearer to the eye, or farther from it, you ſee that in the latter caſe the focus does not reach the retina, and in the former it would fall beyond it; conſequently, as the image in either of theſe caſes would be confuſed, the arrow could not be diſtinctly ſeen; but it is well known that we ſee an object equally well in proportion to its apparent ſize, whether its diſtance from the eye be greater or leſs. Thus, the arrow when at two yards diſtance does not appear more confuſed than when only at one. The reaſon of this difference is, that the glaſs lens retains the ſame figure or ſhape, whatever be the diſtance of the object, and therefore, according to the laws of refraction, the focal diſtance muſt vary as above. But the eye has the wonderful faculty of adapting its figure to the diſtance of the object, ſo as always to have the retina in the focus of the rays; and this is effected by means of the cryſtalline humour, which ſerves the purpoſe of a convex lens. When the object is at a diſtance, and the focus would fall ſhort of the retina, the cryſtalline lens forms itſelf into a leſs convex figure, and therefore refracts the rays leſs; ſo that the

focus

focus is made to fall more diſtant than it would naturally do. But when the object is near, and the focus would naturally fall beyond the retina, the cryſtalline lens becomes more convex, ſo as to refract the rays more, and bring the focus nearer, ſo that whatever be the diſtance of the object, the focus, by means of this admirable contrivance, always falls on the retina; and of courſe the object, at whatever diſtance, is ſeen diſtinct.

The uſe of a convex lens is to make rays converge or approach nearer to each other, as hath been ſhewn; and the greater its convexity, the more does it increaſe their convergency: but a concave lens, on the contrary, cauſeth rays to diverge or recede from each other, and the more ſo, as the concavity is greater. The figures 12 and 13 repreſent ſuch lenſes; the rays falling on them in parallel directions, are turned from their parallel, to a diverging tendency, by the concave lens *b*, and to a converging tendency, by the convex lens *a*. The reaſons of this difference will eaſily be underſtood by tracing the refraction of a ray falling obliquely on each of theſe glaſſes, according to the rules already laid down.

People advanced in years are generally obliged to uſe ſpectacles. Of ſpectacles however, there are two kinds, thoſe made of *concave*, and thoſe made of *convex* glaſs lenſes. When the eye becomes old, it ſhrinks or loſes part of its plumpneſs or convexity; ſo that it cannot, even with the aſſiſtance of the change of figure of the cryſtalline humour, ſufficiently refract the rays, and therefore they will converge to points beyond the retina. A convex lens increaſes the convergency of the rays, and therefore if placed before the eye, will cauſe the focus to fall nearer to the cryſtalline humour. The ſpectacles uſed by aged people are therefore made of convex lenſes. But the eyes of ſome are more withered than thoſe of others, and thoſe in whom this defect is greateſt, require lenſes of a more convex figure in order to make the rays converge to the retina. Hence the reaſon why the ſame ſpectacles will not ſerve for different people; and we find that opticians number their ſpectacles according to the degrees of their convexity.

There are likewiſe many people who are *near ſighted*, the defect of whoſe eyes is directly the reverſe of thoſe juſt diſcourſed of. For they are too plump or convex, ſo that they converge the rays before they arrive at the retina. Now the concave lens, by increaſing the divergency of the rays before they enter the eye, prevents their being converged ſo ſoon as before; and hence according as the eyes are more plump, ſpectacles of greater concavity are required, in order that the foci of the rays may be made to fall on the retina;

retina; which, as hath already been ſhewn, is neceſſary to diſtinct viſion. As the eye naturally grows flatter by age, the ſight of theſe people mends as they become older, and therefore they are ſaid to have the moſt laſting eyes.

Having thus given a general idea of viſion, I ſhall now proceed to explain ſome of the particular phenomena thereof.

You may have obſerved, that objects appear through convex lenſes at different diſtances from what they do to the naked eye. Thus, the object *L*, fig. 14, when ſeen by the naked eye, appears at *L*; but if a convex lens be placed before the eye, the rays, after refraction, if they were continued on in ſtrait lines, would not meet at *L*, but at the point *l* beyond it, at which place the object will appear; for you may gather from what has been ſaid before, that "*an object always appears in that place to which the rays would converge, or from which they would diverge, in falling on the eye.*" It has already been ſhewn, that according as an object is more diſtant, the angle which the rays iſſuing from a point thereof, form with the eye is leſs; now the eye judges of the diſtance according to that angle. As the apparent diſtance therefore depends on that angle, it follows that the eye muſt form the ſame judgment of the diſtance of the object *l*, whether the rays *really* flow from that diſtance, or only *ſeem* to do ſo; and hence we have the cauſe of many curious deceptions of viſion. Thus, a concave lens (fig. 15.) makes an object appear nearer, becauſe by diverging the rays, it makes them flow as from the point *m*, leſs diſtant than *M*, the point from whence they diverged before.

If an object behind you be ſeen by reflection from a common, or plane mirror, it does not appear as upon the ſurface of the glaſs, from whence the rays really come, but as far beyond that ſurface as the object itſelf is diſtant from it. Let *S S*, (fig. 16.) be the ſurface of the mirror, *A* the object, and *R r* rays flowing from a point of that object to the glaſs from whence they are reflected to the eye. If the rays were continued from the eye, according to the dotted lines, they would meet in the point *p*, and therefore the object muſt appear as at *a*, as we find to be the caſe.

If the ſurface of the mirror be not plane, but convex, as *b b*, (fig. 17.) the rays will be more diverged after reflection from the glaſs to the eye, and therefore if continued, would meet in a point *p*, nearer to the eye than in the laſt caſe, and hence the object would ſeem to be nearer.

On the contrary, if the ſurface be concave, as *C C*, (fig. 18.) the rays will be rendered leſs diverging as they flow from the glaſs, than by the plane

plane mirror, and therefore the point p, at which they would meet, would be more diſtant; ſo that the object would appear more remote. But if the concavity be ſo great as to render the rays converging, as they flow from it to the eye, the point will be before the ſurface as at p, fig. 19, and therefore the object will appear leſs diſtant than the glaſs.

If the object Q, (fig. 20.) be viewed through a glaſs priſm P, it will not appear at Q, but at q, the point to which the rays after refraction would converge. So the ſhilling in fig. 2. appeared to be removed out of its place. Hence alſo a ſtick partly placed in water does not appear ſtrait, as before, but bent; and other inſtances of the changes of place, or diſtance of objects, by reflection and refraction, may be underſtood by means of this rule.

You may likewiſe have remarked, that objects when ſeen in ſome caſes of reflection and refraction, appear to be bigger or leſs than naturally. Thus, an object ſeen through a convex lens appears bigger; and through a concave lens leſs. You will underſtand the reaſon of this, by obſerving that the points of which their images are compoſed, are by the refraction or reflection, removed further from, or brought nearer to each other than before. Thus, the points of the arrow a b, in fig. 14, are, by means of the convex lens,

lens, removed farther from each other, than in A B, and by the concave lens in figure 15, brought nearer to each other than in A B, and of courſe the object muſt appear larger in the former, and leſs in the latter caſe, than to the naked eye. For like reaſons a concave mirror makes objects appear larger, and a convex one ſmaller than naturally. On theſe principles the conſtruction of teleſcopes, and other magnifying glaſſes depend.

The image of the ſame object in the eye is leſs, according as the diſtance is greater. Thus, let E, fig. 21, be the eye, A B an object at a certain diſtance from the eye, and a b, the ſame object, at twice that diſtance; the image in the retina in the latter caſe is but half the length of that in the former. You may prove this by placing two ſticks of equal lengths, one at a yard, the other at two yards diſtance from the eye, ſo that the lower ends of them may appear parallel, and you will find that the nearer one has twice the apparent length of the farther. The reaſon of this is, that the angle formed with the eye by the rays proceeding from A B is greater than that formed by the rays from a b. The angle which an object forms with the eye is called the *viſual angle*; this angle is diminiſhed as the ſame object is removed to a greater diſtance, and alſo when viewed through a concave lens, or by reflection from a convex mirror; on the contrary, in proportion

as

as the object is brought nearer, and when it is viewed through a convex lens, or from a concave mirror, the visual angle is greater. The apparent size of an object therefore, is according to this angle. But when this angle becomes too large, the whole of an object cannot be seen; thus, if we stand near a church, only part of the church can be seen at a time. And when it becomes too small, objects cease to be visible; thus the animalculæ in vinegar are not perceptible, because the angles which they make with the eye are too small. A microscope, by encreasing those angles, renders them visible; and glasses might also be contrived, with concave lenses, to render visible objects invisible, by decreasing their visual angles. You may observe that the increasing or diminishing the visual angle of an object is the same thing in effect with removing the points of the image thereof to a greater or less distance than naturally, as mentioned in the last paragraph.

When an object is strongly illuminated, the pupil of the eye contracts or becomes less, in order that less light may be admitted; and on the contrary, when the object is but faintly illuminated, the pupil dilates, in order that more light may be admitted, and the image painted stronger. If it was not for this contrivance, the eye would be hurt by the great quantity of light in one case; and objects would not

be

be visible, on account of the rarity of it, in the other.

At an equal height with your eyes, against a wall, make two small spots, with ink or otherwise, about four inches distance from each. Close one of your eyes with your finger, and with the other look at that spot which is opposite to the eye closed; move backward or forward, and at length when you have hit the proper distance, the spot not looked at, will intirely disappear. The reason of this is, that the part of the retina where the optic nerve enters is insensible; and in course rays of light, or images of objects falling on that part are not perceived. This spot is in that part of the retina which is next the nose. Yet if a quire of paper or the like be held before the eye, we do not perceive any hole or dark spot in the side of it furthest from the nose, answerable to this insensible spot in the retina, as should seem to be the case; which further proves what I formerly explained, "that vision is not made in the eye, but in "the sensory. And it appears from hence that there is no vacuity or insensible spot in the retina of the sensory, though there is in that of the eye.

Hitherto I have considered the eye as single. I shall now consider vision with respect to both eyes.

It

It muſt be underſtood then, that every part of the retina of one eye has a correſponding part in the other; ſo that when the image of the ſame object falls, in the ſame manner, upon the anſwerable parts of both eyes, only one object is perceived, as if the image had fallen upon one eye only. Thus, if you look at a ſhilling, you ſee it with both eyes at once, as you may prove by ſhutting one of them, and yet with both eyes you ſee only one ſhilling.

It was ſhewn before that viſion is not made in the eye, but by the nervous expanſion in the *ſenſory*. If you imagine each of the fibres of the optic nerve, of which this is formed, to be double, or compoſed of two, one of which goes to the anſwerable part of each eye, you will be able to form a very clear idea of this phenomenon; and that this is the caſe, appears by the following experiment. Look at any object, ſuppoſe the flame of a candle, ſteadfaſtly with both eyes, you behold it ſingle; but force one of your eyes, out of its poſition with your finger, the object is no longer ſeen ſingle, but two flames are beheld inſtead of one; and the more the eye is forced out of its direction, the more diſtant from each other will the two flames appear. And this ought to happen, according to the theory; for the image of the object in one eye, can now no longer fall on the correſponding part of the other; and this variation muſt needs be greater, according

ing as the eye is forced more aside, as appears by experiment to be the case.

If you fix any object against a wall, or otherwise, and let a person stand very near it, looking at it steadfastly, so as to view it single, and if then he removes backward, still looking at the object, you will find that when he was near it, his eyes were turned more towards each other, than when he was at a distance, and that his eyes as he retired, continually receded from each other. Now in order to see an object well, its image must fall on the centre or middle part of the retina. If any person looks at an object with one eye, you will find that he turns his eye directly towards it; for though it may be seen otherwise, yet it is not seen distinct or clear, as will be found upon trial. If you imagine a right line perpendicular to the centre of the retina, that right line will pass directly through the center of the eye to the object beheld, and this line is called by opticians the *optic axis*. When you see an object singly with both eyes, the two optic axes meet in the object; or in other words "the "image of that object is then painted exactly "on the corresponding parts of the centres of "both eyes." Consequently when the object is near, the optic axes must meet near, or form a greater angle, for which purpose the eyes must be turned more towards each other. But when the object is remote, the axes must meet at a greater

greater diſtance, and therefore the eyes muſt be turned more away from each other as the 22d figure will alſo more fully explain, for unleſs the optic axes meet in the object, the images of the object are not painted on the corresponding parts of both eyes, and of courſe the object will not be viewed ſingle; the contrary of which always happens when the axes meet in the object. We have therefore, you find, ſeveral ways of judging of the diſtances of objects by viſion. 1. By both eyes, according as they are turned more away from each other to view them ſingly; 2. By each eye, according as it muſt alter its figure for throwing the image of the object diſtinctly on the retina; and, 3. By the ſmallneſs and indiſtinctneſs with which objects of a known ſize appear. Thus, diſtant hills appear ſmaller and more obſcured by miſts, &c. than when they are near, and thence are known to be remote; and there are alſo other auxiliary methods of judging of the diſtances of objects; as by compariſon with others whoſe diſtances are better known, and the like.

In ſome people we find that the eyes are naturally diſtorted, or they *ſquint*, and yet they ſee objects ſingly as well as others who have not that deformity. In theſe people, the globe of one of the eyes is turned awry with reſpect to the retina, ſo that the optic axis coming from the centre of the retina, does not paſs through the centre

centre of the cornea, or globe of the eye, as happens when the eye is perfect; and therefore when the images fall on the correſponding parts of both retinæ, the eyes will not appear to an obſerver to look the ſame way. Thus, in fig. 23, *S* is the ſquinting eye, *N* the natural one. The optic axis of *S* does not paſs through *a*, the axis of the globe, but on one ſide of it, and of courſe in order that the images may fall on the correſponding parts of both retinæ, that eye muſt be turned ſo as to appear diſtorted. In ſome caſes however, theſe people only ſee objects with the ſound eye, the image in the other falling on the inſenſible ſpot at the entrance of the optic nerve, already deſcribed.

If the retina loſes its ſenſibility, as ſometimes happens from an oppreſſion of the optic nerve, or other cauſe, no objects will be ſeen, though their images are thrown on the retina as uſual; or in other words a total blindneſs will take place; and if the ſenſibility be loſt in part, viſion will be leſs ſtrong in proportion. Alſo if any particular part of the retina ſhould happen to loſe its ſenſibility, either wholly or in part, a partial blindneſs, or defect of ſight, will enſue; the other parts of the retina enjoying their power of viſion as uſual.

If either of the coats or humours of the eye becomes totally opake, viſion will alſo be loſt, becauſe becaufe no rays can then pafs to the retina. And if the opacity be imperfect, the fight will become more obfcure in proportion. Sometimes the cryftalline humour becomes opake, but if it be removed by extraction, the fight will be reftored, except that a convex glafs lens is required to be ufed, to fupply the place of the humour loft. This is not requifite when the aqueous humour is extracted, as that humour foon regenerates; which the cryftalline does not.

In fome cafes the opacity is not total, but only partial; and fometimes there is a difficulty of knowing in what part of the eye the opacity exifts. The doctrine of vifion already explained will affift in afcertaining it.

When large particles float in the aqueous humour, gnats, flies, webs, and the like, feem to float before the eyes.

When a perfon has the jaundice, and the eye becomes tinged yellow, the objects feen appear alfo to be tinged with that colour.

OF THE COLOURS OF LIGHT.

Into fuch an hole of a window-fhutter as was defcribed at the beginning of this chapter, let a beam of the fun's light be admitted, and it will paint a round *white* fpot on the oppofite wall.

 But

But if the beam paſſes through a glaſs priſm, ſo that it may be properly refracted, the round ſpot will be changed into an oblong one; and inſtead of being white, as before, it will appear of various colours; its lower part will be red, its upper part violet, and the intermediate parts of other colours. If other priſms are uſed ſo as to refract the beam again ſufficiently, the colours will be found to lie in the following order; *red*, *orange*, *yellow*, *green*, *blue*, *indigo*, *violet*, the red running gradually through all its ſhades into orange; the orange into yellow, and the others into thoſe next following, till we come to the deepeſt violet. From whence it is plain that light conſiſts of rays of various ſorts; ſome of which are more refracted by the priſm than others, the red making rays leaſt, the violet moſt, and the others intermediate to thoſe according as they ſtand in the above ſeries.

The rays of light therefore are not alike, for it appears that ſome of them are more, others leſs eaſily refracted by the priſm. Theſe different rays have alſo the property of cauſing different colours in the eye, the leaſt refrangible ones cauſing red, the moſt refrangible violet, and the others other colours according to the order deſcribed above; and all the colours in the univerſe depend on this diverſity of the rays. When all the rays are mixed together they cauſe a white colour, and hence the light of of the ſun, which is compoſed of all ſorts of rays, appears white. If the blue and yellow-making rays are mixed together they cauſe a green. If red and violet ones are thus mixed they cauſe a purple. And mixtures of other rays produce other colours. The colours of all bodies depend on the kind of rays which they reflect to the eye. Thus paper reflects all the rays equally, and thence appears white. But if we put a ſlip of paper in the red part of the *ſpectrum* (for ſo the long ſpot of coloured light made by the refraction of the priſm is called by opticians) we find that it no longer appears white, but red, becauſe now it reflects only the red-making rays to the eye. If we place it in the blue part of the ſpectrum, it appears blue, by reaſon that it now reflects only the blue-making rays. Sealing-wax naturally appears red, by reflecting moſt copiouſly the red-making rays, but if it be held in the blue part of the ſpectrum, it appears no longer red, but blue; and the like may be obſerved of other bodies. Painters knew part of this doctrine by practice, long before the theory was found out. Thus by mixing a blue and yellow colour together, they compound a green. Red and blue, a purple; and by mixing ſeveral compound colours, which, together, contain all the original colours mentioned above, in proper proportions, they form a white, and the like. That is, thoſe mixtures reflect the rays producing thoſe reſpective

 colours

colours to the eye, and thence appear to us of thofe colours.

If water be made tenacious with foap, and then blown into a bubble, it is well known that after a while a variety of colours will appear. Thefe colours depend on the thicknefs of the coat of the bubble, and vary continually as the thicknefs decreafes.

To explain the reafon of this, let *A*, *B*, *C*, (fig. 24.) reprefent a thin plate of air between two glaffes, the upper one *A B* being plane, and the lower one convex; and let the lines inclining from the right to the left reprefent the red-making, or leaft refrangible rays, falling, without any others, on the plate of air. It will be found that from the concourfe of the glaffes *A*, to *a* the rays will pafs through that plate, or be tranfmitted; but from *a* to *b* they will be reflected. From *b* to *c* they will be tranfmitted; but from *c* to *d* they will be reflected; and fo on alternately, according to the thicknefs of the plate of air.

In like manner, if upon the bubble of water, we throw only the red-making rays, the bubble will not become varioufly coloured, as is the cafe when rays of all forts fall on it, but rings of red and black alternately will be feen. The red rings are caufed by the rays reflected at thofe thickneffes of the bubble, the black ones arife becaufe no rays are reflected at thefe thickneffes; and if the bubble be viewed on the contrary fide,

or

or by the tranſmitted rays, thoſe parts which by the reflected light looked red, will now appear black; and contrariwiſe.

When therefore the rays entered the air any where between *A* and *a*, they preſerved their diſpoſition to be tranſmitted till they arrived at the further ſurface of the air, and therefore were tranſmitted. But when they entered the air at the thickneſs any where between *a* and *b*, they loſt their diſpoſition to be tranſmitted by the time that they arrived at the further ſurface of the plate, and therefore were not tranſmitted, but *reflected*. The like may be obſerved of the thickneſſes, *b*, *c*; *c*, *d*; *d*, *e*; &c. but the thickneſs *c d* being double that of *a b*, the rays muſt have had two fits or diſpoſitions to be reflected in their paſſage through the latter thickneſs, and for the ſame reaſon they muſt have had two fits or diſpoſitions to be tranſmitted during their paſſage through the thickneſs *b c*; and ſo in proportion for a greater thickneſs. From hence it appears, that the rays of light do not move on uniformly, but by fits, or ſtarts; that if they arrive at the further ſurface of the plate in the progreſſive fit, they break through that ſurface and ſo are tranſmitted; but that if they arrive at that ſurface between theſe progreſſive fits, they are on the contrary reflected. This pulſatory motion of a ray of light is called the *vibration* of the ray.

The rays of light of all other colours move on in like manner by fits or ſtarts, or have a like vibratory motion, but with this difference, that their vibrations are ſwifter; that is, they have a greater number of them in the ſame time, or in moving through the ſame ſpace, than the red-making ones. The violet-making rays, for example, vibrate almoſt twice as ſwift as the red; that is, though they move on with the ſame velocity as the red, yet in moving through the ſame ſpace they make almoſt twice the number of vibrations. Hence the violet rays begin to be reflected at a leſs diſtance from *A* than the red ones, at *x* for example; and begin to be again tranſmitted at a leſs diſtance than *b*, or even within *a*, and ſo on continually; and the times of vibration of the other rays, and of courſe the ſpaces or diſtances from *A*, at which they begin to be reflected and tranſmitted, are greater than thoſe of the violet, in proportion as thoſe rays are nearer to the red ones in the ſpectrum; that is, in the order of violet, indigo, blue, green, yellow, orange, and red. Agreeable to this theory we find that in the bubble of water on which all ſorts of rays fall, the red in every order of the colours is outermoſt, and the violet inwards; the other colours lying between, according to the order of their reflection as above; ſo far at leaſt, as from their mixture in ſo ſmall a compaſs they can be diſtinguiſhed from each other.

From this curious theory we have the cauſe of the colours of bodies; the particles of which, according to their different ſizes or thickneſſes, reflect rays of different colours to the eye, on the ſame principle as theſe colours are exhibited by different thickneſſes of the bubble. Sir Iſaac Newton, to whoſe tranſcendent genius we are indebted for this theory, has even calculated the thickneſſes of a bubble of water, and of the particles of bodies, requiſite to their exhibiting the various colours.

From hence alſo we are furniſhed with the ſolution of a variety of phenomena in chemiſtry. If an acid be added to a blue vegetable infuſion, as ſyrup of violets, it changes its colour to red. If an alcali be added to the ſame ſyrup, it alters the colour to green; which ariſeth from hence, that the ſizes or thickneſſes of the colouring particles of the ſyrup are in theſe caſes varied by the reſpective additions, ſo as to cauſe them to reflect rays of different colours. The particles of venous blood exhibit a deep red; but by expoſure to air, and the conſequent loſs of their phlogiſton to that fluid, their ſizes or thickneſſes are altered ſo as to reflect thoſe rays which conſtitute ſcarlet. By mixing chemical liquids, 'tis well known that a variety of odd changes of colour ſucceed, which are eaſily accounted for by this theory. But for farther information in this curious doctrine the reader is referred to the illuſtrious author juſt mentioned, and alſo to the ingenious Mr. Delaval's treatiſe on colours. I have only introduced thus much of it to explain the vibrations of the rays of light, the underſtanding of which will be neceſſary to what will be advanced in a future chapter relating to viſion.

I have now gone through as much of the delightful ſcience of optics as is neceſſary to the illuſtration of the doctrine of viſion; with the following particular therefore, I ſhall cloſe this chapter.

The refrangibility of the rays of light as above deſcribed, is cauſed by the attracting power of the priſm; and as the violet-making rays are moſt refracted, and the red-making ones leaſt, it follows that the former are ſo conſtructed (whether by being compoſed of ſmaller particles, or otherwiſe) as to be more eaſily drawn out of their right-lined direction.

When incombuſtible bodies are heated, it is well known that they ſhine, or emit light. They are then ſaid to be *ignited*. Now the rays that are leaſt refracted by bodies are moſt eaſily expelled in ignition; for bodies when heated, firſt ſhine with a red-coloured light; and this argues that as the red-making rays are leaſt attracted by the priſm, ſo the particles of which they are

compoſed

composed are retained by bodies with least force. As the heat increases, the particles which constitute the more refrangible rays begin likewise to be expelled, and by their mixture with the others, the red colour of the body verges more towards white; and when the heat is sufficient, so as to expel all the particles equally alike, the colour must be white; hence the body is said to be *white hot*.

But the flames of phosphorus, of sulphur, and of some other bodies are not ignited, for if they were, they would shine with a colour somewhere betwixt reddish, and white, for reasons just given. On the contrary, their colours are *blue*: their light therefore must be emitted on a different principle from that of ignition.

To understand the reason of this, suppose that either *the inflammable body*, or *the air*, contains a quantity of particles of light; and that in the process of combustion it is transferred from the one of those substances to the other. But that the quantity extricated from the one, is greater than the other can absorb. That therefore which is not absorbed will fly off, or appear, under the form of *light*.

As in ignition bodies retain the blue light most powerfully, and part most easily with the red,

red, and other particles which compofe the lefs refrangible rays, fo in combuftion the abforbing fubftance will, for the fame reafon, moft eafily acquire the particles which compofe the lefs refrangible rays; with which being firft faturated, the others remain behind as the fuperabundant particles above fpoken of, to be driven off in the form of *light*. The flame therefore muft appear of a *blue* colour, as we find by experience to be the cafe.

From hence therefore it appears that light exifted in a latent ftate, either in the air, or the inflammable body, as was mentioned before. For that part of it which was not abforbed, affumed the form of the more refrangible or blue-making rays; and of courfe, if that which was abforbed had alfo refumed its luminous ftate, it would have conftituted thofe rays which are lefs refrangible.

It may be obferved, that thofe flames which are hotter than the above, as of tallow, oil, &c. are alfo *ignited*; and therefore their colours are compounds of the lights of ignition and of combuftion.

The blue light of the *latter* may be feen at the bottom of the flame. For the particles take fome little time to become red hot; and therefore

fore they do not begin to emit the light of ignition till they have aſcended ſome little way up the vapour. When the flame is ſufficiently minute, nothing but this blue light is ſeen.

CHAPTER II.

OF

SOUND.

SOUND is demonſtrated by philoſophers to depend on the air: for if a bell be ſtruck in a veſſel exhauſted of air, it yields no ſound.

I have already ſhewn that the particles of air are elaſtic, or that they *repel* one another, and therefore are kept at a diſtance from each.

If a muſical ſtring, ſtretched ſufficiently tight, be drawn into a curved figure, and then let go, it cauſeth a ſound.

The ſound is occaſioned by the vibration of the ſtring, or motion of it continually to and fro, in the manner of a pendulum, till it returns to a ſtate of reſt.

As

As the ſtring moves to and fro, it drives the particles of air contiguous, a little forward. Theſe particles urge on thoſe next them, thoſe again others, and ſo on to a diſtance, till the force of the ſtroke is ſpent. Hence

1. The effect of one ſtroke or pulſe will be propagated to a greater diſtance, according as that pulſe is ſtronger. Thus loud ſounds are heard at a greater diſtance than weak ones.

2. The effect of a pulſe or ſtroke, is propagated through the air in *time*, and the time is greater according to the diſtance. For it muſt take up twice the time for a pulſe to be propagated two miles than one. Hence when we are at a diſtance we ſee an object ſtruck, or view the flaſh of a gun, ſome time before we hear the ſound, and this difference is greater according as we are at a greater diſtance. Sound moves about 1142 feet in a ſecond; and all ſounds, whether ſtrong or weak, move with equal ſwiftneſs; the particles of air, like a pendulum, vibrating in equal times, whether the latitude of that vibration be greater or leſs.

3. For while the ſtring is going back after the ſtroke, the particles of air, which it immediately impelled, return to their former places, or rather beyond, in the manner of a pendulum; and the particles beyond theſe do the ſame in a continual

continual ſucceſſion, according to their diſtance; but when the ſtring returns, it again drives them forward as before, and ſo on alternately, as long as the ſtring continues to vibrate. This agitation is propagated alike on every ſide, from the ſtring through the air.

This reaſoning however, is ſomewhat abſtruſe. In order therefore to form a clearer idea of this matter, drop a ſmall round pebble into a pond of water; immediately a ring, or circle will be ſeen, propagated from that point, and ſwelling, or extending itſelf to a diſtance. This ring is ſucceeded by another, that again by another, and ſo continually, till the effect ceaſes. If inſtead of rings, or circles, hollow ſpheres be imagined to flow in like manner, from the vibrating ſtring, it will give a proper idea of the manner in which ſounds are propagated through the air. But as air is above 800 times rarer than water, the waves or pulſes of air, move above 800 times as faſt as thoſe of water. The ſounds of all other bodies are cauſed by like vibrations of the bodies, and thoſe vibrations cauſe ſpherical waves or pulſes in the air, in the ſame manner as hath been deſcribed of muſical ſtrings.

Some ſounds are more acute or ſhrill; others lower, or more grave. Thus, a woman ſings in an high, ſhrill voice, but a man much deeper; or the difference may be ſtill better illuſtrated, by by means of an harpſichord or organ. The treble keys, or thoſe on the right hand, cauſe higher notes; and the baſs keys, or thoſe on the left, notes which are deeper; and there is a regular gradation of them, from the higheſt, or moſt ſhrill, to the loweſt, or moſt grave.

The ſtrings which yield the high notes are ſhorter, ſmaller, and drawn tighter than thoſe which give the low ones; the vibrations of the deepeſt baſs ſtrings are ſo ſlow that they may be ſeen by the eye. They are ſwifter as we approach towards the treble ſtrings, and in theſe latter, the vibrations are ſo ſwift, that the eye can no longer diſtinguiſh them. The ſounds therefore are higher in note, according to the ſwiftneſs of the vibrations of the ſtrings; and the like may be obſerved of the ſounds of other bodies. Now as every vibration of the ſtring cauſeth a wave or pulſe in the air, it follows, that the acuteneſs of the ſound is greater, according as theſe pulſes, or waves ſucceed each other more ſwiftly on the ear; or according as there are a greater number of them in a given time. Pulſes that are twice as ſwift as others, cauſe ſounds which are octaves. Pulſes which are four times as ſwift as others, cauſe double octaves, and ſo on.

Two ſounds whoſe pulſes ſucceed each other, equally ſwift, are *uniſons*; their pulſes happening

at

at the ſame inſtant of time, and hence an uniſon is the moſt perfect concord in muſic.

Two ſounds whoſe pulſes are in ſwiftneſs as two to one, are octaves. Their pulſes meet at every ſecond vibration of the ſwifteſt, and at every vibration of the ſloweſt. This therefore is the ſecond concord in muſic.

The ſounds whoſe pulſes are as three to two, meet at every ſecond of the ſloweſt, and at every third of the ſwifteſt. This concord is called a *fifth*, and is the third and laſt perfect concord.

Sounds whoſe pulſes are as four to three, as five to four, as ſix to five, &c. are leſs harmonious when ſounded together, than the concords, and are therefore called *diſcords*, and they are more diſcordant, according as their pulſes meet leſs frequently. They are uſed in muſic to give a variety to the concords, which would otherwiſe be too luſcious for the ear.

On this coincidence of pulſes depends another curious property of ſounds. If two muſical ſtrings are drawn into uniſon with each other, and one of them be put into vibration, it will cauſe the other alſo to vibrate, ſo as to yield a ſound. This ſecond ſtring is put into vibration by the pulſes excited in the air by the firſt, which pulſes correſpond with the times of vibration

vibration of this ſecond ſtring; the ſound of a flute, the voice, &c. in uniſon with a ſtring, would equally put it into vibration.

A ſtring will alſo be affected in this manner, though in a leſs eminent degree, by a ſound which is an octave to it; and in a degree ſtill leſs by a ſound which is a fifth. But as the coincidence of the pulſes is not at every vibration, the effect, eſpecially in the latter caſe, is not conſiderable; and therefore uniſons only are uſually conſidered in this view.

I ſhewed before, that light moves on in a right line; and when the ear is ſo ſituated, that the ſound may come to it, directly from the ſonorous body through the air, the ſound is heard directly in that ſituation. If four ſonorous bodies are placed eaſt, weſt, north, and ſouth, and no obſtacle intervenes, their ſounds are heard directly in the lines of their reſpective ſituations.

I explained likewiſe that light is reflected in an angle equal to that of its incidence, and the ſame happens with ſound. If a ſound coming from a body be reflected by a wall, or hill beyond us, the original and reflected ſounds are both heard in their reſpective ſituations. Echoes are ſounds reflected according to this law.

There

There is, however, this difference between light and ſound, that an object cannot be ſeen out of the right line, or in the ſhade. But ſound being made, not by the emiſſion of particles in right lines, like light, but by preſſion, or propagation through a medium, or fluid, which is on every ſide, ſounds may be heard out of the right line, or when the bodies yielding them are not ſeen, only they are heard to leſs advantage. Thus an echo is heard moſt perfectly at the place where the ſound is reflected in the angle equal to that of its incidence. But it may alſo be heard in other places.

When ſound paſſes through an hollow tube of a conical form, it is ſtronger, or louder at its exit through the ſmaller aperture, than it was at its entrance at the larger. The reaſon of this is obvious, the ſound being *condenſed* in its paſſage through the tube. On this principle, eſpecially when conjoined with the following, ear-trumpets are formed; the ſounds being collected by the large aperture of the tube, and thrown in a more condenſed form on the ear.

When ſound paſſes through a long tube, it is alſo ſtronger at its exit, than it was at its entrance. For as light reflected by mirrors is brighter and hotter, ſo, ſound reflected by elaſtic bodies, is made ſtronger, or louder than before. The ſound in paſſing through the tube is continually reflect-ed by the ſides thereof, and of courſe condenſed and ſtrengthened in the axis. Hence ſpeaking-trumpets, horns, &c. encreaſe the loudneſs of ſound.

When ſounds are weak, the tympanum has the faculty of becoming more tight, ſo as to receive a ſtronger impreſſion from them. On the contrary, when the ſounds are ſtrong, the tympanum relaxes, ſo that the impreſſion which they make on it may be leſs violent. This is analogous to the contraction and dilatation of the pupil of the eye in like circumſtances.

Diſtance is judged partly by the faintneſs and indiſtinctneſs of the ſound, and partly by other means not yet wholly diſcovered.

CHAPTER III.

OF

HYDROSTATICS.

IF a body be let fall in vacuo, it will deſcend towards the earth with the greateſt velocity or ſwiftneſs that the power of gravity is capable of giving it. A feather let fall in an exhauſted receiver deſcends to the bottom as faſt as a ſhilling.

But if the feather be let fall in a fluid, its deſcent will be hindered, and that more according as the fluid is denſer; ſo that if the fluid is of equal denſity with the feather, the latter will not deſcend; and if the feather be rarer than the fluid, it will, on the contrary, levitate, or riſe to the top. See likewiſe what was ſaid of ſpecific gravity in the introduction.

A feather and a ſhilling, in vacuo, deſcend with equal velocity. In air the feather hardly deſcends at all, becauſe of its rarity: whereas the ſhilling, being much denſer, is very little interrupted by the air in its deſcent. But in quickſilver, the ſhilling riſes to the top as well as the feather, though with leſs velocity.

Now the fundamental law in hydroſtatics depends on the force with which any body deſcends in a fluid. In vacuo this force is greateſt of all; in air 'tis leſs; in water ſtill leſs, and in quickſilver, or other denſer fluids, ſtill leſs than in water. The force of deſcent is called the *weight* of the body in the given fluid. And hence we ſay that any body, ſuppoſe gold, weighs lighter in air than in vacuo; lighter in water than in air, and lighter in quickſilver than in water.

If I would know the comparative weight of ivory in water and in air, I faſten the ivory by a ſlender thread to one of the ſcales of a balance, ſo as that it may hang down below the ſcale; I weigh it in air, and find that it weighs 60 grains. I now let the ſuſpended ivory down into water in a baſon, the ſcales themſelves remaining in the air, and find that the ivory weighs lighter in the water than it did in the air, the ſcale with the weights in it deſcending. I therefore add weights to the ſcale to which the ivory is ſuſpended, till the equilibrium is reſtored, and find that 31 grains are neceſſary for that purpoſe; 31 ſubtracted from 60, leaves 29; ſo that a piece of ivory, which in air weighs 60 grains, weighs, in water, only 29.

Solid bodies are weighed in fluids for the purpoſe of diſcovering their ſpecific gravities. I would know, for example, the proportion that the

the ſpecific gravity of ivory bears to that of lead. I take a piece of each of them, weighing in air exactly 60 grains each. By weighing them in water, I find that the lead loſes $5\frac{3}{4}$ grains, and the ivory 31 grains. Conſequently the ſpecific gravity of lead, is to that of ivory as 31 to $5\frac{3}{4}$, or in the inverſe proportion of their weights. That is, lead is above five times heavier than ivory. In this manner may the ſpecific gravities of ſolids be aſcertained. If the ſolid to be weighed is liable to be diſſolved in water, it may be weighed in ſome other fluid, in which it will not be diſſolved. In oil, ſpirit of wine, or quickſilver, for example.

By this method the comparative ſpecific gravities of ſolid bodies may be eſtimated. Thoſe of liquids may be diſcovered in a manner ſomewhat ſimilar.

The proportions of the ſpecific gravities of water, and oil of vitriol, for example, are required. I take a piece of lead, which in air, I find to weigh 455 grains. I weigh it in oil of vitriol, and afterwards in water, and the weights are 379, and 414 grains. The loſs of weight in the firſt caſe is 76, in the latter 41 grains; theſe numbers are inverſely as their ſpecific gravities; and of courſe the ſpecific gravity of oil of vitriol, is to that of water, as 76 to 41; that is, almoſt twice as great. It is by theſe means that the tables of ſpecific gravities of bodies are conſtructed, and their denſities known.

On this principle likewiſe, *hydrometers* may be conſtructed, which are ſo uſeful for diſcovering the purity of vinous ſpirits, and other liquids. If a piece of metal, glaſs, &c. be made hollow and thin, it will ſwim in a liquid ſpecifically lighter than itſelf; but with this difference, that the lighter the liquid, the deeper will ſuch a veſſel ſink, or be immerſed therein. Spirit of wine is lighter, according as it is more pure, and therefore the deeper ſuch an inſtrument ſinks in it, the greater is its purity. But the hydrometer moſt frequently uſed, is a thin, hollow globe of copper (*g*, fig. 25.) with the handle *h*. This globe is ſo contrived as to be barely ſuſtained in ſpirit of a certain purity or denſity, which therefore is called *proof*. If it ſinks in a ſpirit, the ſpecific gravity of the latter is too little, or it is above *proof*. If it requires an addition of weight to make it ſink, the ſpecific gravity of the ſpirit is too great, that is, it is not ſufficiently pure. And as heat, by expanding bodies, leſſens their ſpecific gravity, there are bits of metal, or the like, to be occaſionally ſcrewed on to, or taken from the point *p*, anſwerable to the degree of heat, and the conſequent change of ſpecific gravity of the liquid.

CHAP-

CHAPTER IV.

OF

ELECTRICITY.

Electricity is applied to medical purpoſes, and frequently with good effect. I ſhall therefore next proceed to give the reader an idea of that entertaining branch of philoſophy.

Bodies are divided, by writers on this ſcience, into *electrics* and *non-electrics*.

The electrics are glaſs, amber, roſin, ſulphur, air, ſilk, and certain other ſubſtances;

The non-electrics are metals, water, the earth, animal and vegetable fluids, &c.

Electricity is an exceedingly ſubtile and elaſtic fluid, which may be rendered ſenſible, by its effects, to the feeling and other ſenſes.

Electrics are impervious to the electric fluid. Non-electrics are readily pervaded by it. For this reaſon the latter are alſo called *conductors*, the former *non-conductors* of electricity.

It was ſhewn in a former chapter, that different bodies have different capacities for containing *fire*; and that at the common temperature ſome bodies retain a greater proportion of it than others. But that fire has a tendency to diffuſe itſelf over all bodies in ſuch a manner as to preſerve an equilibrium with regard to their capacities for containing it; or in other words, till thoſe bodies are reſtored to an equal degree of ſenſible heat. When an hotter body is applied to a colder one, the former loſes, and the latter gains heat, till the equilibrium between them is reſtored.

The ſame rule obtains with regard to electricity. Some bodies naturally retain more of it than others*; but yet there is a like tendency to an equilibrium, as in the caſe of fire; with this difference, that whereas it is ſome time before the equilibrium is reſtored with reſpect to heat, in electricity it is effected in an inſtant.

The equilibrium is deſtroyed by ſeveral methods; but that uſually employed is *friction*.

If glaſs, which is an electric, be rubbed with leather, a non-electric, the part of the ſurface of the

* This holds good not only with different bodies, but even with the ſame body in different ſtates, as was ſhewn with regard to fire. Thus glaſs is an electric in the ordinary temperature of the atmoſphere, but if made hot it becomes a conductor. Water is a conductor; but if frozen with a due degree of cold it becomes an electric; and this is alſo the caſe with water in its elaſtic ſtate.

the former which is affected by the friction, will become difpofed to attract * or receive the electrical fluid. It will therefore flow from the leather to the glafs; and of courfe from the non-electrics around to the leather, in order to reftore the equilibrium.

This increafed attraction, or difpofition of the glafs to receive electricity, however, is but momentary; for as foon as the friction is over, it diminifhes; and the glafs gives out, by degrees, the whole of the fluid which it had abforbed.

If feathers, or other light, non-electric fubftances, be applied to the glafs in this ftate, they violently attract its redundant electricity, and therefore the glafs itfelf which contains it. But as the glafs is heavy, and the feather light, inftead of the former moving towards the latter, the feather, as being moft eafily moved, will rufh upon the glafs.

But when the feather has taken fo much electricity from the glafs, as that an equilibrium obtains between them, they mutually repel each other, and the latter, being the lighteft, is driven away: nor will it be attracted again till it has touched fome other fubftance, to which it may

* The term *attraction*, though ftrictly fpeaking it may be improper, yet having been commonly ufed as being moft convenient for the comprehending of the phenomena of electricity, is here retained.

may impart its acquired electricity. Having done this, it is again attracted by the glafs, and afterwards repelled, for the reafons juft given: and this happens till the feather and glafs have only their natural quantities of electricity, when the attraction and repulfion ceafe.

To collect this fluid for the purpofe of experiments, philofophers have contrived the following apparatus.

A glafs globe *G*, (fig. 26.) is mounted, and furnifhed with a rubber *R*, as in an electrical machine. The rubber is a piece of leather, ftuffed, and faftened on a brafs handle, with a fpring, fo as to prefs againft the globe. A gun-barrel, or other non-electric body is *infulated*, (that is, fufpended by filken ftrings, or otherwife, fo as to have no communication with any non-electric;) one end of it armed with points, being at a fmall diftance from the globe. This is called the prime conductor (*C*). It may be obferved, that the rubber fhould alfo be infulated, or fixed upon baked wood, glafs, or the like, fo as not to be in contact with any other non-electric.

If the globe be whirled round by means of the wheel *W* and the ftring *S S*, a friction will take place between it and the rubber, and it will become difpofed to receive electricity; as mentioned before. It will therefore begin to draw the electric fluid out of the rubber; but as the parts

parts of the ſurface ſucceſſively rubbed, will alſo preſently begin to let it go again, it will be attracted by the conductor (*C*), and accumulated thereon. But when the fluid is all attracted from the rubber, the accumulation on the conductor can be no farther increaſed, and the proceſs is at a ſtand.

If however, the rubber be made to communicate with the floor, the earth, or any other non-electric, (as might eaſily be done, by means of a metal chain, or other conducting ſubſtance,) the electricity contained in thoſe bodies will flow to the rubber to reſtore the equilibrium. The globe may again be excited by friction againſt the rubber. The operation may be continued at pleaſure, and the fluid may be accumulated on the conductor in ſtill greater quantity.

It may at firſt view be imagined that the faſter the globe is whirled, the more electricity will be thrown on the conductor. But this will not happen when the velocity of the rotation exceeds a certain degree, becauſe the diſpoſition given to the parts rubbed, of abſorbing electricity, does not go off before theſe parts ſucceſſively arrive at the conductor; and to the effect in queſtion, it is neceſſary that they ſhould on the contrary have begun to *give out* their acquired electricity by that time.

As

As there is a violent tendency in the electric fluid to disperse itself in equilibrio in all bodies, according to their dispositions for retaining it, any non-electric applied to the conductor, having a less relative quantity of that fluid, will take from it so much of its electricity as to restore an equilibrium between them; or the fluid will rush with great violence from the conductor into the body, in order to restore that equilibrium.

The human body is a non-electric, and of course this will also be the case with it. If the finger, or any other part, be applied to the conductor, the fluid rushes with great violence into that part, and hence the uneasy sensation, or painful shock which is felt on those occasions.

If the person stands on a non-electric, the fluid will pass thro' his body into the floor, &c.

But if he stands on an electric, (suppose resin, or glass,) the fluid which he received from the conductor will remain in his body, being hindered from passing off by that electric, and by the air on every side around him, which is also an electric; and therefore he will be electrified as well as the prime conductor; and indeed an human body thus insulated, or placed on electric substances, might serve for a prime conductor, and

and receive an accumulated quantity of electricity.

If any person not electrified, or any non-electric, be applied to the person thus electrised, or, which is the same thing, if he steps on the floor, or touches any other non-electric not insulated, the fluid will rush from him into that other body, the same as it would from the conductor; and he will feel the same sensation at parting with the fluid as he did in receiving it from the conductor. 'Tis remarkable that a visible spark, and a snapping noise happen on these occasions, together with a sulphureous, or phosphoreal smell.

If the electrified person touches another who is insulated, or placed on electrics, the fluid will not pass off entirely, as happens where the person, or other non-electric touched is not electrified, but only half of the accumulated fluid will pass from the former into the latter, or so as to preserve an equilibrium of the fluid between them. Both these persons therefore will be electrified, but only half as much as the first was before such communication.

When a person is electrified, the fluid may be drawn off from him at any part by applying a non-electric substance to that part. Thus, if the finger, knuckle, a key, or the like, be applied to the eye, the fluid will be discharged through that

that organ. If it be applied to the ear, the fluid will be difcharged into it through the ear, and fo of any other part. Hence in medical electricity, we can draw off the fluid through any part that happens to be affected, and thereby are frequently enabled to do fervice, or even effect a cure. The fluid may alfo be received into an infulated body at any particular part. It may likewife be made to enter the body at any part, and pafs through, or out of it at any other part, by letting the prime conductor, and the non-electric properly communicate with thofe parts. Thus, if a finger touch the prime conductor, and the toe the floor, the fluid will enter the body at the finger, and pafs out of it at the toe.

When the human body, or other conductor, contains more of the electric fluid than it naturally would, it is faid to be electrified *pofitively*, or *plus*. But if it be made to contain lefs of that fluid than its natural quantity, it is faid to be electrified *negatively*, or *minus*.

It was fhewn, for example, that when the rubber is infulated, or has no communication with other non-electrics, the excited globe prefently draws away all the electricity which that rubber naturally contains, and which is again attracted from it by the prime conductor. The conductor therefore is electrified *pofitively*, or has *more* of the fluid than its natural quantity, the rubber on

the

the contrary is electrified *negatively*, or has *leſs* of the electric fluid than it would naturally contain. From whence it will eaſily be perceived, that whereas the conductor will *part with* electricity to any non-electric applied to it, the rubber will, on the contrary *attract* electricity from ſuch non-electric; theſe oppoſite affections of thoſe bodies being equally the effects of the tendency of the fluid to reſtore the equilibrium.

Thus, ſuppoſe three bodies, hot, lukewarm, and cold. The lukewarm body applied to the cold one, will communicate fire to it, till both become of an equal heat. But if the lukewarm be applied to the hot one, the latter will communicate fire to the former; and when the equilibrium is reſtored between them, they will both be hotter than naturally, as in the other caſe they were colder.

In like manner, if the human body, or other non-electric, *inſulated*, touch the prime conductor, part of the fluid will ruſh from the conductor into the body, and they will both be electrified poſitively, though in a leſs degree than the conductor was before. But if the body touch the rubber, the electricity which the body naturally contains, will on the contrary, ruſh from the body to the rubber, till an equilibrium obtains, and then both will be electrified negatively, tho' in a lefs degree than the rubber was previous to fuch communication.

If now the machine be worked, the globe will again attract electricity from the rubber, and the rubber from the infulated human body in contact with it; the fluid will be accumulated upon the conductor; and this procefs may be continued till all the electricity which the body naturally contains, be drawn out of it, when the procefs will be interrupted, or ceafe, as before. The body therefore will now be electrified *minus*, in the greateft poffible degree, and will therefore attract the electric fluid with the greateft violence from any non-electrics which contain it; and thus may we electrify with the body in a negative ftate as well as when in a pofitive one; for whether the body receive or part with this fluid, the fenfation and other effects are the fame, fo it be done in an equal degree. It may likewife be remarked, that if the body be in a negative ftate, yet if a body ftill more negative be applied to it, it will part with electricity to that body; on the contrary, if it be in a pofitive ftate, yet if a body ftill more pofitive be applied to it, it will receive electricity from that body; and the fenfation, and other effects will be the fame as if the differences, which are here only relative, had been abfolute.

Hitherto I have difcourfed only of fimple electrification. I fhall now proceed to the elec-

tric

tric ſhock, or of the famous phenomenon of the Leyden phial.

Let a pane of glaſs be coated, or covered with tin-foil, or other proper non-electric matter, ſo as to leave a ſufficient margin all round, See figure 27. and let one ſide of this coated pane be made to communicate with the inſulated rubber by means of a non-electric, ſuppoſe a wire. If now the machine be worked, the globe will attract the electricity from the rubber, and the rubber from the ſide of the coated glaſs, till it has taken all the electricity out of that ſide. If a proper communication had alſo been made between the conductor and the other ſide of the glaſs, all the electricity that was in the firſt ſide would be communicated to the ſecond, ſo that the firſt ſide will be electrified negatively, being deprived of its natural quantity of the electrical fluid, the ſecond ſide poſitively, containing twice its natural ſhare. The glaſs in this ſtate is ſaid to be *charged*.

Now from what has been ſaid it will eaſily be underſtood that the negative ſide has a violent attraction for its natural quantity of electricity, and that the poſitive ſide has as violent a tendency to part with it to bodies which have leſs. But as glaſs is an electric ſubſtance, and therefore impervious to electricity, the fluid cannot

 paſs

paſs through it to reſtore the equilibrium, neither can it paſs over the edges of the glaſs from the poſitive ſide, on account of the margin, for the ſame reaſon. But if a communication be made from one ſide to the other, by means of non-electrics, or conductors of electricity, the fluid from the poſitive ſide will inſtantly ruſh with great violence through ſuch conductors to the oppoſite ſide to reſtore the equilibrium; and if the human body be uſed for that purpoſe, the fluid will in courſe paſs through *it* to the negative ſide of the glaſs. And as in its paſſage it gives a very ſmart, ſudden, and painful ſenſation to the body, this is called the *electric ſhock*.

A *pane* of glaſs however is not abſolutely neceſſary for this purpoſe. Any glaſs veſſel may be made uſe of with equal effect, and a large phial, or elſe a glaſs jar, is uſually employed.

When the ſhock is required to be ſtrong, ſeveral or many ſuch jars are connected together by means of wires, from their inſides and outſides, terminating in two rods; and the diſcharge is made by forming a communication between them, either by means of the human body, or other non-electrics, and the ſhock is greater according as more jars are employed; inſomuch that not only ſmall animals, but even human beings, may

may be killed by the ſhock from a ſufficient number of ſuch jars.

When ſeveral or many jars are employed in this manner, it is called an *electrical battery*, and the diſcharge is called an *exploſion*, the report being as loud as that of ſome piſtols.

There are other methods of exciting electricity beſides friction, as, by heat and cold, &c. but which do it on a ſimilar principle to that, viz. either by encreaſing or diminiſhing the attraction of the body for electricity. But of late years philoſophers have diſcovered a moſt extraordinary mode of obtaining this fluid, for the diſcovery of which we are indebted to the illuſtrious Dr. Franklin; and this is, *the drawing it down from the clouds.* For that great man has found that the electrical fluid and lightning are one and the ſame matter: that the clouds uſually contain a conſiderable quantity of it: that it might be obtained from them by means of a kite, or even by a pointed metallic rod, reaching but a little way up into the air: and that this rod, by communicating with an electrical apparatus, will, when the air abounds with electricity, furniſh it as well, and often in greater quantity, than can be ordinarily collected by means of a globe. The ſame philoſopher has further proved, that a flaſh of lightning is only a greater electrical ſpark,

 and

and thunder a louder electrical ſnap or exploſion than what are ordinarily produced by our electrical experiments.

Dr. Franklin has farther ſhewn, that as metals are the moſt perfect conductors, or attract the electrical fluid more than other non-electric ſubſtances, buildings, ſhips, &c. may be ſecured from damage by lightning, by means of ſlender pointed rods made of thoſe ſubſtances, reaching a little way above the higheſt part of the building, and terminating in the earth, or in water. For a flaſh of lightning falling on the building or ſhip, will be attracted by the rod, and ſafely conducted into the earth. By the ſame ſimple method we may alſo ſecure ourſelves from damage by lightning, though ever ſo ſtrong or violent.

If the reader is deſirous of further acquaintance with this very entertaining branch of ſcience, he is referred to Dr. Prieſtley's celebrated hiſtory of electricity; or to Mr. Cavallo's, and Lord Mahon's performances; in which works he will find all that is yet known on the ſubject.

Electricity has long been applied to medical purpoſes, and often with good effect. The diſorders relievable by it are chiefly thoſe ſuppoſed to ariſe from obſtructions in the nerves; as palſies, gutta ſerena, epilepſies, and the like. Rheumatiſms,

matiſms, and other ſimilar complaints, have alſo been cured by it.

The method of application in topical caſes, is either by firſt electrifying the patient, and then drawing off ſparks from the part; or elſe by diſcharging the electrical ſhock through it. It is moſt prudent to try the former method firſt. If that fails, the latter may be had recourſe to; and in obſtinate caſes the ſtrength and frequency of the ſhocks may be diſcretionally encreaſed.

The electric fluid has the effect of a *ſtimulus* on the body; for when a perſon is ſtrongly electrified, the momentum of the blood, and perſpiration, are encreaſed. From a knowledge of this property of electricity, we may frequently be enabled to judge à priori, in what caſes it is likely to be of uſe.

Violent ſhocks ſhould be adminiſtered with caution; but there can ſeldom any injury ariſe from gentle, continued electrification; and much good may be expected from a prudent uſe of it *.

* See Mr. Cavallo's treatiſe on medical electricity, and Dr. Prieſtley's hiſtory.

PART III.

PHYSIOLOGY.

INTRODUCTION.

AN human body may be defined to be "a "machine composed of bones and muscles, "with their proper appendages, for the purpose "of motion at the instance of its intelligent principle; from this principle nerves, or instruments of sensation, are likewise detached to "the various parts of the body, for such information as may be necessary for determining it "to those motions of the body which may be "most conducive to the happiness of the former, "and preservation of both."

The reader may object, that the body consists of other parts besides bones, muscles, and nerves; and may wonder that they were omitted in the definition: but all the other parts, as well as functions of the body, seem to be only subservient to the purposes which the definition expresses: For,

1. The muſcles which are neceſſary to the motions of the body are, from the nature of their conſtitution, ſubject to continual waſte; which therefore is to be repaired by means of ſome of theſe.

2. Moſt of the other parts and functions of the body are either neceſſary to the action of the muſcles, or to the operation of the intelligent principle, or both; and

3. From the ſenſibility, and delicate ſtructure of the parts, they require to be defended from external injuries.

To illuſtrate this it may be obſerved,

1. That the ſtomach and digeſtive faculties aſſimilate the food which is taken to repair the continual waſte; and the circulation, beſides being abſolutely neceſſary to the action of the muſcles, as will appear, diſtributes this nouriſhment to the ſeveral parts of the body. The glands ſeparate liquors from the blood for theſe uſeful ſubſervient purpoſes. Thus, the liver, the pancreas, and other glands, ſeparate juices neceſſary to the proper digeſtion and aſſimilation of the food. The kidneys ſtrain off the uſeleſs and ſuperfluous water, ſalts, &c. which otherwiſe, by remaining in the body, would be injurious to it. The brain is ſuppoſed to ſeparate a

fluid for the purpoſes of ſenſe and motion. And ſo of other parts.

2. The nerves are not only the inſtruments of ſenſation, but 'tis immediately by their means that the muſcles are moved. To the motion of the voluntary muſcles, the motion of the blood, and of courſe the vital motions of the ſyſtem alſo are neceſſary; for as the muſcles cannot be moved but by means of the nerves, ſo neither can they if the blood does not flow from them. A certain degree of heat is neceſſary to keep the blood fluid, and alſo to the action of the nerves, without either of which, motion could not be performed. Breathing is ſo neceſſary to life, that it cannot exiſt even a few minutes without the exerciſe of that function; and yet the uſe of reſpiration, whereby it becomes ſo neceſſary to life, ſeems to be to keep the body in a proper ſtate for the purpoſes of muſcular motion, &c.

3. The ſkin, like a ſheath, ſerves to defend the body from injuries. The ſkull ſerves for the ſame purpoſe to the brain, and the ribs to the heart. The membranes ſeparate the muſcles, fibres, &c. from each other; and ſomething ſimilar may be obſerved of the other parts of the body.

The parts of generation may indeed at firſt view be conſidered as an objection; but when we reflect that pleaſure is the only end which is had in view by fruition, the objection will be found of no moment.

CHAPTER I.

OF THE BONES AND MUSCLES.

THE bones ſerve to give firmneſs and ſhape to the body.

Some of them ſerve likewiſe for defence. Thus, the ſkull defends the brain, and the ribs the heart, as before obſerved.

But they have alſo a more important uſe; for it is by the muſcles moving the bones, that the various motions of the limbs, and other parts of the body, are performed.

The whole ſyſtem of bones (called a *ſkeleton*) is conſtructed of many parts, of different ſhapes, and ſizes; joining with one another in various manners, and ſo knit together, as beſt to anſwer to the motions which the occaſions of the animal might require.

The muſcles move thoſe bones at the command of the will, or otherwiſe, by contracting their lengths. Imagine two bones knit together, ſo as to be moveable, and that two equal muſcles are affixed to them, one on each ſide.

Theſe

Thefe mufcles may be either fhortened, or lengthened; or, to fpeak in the language of anatomifts, *contracted*, or *relaxed*. If the will acts on the right hand mufcle, it will contract, and bend the bones to the right. If the will acts on the left hand mufcle, it will contract, and thereby bend the bones to the left. But when neither mufcle is more contracted than the other, the bones remain ftrait.

Mufcles in general, at leaft thofe which ferve for voluntary motion, are balanced by antagonifts, as in the inftance juft defcribed. By this means they are kept beyond their natural ftretch. When one is contracted by the will, the other relaxes, in order to give it play, or at leaft is more eafily overpowered by the contraction of its antagonift. Alfo when one of fuch mufcles happens to be paralytic, or deftroyed, the other, being no longer balanced or kept on the ftretch, immediately contracts into its natural length, and remains in that fituation. The part to which it is fixed will in courfe be affected accordingly. If one of the mufcles which move the mouth fideways be deftroyed, the other immediately contracting, draws the mouth awry, and in that fituation it remains. The like may be obferved of the leg, the arm, and other parts. Some mufcles affift one another in their action; and others have different actions, according to their

fhapes,

ſhapes, the courſe of their fibres, and the ſtructure of the parts which they move.

According to the ſhape and nature of the bones to be moved, and of the motions to be performed, the muſcles are either long, or ſhort, ſlender, or bulky; ſtrait, or round, &c. Where a great motion is required, as of the leg, or arm, the muſcles are long; where a ſmall motion is required, the muſcles are ſhort, for a ſtrong motion they are thick, and for a weak one ſlender. For a direct motion, the muſcles are ſtrait; for an orbicular motion, circular, as in the ſphincters of the anus, and bladder.

Alſo ſome of theſe muſcles are faſtened to, and move bones, others cartilages; and others again other muſcles, according as may beſt ſuit the intention to be anſwered.

Some of the muſcles terminate at both extremities in tendons, others only at one end, and others again at neither, for a ſimilar reaſon.

Each muſcle is furniſhed with a nerve, an artery, and a vein; all of which are neceſſary to its action, as has been proved by a variety of experiments.

As a particular deſcription of the parts does not come either within the limits, or the plan of this

this work, the reader, not yet acquainted with theſe matters, is referred to anatomical authors who treat profeſſedly on them *.

CHAPTER II.

OF THE MOVING FIBRES.

THE fibres may be conſidered as the component parts of the ſolids; and they are denominated according to the parts which they compoſe. Thus the fibres which compoſe the muſcles are called muſcular fibres. Thoſe which compoſe the membranes, membranous fibres; and ſo of others. But the former are the only ones which we ſhall have occaſion to conſider in this diſcourſe, and they may be called *moving fibres*.

When a fibre is drawn out into a greater length than naturally, it has an endeavour to contract.

On the contrary, the nerves have a power of contracting thoſe fibres, or making them become ſhorter than naturally; but when the influence of the nerve ceaſes, the fibres become capable of returning to their uſual length.

Whatever irritates the fibres occaſions this influence of the nerves on them.

Some

* See the ingenious Dr. Simmons's Elements of Anatomy, &c.

Some fibres while in the living body are more irritable than others, or they contract more forcibly with the fame degree of ftimulus. The fibres which compofe the heart are more irritable than thofe which compofe the mufcles moving the limbs; this was requifite, becaufe a greater and more conftant motion is required in the heart than in the mufcles laft mentioned.

Some of thofe fibres are alfo more fenfible, or endued with a greater degree of feeling, than others. But the feeling is not always proportionable to the degree of irritability. The heart, though more irritable than the mufcles of the limbs, is lefs fenfible. This alfo was neceffary, for if the heart was very fenfible, its labour in circulating the blood would be fo painful as to be intolerable; whereas now it is never felt, unlefs on particular occafions.

The fibres have alfo an *elafticity*, which is different from the *irritability* defcribed; and remains after the latter is deftroyed. The elafticity is of ufe to their action. When they are diftended, the elafticity helps to contract them; and contrariwife.

The red colour of mufcular fibres depends on the blood. If that be wafhed out, the fibres are then white.

If fibres are too much diſtended, their contractile powers are either deſtroyed or weakened; and if they are only impaired, ſome time is required to reſtore them to their proper ſtate; and in ſome caſes even this is impracticable, the miſchief continuing for life. This is the cauſe of ſome of thoſe melancholy diſorders which are improperly called *nervous*; and of others.

As on the action of the fibres the *functions*, ſo on the ſtate of the fibres the *conſtitution*, of the body ſeems to depend. If the fibres are ſtrong, the individual is ſtrong; if weak, he is feeble. If the fibres are very irritable, he is paſſionate; if the contrary, inactive and dull. In health the fibres are ſtronger than after illneſs. Their ſtate depends alſo very much on that of the atmoſphere. If the atmoſphere is heavy, cold, and dry, the fibres are elaſtic and ſtrong. If light, hot, and moiſt, the contrary. Moderate cold ſtrengthens or braces up theſe fibres; but exceſs of heat weakens them. Hence heat makes us feeble and faint; cold the reverſe. From knowing the ſtate of the fibres, we are directed to apply the ſuitable remedies. If they are relaxed, bracing and ſtimulating remedies are indicated; but if too tenſe, thoſe of a contrary nature.

CHAPTER III.

OF THE BRAIN AND NERVES.

THE brain is the ſeat of the intelligent principle. From that principle nerves ſerving for ſenſation are ſent off to every part of the body, to receive the neceſſary information of the ſtate of the body itſelf, and of things without.

Another ſet of nerves are detached to the muſcles, or thoſe parts which are to ſerve for the motions of the body at the inſtance of the will. Thoſe two ſets of nerves ſeem to be different, becauſe ſenſation may be loſt in a part, yet motion remain.

A third ſet of nerves ſerve for the merely involuntary or vital motions of the ſyſtem, and do not appear to have any connection with the intelligent principle. They perform their offices continually, in ſleeping, as well as waking; but the others in waking only.

By theſe the fibres and parts ſeem to be recruited, or nouriſhed, in conjunction with the blood; for nutrition is chiefly performed in ſleep, when the other nerves are inactive; and it is well known,

known, that if the nerve be deftroyed, the part which it ferves waftes, notwithftanding that the blood and lymph flow through it as ufual.

The *heat of the body* feems alfo to depend either wholly, or chiefly, on this fet of nerves; for it is nearly as great in fleep as in waking, though then thefe nerves only act; and yet if a nerve be deftroyed, the part which it ferves becomes cold, notwithftanding that the blood continues to circulate through it *.

That the heat of the blood does not depend on the nerves which ferve for fenfation is plain, becaufe heat continues in fleep, when they are inactive; alfo a part which has loft its feeling, but retains its motion, does not always lofe its heat.

As the nerves ferve for motion and fenfation, any obftruction, or compreffion of them, will occafion palfy of the part or parts which they ferve; that is, it will occafion either lofs of fenfe, or motion, or both, according to the nature of the injury. Thus, the optic nerve being compreffed, blindnefs enfues; and the nerves of the leg, lofs of motion of that part. By deftroying the nerve, nutrition and animal heat will alfo be injured, as hath already been obferved. But the diforders commonly called *nervous*, feem to proceed

* See Dr. Caverhill's Experiments on animal heat.

proceed for the moſt part from injuries of the moving fibres, as mentioned in the laſt chapter.

CHAPTER IV.

OF THE CIRCULATION OF THE BLOOD.

THE circulation of the blood was unknown till about 150 years ago, when it was diſcovered by a countryman of our own, the celebrated Dr. Harvey. For this great diſcovery, ſtatues are juſtly erected, and orations yearly pronounced in his honour.

With reſpect to the circulation of the blood, the body muſt be conſidered as diſtinguiſhed into two portions, the *lungs*, and *the other parts*.

The heart is the power, or mechanical cauſe by which the blood is circulated. From the right ventricle of the heart there iſſues a large artery, called the *pulmonary* artery; which goes to the lungs, and is there divided and ſubdivided into a vaſt number of branches, too ſmall to be viſible. The ultimate ramifications of theſe branches may be conſidered as uniting again into larger branches; theſe again into branches ſtill larger, and ſo on continually, till at laſt they form only one large pipe, called the pulmonary vein, which is inferted into the left auricle of the heart.

From the left ventricle there iffues another large artery called the aörta, which in its paffage fends off branches to the arms, legs, head, and every other part of the body. Thefe branches, in the courfe of their progrefs, are divided and fubdivided into innumerable invifible branches, as was mentioned of the pulmonary artery; and their laft ramifications may alfo be confidered as reuniting into branches continually larger and larger, till at length they form only one great pipe, called the vena cava, which is inferted in the right auricle of the heart.

Now the blood is driven out of the right ventricle of the heart into the pulmonary artery, and to all the branches of that artery which are difperfed through every part of the lungs. From thefe it paffes into the branches of the veins; and from all thefe branches at length into the pulmonary vein itfelf, which empties it into the left auricle of the heart. This may be called the firft ftage of its circulation.

From the left auricle it paffes into the left ventricle; from thence it is driven into the aörta, or great artery, and into all its branches in every part of the body. From the ramifications of theſe arteries it paſſes into thoſe of the veins; from theſe into larger branches, and ſo on by degrees till at length it arrives at the vena cava, which empties it into the right auricle of the heart. This is the ſecond ſtage of its circulation.

But from the right auricle it paſſes again into the right ventricle; from thence, as before, ſucceſſively to the pulmonary artery, the pulmonary vein, the left auricle, the left ventricle, the aörta, and vena cava, and ſo on in a perpetual round, which therefore is called *the circulation of the blood*.

The blood however does not flow out of the heart into the arteries continually, but by pulſes or fits; when the ventricles are filled with blood from the auricles, the blood ſtimulates them; and thereby occaſions them to *contract*; by ſuch contraction they force the blood which they contain into the arteries. This contraction is called the *ſyſtole* of the heart. As ſoon as they have finiſhed their contraction they relax, and are again filled with blood from the auricles, and this ſtate of the heart is called its *diaſtole*. The ſyſtole and diaſtole of the heart therefore continue on alternately, and hence the *pulſation* or *beating* of the heart.

The arteries muſt of courſe have the like pulſation; the blood being driven into them only by ſtarts; and accordingly we find it in the artery of the wriſt, called the *pulſe*; the like may alſo be obſerved in thoſe of the temples, and other parts of the body. But we may likewiſe obſerve that the veins do not beat; the blood flowing on through them in an uninterrupted courſe; its pulſe, by the time that it has paſſed through ſuch an infinite number of ſmall branches, into larger ones, being entirely deſtroyed.

The two ventricles therefore contract and drive out the blood into their reſpective arteries both at the ſame time. The two auricles likewiſe contract and drive their blood into the ventricles at the ſame time; and hence you will alſo perceive that the ventricles contract and empty themſelves while the auricles are relaxing and receiving blood from their reſpective veins; and contrariwiſe; ſo that their action is alternate.

The heart is a mere muſcle, as hath already been obſerved. The fibres of which it is compoſed are conſtructed into auricles and ventricles, for the purpoſe of receiving and expelling the blood. The coats of the arteries are furniſhed with muſcular fibres, encompaſſing them circularly; conſequently when the arteries are dilated by the blood driven into them from the heart, they will contract again, and thereby help to drive forward the blood. The veins likewise have this contractile faculty, though in a less degree than the arteries, as having less need of it. And they are besides furnished with valves, which hinder the blood from flowing back into the arteries, though they let it pass on freely to the heart: the latter direction of the blood's motion opening, the former shutting those valves.

From this account of the blood's circulation it will easily be seen that it moves in a direct contrary course in the arteries to what it does in the veins; in the latter it passes *towards*, and in the former *from* the heart. We have an easy proof of this in the common operation of blood-letting. When we have tied up the arm, we do not make the orifice above the ligature, or next to the heart, but below it. If the vein were opened above the ligature it would not bleed. For it only swells next to the hand; which shews that the blood does not flow into the vein from the heart, but from the hand.

It may also have been observed that if the ligature be too tight, the blood will not flow. The reason of this is, that the *artery* is compressed in this case, as well as the vein. And as the *veins* derive their blood from the *arteries*, it follows, that if the blood's motion be hindered in the latter, none can flow from them into the former. The ligature therefore muſt be only ſo moderately tight as to compreſs the veins, leaving the arteries, which are ſituated deeper, free. Hence alſo it may be perceived that the blood really paſſes from the arteries into the veins, as was deſcribed; and that if an artery is to be opened, the orifice muſt be made above the ligature, becauſe the blood flows into the artery immediately from the heart, and therefore only ſwells on that ſide of the ligature.

It may ſeem ſtrange that theſe particulars concerning bleeding had been obſerved by every phlebotomiſt, and known to almoſt every medical practitioner for above 2000 years; and yet that none of them ſhould have had the ſagacity to infer that the blood circulates, till it occurred to our own countryman before mentioned. When a thing is known, we wonder how it could poſſibly have eſcaped our notice; though before, the utmoſt exertion of the human faculties ſeemed unequal to the diſcovery.

Each ventricle of the heart is concluded to expel at leaſt an ounce of blood at a time, and there are about 4000 pulſations of the heart in an hour. If we ſuppoſe the quantity of blood circulating in an human adult to be 16 pounds, the whole maſs will circulate many times in the

courſe

courſe of an hour; eſpecially when the pulſe is quickened by a fever.

In the preceding account I ſaid, for perſpicuity's ſake, that the laſt branches of the arteries run into thoſe of the veins. But it is now the opinion of anatomiſts, that the arteries carry the blood to the parts to nouriſh them, and that the veins abſorb, or ſuck up what is ſuperfluous, and return it back to the heart.

As the blood is circulated by pulſes, or ſtarts, theſe pulſations form the grand index to phyſicians with regard to the health of the body. If the pulſe be full and ſtrong, a plethora and increaſed action of the fibres are indicated: if weak and feeble, the contrary. If quick, a fever; if ſlow, the reverſe. From a variety of other differences in the pulſe, deſcribed by medical writers, and which are better underſtood by practice and obſervation, a number of particulars reſpecting the ſtate of the fluids and ſolids may be obtained, from which the proper methods of cure are inferred, and which are of important uſe in the practice of phyſic.

CHAPTER V.

OF THE LYMPHATICS.

INTO the various cells and cavities of the body a thin tranſparent liquor is poured by the extremities of the arteries, called by anatomiſts *lymph*. Its uſe is to moiſten and lubricate the parts, for which purpoſe, by its ſoft gelatinous nature, it is well calculated. It ſeems alſo to contribute to nutrition. This fluid is abſorbed from thoſe cavities by a ſet of veſſels called *lymphatics*.

Theſe veſſels are very minute, and pellucid; and abſorb the lymph on the ſame principle as ſmall glaſs tubes ſuck up water. If a ſlender glaſs tube be placed in water, the ſurface of the water in the tube will be higher than that of the water without the tube; and this difference will be greater as the tube is of leſs diameter. This phenomenon depends on the attraction between the water, and the inner ſurface of the tube.

The caſe is the ſame with the lymphatics. But theſe are alſo furniſhed with valves, which ſuffer the fluid to go forwards, but hinder it from

from returning. The lymph, when abſorbed as above, is afterwards urged forward by the muſcular coats of theſe veſſels, in like manner as hath been ſhewn with regard to the inteſtines, and blood veſſels.

The lymphatics from all parts of the body direct their courſe towards the ſame part with the *lacteals*, or *chyle veſſels*, already ſpoken of; with which they form one general ſyſtem of *abſorbents*. The lymph is poured, together with the chyle, into the left ſubclavian vein, where they mix with the blood.

If through weakneſs, or other cauſe, the lymphatics do not ſufficiently abſorb the lymph, dropſies are the conſequence; and the like happens when theſe veſſels are ruptured.

When mercurial ointment is rubbed upon the ſkin, the mercury is abſorbed and conveyed into the ſyſtem, as appears by the ſalivation which takes place on thoſe occaſions. The abſorption is made by the lymphatics. Other ſubſtances are alſo capable of being abſorbed by theſe veſſels, when properly applied to the ſkin.

Both the lymph and chyle paſs thro' lymphatic glands in their courſe to the ſubclavian vein. But for what reaſon is not yet known.

CHAPTER VI.

OF THE PRIMÆ VIÆ, AND ALIMENT.

THE human machine is formed on ſuch principles that it cannot continue alive unleſs it be occaſionally recruited by means of food. The principles on which it is conſtructed require that a very conſiderable portion of fluids ſhould be continually paſſing off by perſpiration, through inviſible pores, in every part of the ſurface of the body. This evaporation may be rendered ſenſible by violent exerciſe or heat, when it appears in the form of ſweat. From the lungs it is ordinarily ſo copious as to be viſible to the eye, eſpecially in cold weather; they who have had the curioſity to weigh themſelves, have found that the greateſt part of what is ate and drank paſſes off in this manner.

The uſe of food is to recruit this continual waſte. But part of what we uſually eat will not ſerve for this purpoſe. What is uſeful therefore is extracted from it; and the remainder caſt out of the body by ſtool and by urine, as will be ſhewn.

If

If the animal fabric could have been formed in ſuch a manner as that the ſame fluids would have ſerved always, as there would then have been no waſte, ſo there would have been no occaſion for ſupply; and food would have been unneceſſary. But on the contrary, life cannot be preſerved if the evaporation above ſpoken of is not continued.

In this chapter I ſhall deſcribe the progreſs of the food from the mouth to the blood, and the changes it undergoes in that paſſage.

From the back part of the mouth paſſes a tube, called the æſophagus, or gullet, into the ſtomach. From the right ſide of the ſtomach iſſues another tube, called the pylorus, continued to the duodenum. Into this tube enters the bile duct from the liver, and gall bladder, and with, or near it, another tube called the pancreatic duct, from the pancreas or ſweet-bread. The duodenum is continued into the jejunum, which makes the firſt part of that long flexible tube forming the *winding guts*, and is ſo called becauſe it is generally empty. The ſecond part is called ileum, and is only a prolongation of the jejunum, and the ileum terminates in that great gut called the colon, the lower part of which, called the rectum, is fixed into the anus or fundament.

The whole of what has been deſcribed is only a production of the ſame tube, from the æſophagus to the anus. It is called, by anatomiſts, the inteſtinal canal, or *prima via*, by reaſon that this is the firſt paſſage of the food. It has, by means of its circular muſcular fibres, a power or faculty of contracting itſelf when irritated by diſtention, and thereby urges forward the food contained in it, as the arteries do the blood. This occaſions a viſible worm-like motion of the whole guts, when they are expoſed to view, and is called their *periſtaltic motion*.

From the winding or ſmall guts, and even from the ſtomach, but chiefly from the ileum, a vaſt number of very fine ſlender tubes take their riſe. They are inviſible unleſs they happen to be full; and are called *lacteals*, or *chyle veſſels*.

The food taken in at the mouth is broken to pieces by the teeth, and impregnated with ſaliva. From thence it paſſes into the ſtomach. It is there mixed with the gaſtric juice, ſeparated by the ſmall glands of that viſcus, by which it is digeſted, that is, as far as it is capable of being, diſſolved. When it gets out of the ſtomach into the pylorus and duodenum, it is alſo mixed with bile from the gall bladder, and with pancreatic juice from the ſweet-bread; and in conſequence of the changes which it undergoes by its mixture with theſe various liquids, aſſiſted by the

warmth

warmth and gentle triture of the ſtomach and inteſtines, it is quite altered in its nature from what it was when firſt taken *; ſo that when it arrives at the ſmall guts, there is abſorbed from it, by the chyle veſſels above deſcribed, a ſoft and taſteleſs liquid, called by anatomiſts *chyle*. If the digeſtion be perfect, the chyle is the ſame, whatever be the food it is obtained from. The lacteals which collect this chyle, after properly uniting, empty it into the left ſubclavian vein, where it mixes with the blood for nouriſhing the body.

The dregs of the food, from which this liquor was extracted, paſs on through the guts, and is caſt out as uſeleſs.

The chyle therefore may be conſidered as the pabulum of the blood. It was obſerved before, that a conſtant evaporation of fluids from the ſurface of the body is neceſſary. The blood ſupplies this waſte. The parts of the body are continually

* The gaſtric juice has been ſhewn, by Mr. John Hunter, and others, to be a ſolvent of the aliment. If fleſh, or other food, be digeſted in this liquid, out of the body, it will in great meaſure be diſſolved by it; and therefore it is now generally held that digeſtion is performed by *ſolution*; the gaſtric liquor being the menſtruum for that purpoſe. The pancreatic juice ſeems (like the ſaliva, which it reſembles) chiefly deſigned as a diluent. The uſe of the bile is not yet properly known. But ſome experiments which I have made ſeem to ſhew that animal food employs leſs of it than vegetable. It is therefore probably of great uſe in animalizing the aliment: and perhaps the blood derives from it its ſpecific power of attracting phlogiſton from the body, and parting with it to the air; of which notice will be taken in a future chapter.

tinually recruited or nouriſhed thereby; and the blood is again recruited for this purpoſe by the chyle, which, in the courſe of circulation, is alſo converted into blood, to ſerve for the like purpoſes of nutrition.

As life depends on the recruit of the blood by the chyle made in this proceſs, ſo health depends much on the goodneſs of this chyle. If the chyle be perfect, good blood is made; good juices are made from that blood by the glands, and the parts are properly nouriſhed. But if the chyle be bad, it will ultimately affect the body which is to be nouriſhed by it, in proportion. The evil will even be continued in conſequence thereof. For the ſaliva, gaſtric juice, bile, and ſuccus pancreaticus being vitiated, they will affect the chyle hereafter to be prepared from freſh food. Nature has provided as much as a careful guardian can in theſe matters. She has furniſhed the mouth with the faculty of taſting, and the noſtrils (which communicate with the mouth) with that of ſmelling, in order that they may detect any thing improper, and prevent its being taken in to the injury of the animal. If the food endures theſe teſts it is ſuffered to paſs on to the ſtomach. But that organ has alſo the faculty of diſcriminating whether the aliment is proper, and in ſome caſes where the ſenſes of taſte and ſmell are ineffectual. If it be hurtful, or poiſonous, it has in many inſtances the provident faculty of rejecting, or throwing it up. If there are hurtful qualities, which even the ſtomach cannot diſcover, the guts often detect them, and have the no leſs wonderful faculty of hurrying it thro' the body by ſtool. There are caſes however in which none of theſe teſts are ſufficient, and bad chyle is after all ſuffered to paſs into the blood. But even there it is thrown off by urine or other ſecretion, or elſe a fever is raiſed in order to expel it by perſpiration, which is an effect of the ſame kind as vomiting in the ſtomach, and purging in the guts. Abſceſſes, eruptions, and other means are likewiſe occaſionally employed by nature for the ſame intention. But there are caſes, where either the vigilance or power of all theſe are ineffectual, and in conſequence thereof either health is injured, or life deſtroyed.

CHAPTER VII.

OF THE BLOOD.

THE chyle, in the courſe of its circulation, is converted into blood; as hath already been obſerved.

They who have diſſected bodies with a view to the changes wrought on the fluids in the lungs, have

have remarked that chyle is perceivable in the pulmonary artery previous to the paſſage of the blood through that organ, but not in the pulmonary vein, after ſuch paſſage. The chyle is mixed with the lymph in the ſubclavian vein, &c. The more watery part is probably exhaled by the breath; and the remainder incorporated with the maſs of blood by agitation in the pulmonary organ.

When blood flows from a vein, it ſeems to be an homogeneous red fluid. But after reſting a while it ſeparates into two ſubſtances, a watery part, called *ſerum*, and a red coagulum, diſtinguiſhed by the name of *craſſamentum*.

The ſerum, by its ſenſible qualities, appears to reſemble water. It mixes with water into a ſeemingly uniform aqueous fluid. If, however, this mixture be expoſed to a ſufficient heat, the ſerum ſeparates in the form of a white coagulated ſubſtance, which is not rediſſolvable in the water.

If ſerum be expoſed alone to heat, it alſo coagulates; and if it be poured into boiling water the ſame effect takes place. It is coagulated likewiſe by ſpirit of wine, æther, and acids. In theſe and other properties, it bears a very great analogy to the white of an egg.

The *craſſamentum* is compoſed of two diſtinct ſubſtances; 1. the *red*, or colouring part, which may

may be entirely washed out of it by means of water, and, 2. the *coagulable lymph*.

The red part may be diftinguifhed, by means of a microfcope, in the form of little globules, floating in the other parts of the blood, like oil fhook well up with water. By means of the fame inftrument, they may be feen moving in the minute blood veffels of frogs, and other animals, from the arteries into the veins; and hence we have an ocular proof of the circulation of the blood.

This fubftance is of a deeper red in the veins than in the arteries. It acquires its deep colour in the courfe of its circulation through the body, and lofeth it in its paffage through the lungs.

The heat of the blood is greater than that of the furrounding atmofphere, its temperature in health, being at about 98 degrees of Fahrenheit's thermometer. In morbid ftates, it varies from that point; thus, it is hotter in an inflammatory fever, and colder in the cold fit of an ague.

In health, the heat of the blood is nearly the fame, whether the furrounding atmofphere be hotter or colder; the vital powers generating more heat in the latter cafe, and lefs in the former.

The *coagulable lymph*, when ſeparated from the red part, is a white gelatinous ſubſtance, and probably the elaſtic, and glutinous parts of the ſolids are formed of it.

There is a greater proportion of coagulable lymph in the blood of perſons of ſtrong conſtitutions, than in thoſe of weak ones, and the proportion in the blood of the ſame perſon varies according to the ſtrength and other circumſtances. The like may be obſerved of its texture.

While blood remains in the veſſels, it continues fluid much longer than it would do in the open air; the action of which diſpoſes it to a ſpeedy coagulation.

When blood has ſtood for ſome time out of the veſſels, it begins to putrify; and in putrid diſeaſes this is ſaid to take place, in ſome degree, even in the blood of living animals.

From the appearance of the blood, many important indications may be drawn. For example, if the craſſamentum be of a weak, or lax texture, incraſſants are indicated. If tough and viſcid, attenuants and diluents. If in over proportion, evacuations; if the contrary, nutritives. The appearance of ſize, or buff, on the craſſamentum, is ſaid to argue too great a fluidity of the coagulable lymph, ſo that the red globules ſink

 in

in it, leaving the upper part of the cake free from them, or in a ſtate of pure coagulable lymph. Hence it is conſidered as a ſign of inflammation. Other indications are drawn from the appearances of blood by practical writers.

CHAPTER VIII.

OF NUTRITION.

THE ſolids, as well as fluids of the body, are in a ſtate of continual waſte, and therefore require to be recruited. Hence the neceſſity of food, as before obſerved.

The manner in which nutrition is performed is not as yet well underſtood, but it ſeems to be performed by the blood, or rather the lymph, in conjunction with the nerves.

If a nerve be divided, the part which it ſerves, waſtes, (eſpecially if it be muſcular) notwithſtanding that the blood circulates through it as uſual. And there are phænomena which ſhew that the blood is likewiſe neceſſary to nutrition.

In the muſcular fibres, nutrition ſeems to depend chiefly on the nerves; but theſe may require to be aſſiſted by the blood, or its lymph. Other parts may be nouriſhed in different manners, and ſome of them, either wholly or chiefly by the coagulable matter of the blood. The ſolids ſeem for the moſt part to conſiſt of coagulable matter, combined with water. And the various parts of the body may be enabled, by means of glands, elective attractions, or otherwiſe, to ſeparate thoſe particles from the blood, and thoſe only, which are moſt proper for their reſpective purpoſes. But this is a ſubject which requires to be farther inveſtigated by experiments.

CHAPTER IX.

OF THE GLANDS.

FROM the blood are ſeparated many fluids, for different purpoſes, by certain organs called *glands*. Thus,

THE KIDNEYS

Strain off the urine; which conſiſts of the ſuperfluous water, ſalts, &c. and which, if retained, would be prejudicial to the animal œconomy. Critical diſcharges of the utmoſt importance to the body, are alſo not unfrequently made by the ſame outlet. This fluid is retained in the bladder, ſo as to be expelled when convenient. From the appearance of the urine, uſeful practical indications are frequently formed; as may be feen in medical writings.

THE LIVER

Forms the bile or gall; part of which is retained in the gall-bladder, as its refervoir, as the urine is in the *vefica*. The duct of the gall-bladder opens into the duodenum. The preffure of the food, as it paffeth through the pylorus, forces the bile into the inteftines for the purpofe already mentioned.

THE PANCREAS, OR SWEET-BREAD,

Forms the pancreatic juice, which is likewife emptied into the inteftines for diluting and furthering the digeftion of the food.

THE SALIVAL GLANDS

Secrete the fpittle, for the purpofe of moiftening, and perhaps affifting the digeftion of the food.

THE GLANDULES IN THE STOMACH

Secrete the gaftric juice, for the purpofe of diffolving the food. Thofe in the inteftines feparate a liquid which lubricates the guts, for the more eafy paffage of the aliment, and perhaps alfo to affift in its affimilation.

THE TESTICLES

Form the vivifying principle in males, or the feed, improperly fo called, as do

THE OVARIES,

The true feed, in females.

THE BRAIN

Seems to ſecrete a ſubſtance which, being conveyed by the nerves, aſſiſts in nutrition. By means either of the ſame, or ſome other matter or fluid, ſenſation and motion are probably performed.

The other glands have likewiſe their reſpective uſeful offices.

The theory of glandular ſecretion has not as yet been ſatisfactorily explained.

From irregularities in the glandular ſecretions many diſorders ariſe. If the bile be obſtructed, jaundice is often the conſequence. If perſpiration; colds, plethora, and fevers ſucceed. If the gaſtric juice be deficient in quantity, or vitiated in quality, digeſtion is injured. And the like may be obſerved of the other ſecretions.

Medicines, in ſome caſes, act on the glands. Cathartics increaſe the ſecretion by the glands in the inteſtines; and diuretics operate by increaſing the action of the kidneys.

By increaſing ſome of the ſecretions many diſorders may be cured. A dropſy, for example, is removed by diuretics.

When one ſecretion is immoderate, it may, in ſome caſes, be checked by augmenting another.

A ſaliva-

A ſalivation is diminiſhed by a cathartic: and perſpiration by an encreaſed ſecretion of urine. And there are other uſes of the glandular ſecretions to be met with in practical authors.

CHAPTER X.

OF PERSPIRATION.

AN animal body is formed on ſuch principles that its ſolids, particularly the muſcular fibres, are in a ſtate of continual waſte; and both theſe and the fluids require to be conſtantly renewed. Hence follows

1ſt, A neceſſity of their being frequently recruited by means of food, as hath been ſhewn, and

2dly, A like neceſſity of a continual diſcharge of the old and effete materials.

Agreeably to this, we find that from every part of the ſurface of the body, and from the lungs there conſtantly exhales a conſiderable quantity of vapour, called by anatomiſts the matter of perſpiration.

This vapour uſually tranſpires in an inſenſible manner. But if perſpiration be encreaſed by exercife, or other caufe, it appears in the form of fmall vifible drops, and then it is termed fweat. In cold weather the evaporation from the lungs is condenfed into a vifible fteam; it may even be collected in a liquid form by breathing on a glafs, or other proper veffel. More than half of what we eat and drink ufually paffes off in thefe two ways, as may be feen by the experiments of Sanctorius and others.

The perfpiration by the fkin is fuppofed to be either fecreted by glands, or exhaled by minute extremities of the arteries of the cutis. It is probable however, that the matter exhaled by the lungs is different from that which paffes off by the fkin. We already know that phlogifton is difcharged by the lungs, but not by the external furface of the body; the fkin being a fubftance of fuch a nature as to hinder the requifite action of the air on the blood for that purpofe. This obfervation, compared with the following chapter, may enable us to underftand, in fome meafure, the action of air on wounds.

From what has been faid, it is obvious, that perfpiration cannot be much encreafed, or diminifhed, without affecting the health. If it be obftructed, fulnefs of the veffels is apt to be produced; together with colds, fevers, and the like. If it be too copious, laffitude and weaknefs follow; alfo, as the blood is thereby deprived of

its

its more fluid parts, the remainder will be more viſcid, and circulate with leſs freedom. The ſolids will likewiſe become too dry and rigid. A warm atmoſphere encreaſes perſpiration; and a cold one diminiſhes it. It frequently happens that when perſpiration is diminiſhed, the urinary ſecretion is encreaſed; and contrariwiſe. The matter of perſpiration is even ſaid to be very ſimilar to that of the urine.

CHAPTER XI.

OF RESPIRATION, AND ANIMAL HEAT.

IT has been ſhewn that the blood has a *double circulation*, or that the whole maſs paſſes firſt through the lungs, and afterwards through the body.

I have, in ſome meaſure, explained the uſes of the latter circulation; thoſe of the former ſhall next be diſcourſed of.

The lungs are contained in the thorax; and are divided into two lobes. The trachea, or windpipe, alſo divides into two branches, one of which is ſent to each lobe, where it is ſubdivided into a vaſt number of ramifications, ultimately terminating in little veſicles, which, when diſtended with air, make up the greateſt part of the

the bulk of the lungs. The branches of the pulmonary artery and vein accompany thoſe of the windpipe, and are ſpent upon the coats of thoſe veſicles. The maſs of blood is not carried to the lungs for their nouriſhment, there being other ſmaller blood veſſels deſtined for that purpoſe.

The thorax has an alternate motion of ſyſtole and diaſtole, called *reſpiration*. At the diaſtole the air is admitted into the lungs, and this is alſo called *inſpiration*. At the ſyſtole the air is expelled from the lungs, which ſyſtole is likewiſe denominated *expiration*.

The nature and properties of air have already been explained. Among others it was ſhewn, that it preſſes with a great weight on all things about the ſurface of the earth, and that it is elaſtic, or capable of expanſion and compreſſion, of rarefaction by heat, and condenſation by cold.

The muſcles which cauſe expiration having juſt finiſhed their contraction, they begin now to relax; the blood driven from the heart into the pulmonary arteries ſtimulates to inſpiration. The external air ruſhes into the lungs, which are thereby inflated. They fill and dilate the thorax, drive the diaphragm downwards, and by the help of muſcles, which ſerve for inſpiration, diſtend thoſe which ſerve for the contrary motion.

motion. But thoſe muſcles, thus diſtended, re-ſuming their contractions, re-contract the cavity of the thorax, and thereby expel the air from the lungs. the muſcles ſerving for inſpiration, now beginning again to act, the thorax is dilated as before, and this continual alternate dilatation and contraction is called *reſpiration.*

When the lungs are diſtended, the blood circulates freely through them; but its paſſage is much more difficult in expiration. Alſo as the branches of the arteries and veins run in directions parallel to thoſe of the windpipe, the air in inſpiration may perhaps help forward the blood in the arteries running in the ſame direction, and in expiration it may likewiſe aſſiſt the motion of that in the veins. If breathing be ſtopt but for a ſhort time death enſues; for if no blood paſſeth from the lungs to the heart, the circulation, on which life depends, muſt ceaſe.

It had long been obſerved, though the reaſon was not known, that the blood in the veins of the body, and in the arteries of the lungs, was of a darker colour than in the arteries of the body and veins of the lungs; and it was alſo known that it loſt this dark colour during its paſſage through the laſt mentioned organ. It had likewiſe been remarked, that when venous blood was expoſed to the air, the ſurface of it acquired the ſame ſcarlet colour as that in the

arteries

arteries of the body, and veins of the lungs. This change of colour therefore, it was concluded, depended on the action of the air. What kind of action this was, remained unknown till it was discovered, in part, by the industry of the celebrated Dr. Priestley; who found that the dark colour of the venous blood depends on *phlogiston* absorbed by it during its circulation through the body; and that in its passage through the lungs, the air in inspiration attracts this principle from it, for the same reason as it takes it from combustible bodies; whence the air expired is almost the same phlogisticated air as that which is produced by combustion. By the loss of its phlogiston the blood recovers its florid colour. From these facts Dr. Priestley justly concluded, *that the principal use of respiration is to carry off the phlogiston which the blood absorbs during its circulation through the body.* In confirmation of this doctrine it may be observed, that as candles cannot burn, so neither can animals live, in air that is saturated with the phlogistic principle.

From some observations by the author of this work, but more particularly from the experiments of the ingenious Dr. Crawford, and others, it is now pretty generally understood, that the heat of the blood depends on respiration. The heat of animals is usually greater, in proportion

portion to the quantity of air they breathe, compared with the ſize of their bodies. Thus, birds are hotter than land animals, and theſe than amphibiæ, or fiſhes. A quantity of heat is abſorbed by the blood in the lungs, from the air, in lieu of its phlogiſton, and there remains in a *latent* ſtate. But when this blood is circulated by the aörtic ſyſtem through the other parts of the body, the heat is, (by means of the phlogiſton abſorbed,) extricated, or made to become ſenſible, as happens in combuſtion; and is then the cauſe of *animal heat*.

CHAPTER XII.

OF MUSCULAR MOTION.

IT is known that the nerve, the artery, and the vein, are neceſſary to the action of a muſcle.

The nerve ſeems to furniſh it with its power of irritability, whereby it is enabled to contract in conſequence of a ſtimulus, or the will. Its ſenſibility alſo depends on the nerve *. If the nerve be deſtroyed, the power of irritability, as well as of ſenſibility, will be loſt.

A regular ſupply of blood is alſo equally neceſſary to muſcular action; for a ligature on the artery, or vein, deſtroys the power of motion in a muſcle, as well as a ligature on the nerve.

The uſe of the blood in this caſe ſeems to be partly to derive the irritable principle into the muſcular fibres from the nerves, by the ſtimulus of its heat and motion; and alſo to fill up and properly diſtend the muſcle itſelf. The blood has

* It is found that thoſe parts of the body which in health are neither *irritable* nor *ſenſible*, are liable to become ſo by diſeaſe.

has alſo probably ſome other uſe in this buſi-neſs, which we ſhall preſently conſider.

While a muſcle is in action, it is ſhorter, and alſo thicker than in its natural ſtate. But its thickneſs is not increaſed in proportion to its contraction; the bulk of the whole muſcle being leſs during its action than at other times.

The cauſe of muſcular motion in the abſtract ſeems to be, that by the influence of the nerve, the particles of which the fibres are compoſed have their attractive forces increaſed, ſo that they are drawn nearer together.

The theory of animal heat was given in the laſt chapter; that of muſcular motion ſeems to be intimately connected with it, as will perhaps appear from what follows.

The mere cauſing of animal heat does not, by any means, ſeem to account for reſpiration being ſo abſolutely neceſſary to life that an animal cannot exiſt even a few minutes without it. Beſides animal heat, therefore, I formerly ventured to ſuggeſt whether *animal motion*, or the action of the muſcular fibres, on which the circulation, and life, immediately depend, was not alſo connected with this function?

The

The heat of animals is in proportion to the quantity of air which they breathe, as was mentioned in the preceding chapter. The quantity of air breathed by them is therefore in the *direct* proportion to their *heat*, and in the *inverse* proportion to their *irritability*, or dispoſi-tion to contraction in the *moving fibres*. For fiſhes breathe leſs air than amphibiæ *, and thoſe leſs than land animals; and their irritability is now known to be in the contrary order; for this reaſon alſo, the motion or pulſe of the blood in the aörtic ſyſtem is leſs in fiſhes than in land animals, ſo as to give leſs ſtimulus to their fibres.

To animal motion two things are known to be eſſentially neceſſary, viz. *irritability* in the *fibres*, and a *ſtimulus* in the *blood*. The great and principal ſtimulus employed by nature in the blood is *heat*. The influence of this ſtimulus is obvious from hence, that if the heat of the blood be increaſed (as in ardent fevers) the action of the fibres is alſo increaſed, and vice verſa. *Heat therefore is abſolutely neceſſary to the continuance of the vital motions* †: and we alſo

* In this claſs of animals, only part of the blood goes to the lungs, and on its return is mixed and diluted with the remainder of the maſs.

† The ſtimulus of the uſual heat of the body is ſufficient to keep the vital or involuntary fibres in action. But the voluntary muſcles

alſo find that the heat is in the inverſe proportion to the *irritability*, as hath already been obſerved. But to ſupply this heat, *reſpiration* is neceſſary: and from hence it would appear, that reſpiration ſupports life by means of continuing the *vital* and *other motions of the body*, on the principle above deſcribed.

In ſupport of this opinion, it may be obſerved, that the heat (at leaſt the ſummer heat) of the atmoſphere, is ſufficient for the animation of ſome inſects, &c. and hence they have no lungs.

The chick in ovo is heated and *animated* by external warmth, and therefore its breathing is not required. The ſame is partly * the caſe with the fœtus in utero †. Hence, after birth, breathing is abſolutely neceſſary to both. Theſe inſtances ſeem to demonſtrate that motion is dependent

muſcles require an additional ſtimulus from the brain or nerves. This difference was requiſite, becauſe the former are required to act *continually*, the latter only *occaſionally*; and it is well known that the heart, and other *involuntary* muſcles, are more irritable than the *voluntary* ones. Yet the *latter* muſt be previouſly prepared for the action of the nervous ſtimulus by *heat*. See *Eſſays on Phyſiological Subjects*.

* The blood of the fœtus alſo receives a portion of latent heat from the mother, by means of the umbilical veſſels.

† The heat of animals is alſo of uſe to liquefy their blood and juices; but this does not ſeem by any means to be the grand uſe of heat.

pendent on heat, and heat on refpiration, as above fuggefted.

As motion is dependent on heat, fo heat is probably equally dependent on motion. 'Tis known, that if the nerve which ferves a part is divided, the part becomes cold, notwithftanding that the blood flows through it as ufual. And as in fleeping, the voluntary motions, and fenfation, are dormant, and yet the heat continues as great as before, or nearly fo, the heat appears to depend chiefly on thofe nerves which ferve for the vital or *involuntary* motions of the body. Alfo the motion of the blood through a mufcle is known to be as neceffary to its action as the nerve. All this feems to fhew that there is a neceffary connection between the action of the moving fibres, and the heat of the blood.

If animal heat is caufed by phlogifton communicated to the blood during its paffage thro' the body, then we may fay that for a nerve to caufe the motion of a fibre, it is neceffary that it fhould impart phlogifton, either immediately, or mediately, to the blood flowing through or by that fibre *; or in other words, that there is a neceffary

* The venous blood being *denfer* than the arterial, is an argument in favour of this doctrine. It fhould likewife be noted, that the body in health is not in a putrid ftate, and therefore does not on *that* account phlogifticate the blood.

neceſſary connection or dependence between the action of the fibres, and the phlogiſtication of the blood.

The action of the moving fibres may be divided into voluntary and involuntary, ſome ſerving for involuntary motion alone, others for voluntary. According as more of the voluntary muſcles act, or as their action is ſtronger, more blood is phlogiſticated in a given time; the heat is greater, and the reſpirations are quicker. But thoſe muſcles which ſerve for the voluntary motions of the body are alſo continually exerting involuntary action. The contraction of the arteries, the veins, and other veſſels of the body for the purpoſe of circulating the fluids, &c. are performed by means of moving fibres. The muſcles, membranes, coats of veſſels, &c. are made up of ſuch fibres, and there is hardly any part of the body but what abounds with them. All theſe are continually exerting involuntary, and many of them, in waking, voluntary actions, neceſſary to the life and well-being of the animal. Now as there ſeems to be a mutual dependence between thoſe actions, and the phlogiſtication of the blood, as the number of particles of blood is not infinite, but on the contrary, only ſuch a quantity can be admitted into the ſtructure of the animal fabric as is ſufficient to balance the action of the ſolids, if there was no contrivance for dephlogisticating the blood, the whole mass would soon be rendered unfit for the purposes mentioned, and death would presently ensue. Nature has therefore provided the animal with *lungs*. The blood, phlogisticated as already related, is conveyed to that organ: the air in inspiration restores it to its original purity, by taking from it its phlogiston, and furnishing it in return with fire, and thus renders it again fit for the purposes of animal heat and motion. In proportion therefore as the sum of the whole action of the fibres is greater, that is, in proportion as a greater quantity of blood is phlogisticated in a given time, the motion of the blood ought to be increased, and the inspiration of air more frequent, in order that the restauration of the blood to its former purity may keep pace with its phlogistication in the body.

Now as life depends on the action of the fibres, as was shewn above; as there is a necessary connection or dependence between the action of those fibres, and the phlogistication of the blood; and as, from the great number of moving fibres in the body in continual action, and the small quantity of blood, the latter will be presently phlogisticated, we have an idea of the very great importance of respiration, and the absolute necessity of it to the continuance of life, as we find by experience to be the case;

neither

neither *the heat of the blood*, nor even *the vital motions of the body*, being capable of exifting long without it *.

* I have carried thefe ideas to greater lengths on former occafions, (fee *Philofophical Obfervations*; and alfo the *Effays on Phyfiological Subjects*, Part IId.) and have fince had opportunities of obferving, that in cafes where the fibres have not exerted their ufual vital powers the blood is returned by the veins more florid than ufual. But as the fubject requires to be further elucidated by experiments, I fhall not enlarge on it in an elementary work like this. Thofe who wifh to profecute this important branch of phyfiology, may perhaps meet with fome helps from the hints fuggefted in the tracts above referred to. Among thofe hints however fome fallacies may be pointed out. But this muft always be the cafe in reafonings founded chiefly on conjecture, or which have not been duly fubmitted to the rigid teft of experiment.

CHAPTER XIII.

OF THE EFFECTS OF AIR ON THE SYSTEM.

FROM what has been ſaid of air in the XIth chapter, and in the firſt part of this work, it appears that it is a fluid of the utmoſt importance in the animal economy.

By the XIth chapter it appears that air is fitter for reſpiration, or for ſupporting animal life, in proportion as it contains leſs phlogiſton; for then it is more capable of abſorbing that principle from the blood in the lungs. The blood thus freed from phlogiſton will therefore, in the courſe of its circulation, more powerfully attract it from the body.

On what account the diſcharging the blood of phlogiſton is ſo neceſſary to life, we have endeavoured to ſhew in the two laſt chapters: and it is well known that an animal cannot live many minutes in air that is incapable of performing that effect. The fact alone is ſufficient to ſhew the great uſe of pure air, eſpecially in putrid fevers, and ſimilar diſeaſes, when the body abounds with the phlogiſtic principle.

It

It may be obſerved however that phlogiſton is not the only principle by which air is rendered unfit for reſpiration; for if acid, or other irritating particles be contained in it, they will, by irritating the trachea and lungs, alſo injure breathing. Thus, the vapour of burning ſulphur is inſupportable, and that not on account of the phlogiſton, but of the acid particles irritating the organs of reſpiration. The complaints of aſthmatic people, with reſpect to the foulneſs of air, are in great meaſure the effects of thoſe irritating particles.

Nor is the diſcharging of phlogiſton the only uſe of reſpiration. A large quantity of ſuperfluous aqueous matter is carried off by the air in the lungs, as is evident in cold weather, when it is viſible; and it has not yet been proved that this matter is exactly of the ſame kind with that which paſſes off by the ſkin.

A dry and heavy air is better for breathing than a moiſt and light one, reſpiration then being not only performed with greater freedom, but more phlogiſton, and alſo more perſpirable matter is conducted off; and if the air in this ſtate be alſo moderately warm, it is better for breathing than when very cold, becauſe by cold the moiſture is condenſed, and falls back upon the lungs; hence coughs, &c.

The air in the lungs is alfo made fubfervient to other purpofes befides thofe defcribed. Speaking, fmelling, coughing, fneezing, dejection, and various other actions are performed by means of it.

With regard to the *external* effects of air, the elafticity or ftrength of the fibres is known to depend very much on the ftate of the air incumbent on the body.

That the atmofphere preffes upon the body with a very great weight, was fhewn when treating of air: and from thence alfo it may be underftood that the preffure of the external air is refifted, by the fpring of the air within the body. Thefe ought precifely to balance each other.

But when the atmofphere is light, the refiftance of the internal becomes greater than the preffure of the external air; the veffels then become turgid; the fibres cannot contract fo freely and powerfully as they ought; the circulation, fecretions, and other functions will go on more heavily than ufual; a general laffitude is felt; the voluntary motions are performed with more difficulty and labour; and from what we feel, we falfely imagine that the air is *heavier* than ufual.

When

When the atmoſphere is heavy it preſſes with a greater weight on the body, and overcomes the reſiſtance of the internal air, and of courſe the contrary happens to what has juſt been deſcribed. The fibres are more elaſtic; the veſſels contract with greater freedom and force; and the circulation, and other vital functions go on briſker than uſual. The voluntary motions are performed with greater eaſe. The body feels more light and alert; and we falſely imagine the air itſelf to be *lighter*. This ſtate of the air however, is apt to generate an inflamed ſtate of the blood; hence ardent fevers, and other inflammatory diſorders frequently ariſe, as do diſorders of a contrary kind when the atmoſphere is too light.

A moiſt air relaxes the fibres, and diſpoſes the fluids to a putrid ſtate, and as in a moiſt ſtate of the air, the atmoſphere is generally light, the laſſitude, the weak craſis of the blood, the ſluggiſh circulation, and diſorders ariſing from them will conſpire with the ill conſequences of the moiſture.

The effects of a dry air on the body are the reverſe of theſe; and as ſuch a ſtate of it ſeldom happens but when the atmoſphere is alſo heavy, it will be more favourable to the production of inflammatory diſeaſes.

A warm

A warm atmoſphere relaxes the fibres, and favours a diſſolved ſtate of the blood. If this be joined with a light and moiſt air it will augment the ill effects of theſe on the body; but cold will counteract them. A cold air braces up the fibres, and enables the veſſels to contract with greater power. If this be joined with a dry, heavy atmoſphere, it increaſes the evils of which theſe latter may be productive; but the ill conſequences of a moiſt and light atmoſphere are counteracted by it *.

By theſe conſiderations we may be enabled to form proper indications in regard to the treatment of diſeaſes in the different ſtates of the air; and alſo with reſpect to food, or other proper management in health, for preventing or guarding againſt the ill effects of theſe reſpective unfavourable ſtates of that element. For example, when the air is very moiſt, light, and warm, a regimen of a more bracing and antiſeptic kind is requiſite than in a contrary ſtate, where a relaxing and antiphlogiſtic treatment is more proper. But from a knowledge of the diſpoſition of the atmoſphere, and the ſtate of the patient, the practitioner's ſagacity will better point out the mode of treatment than many volumes. Having a clear conception of the premiſes, he will

* Perſpiration is alſo increaſed by a warm atmoſphere, and leſſened by a cold one.

will ſee, as it were by intuition, the conſequences. And I have made it my buſineſs rather to inculcate an idea of the premiſes alluded to, than to ſhew the various and almoſt infinite reſults and applications of them, which is much better left to the reader's ſagacity. He will notice in particular, that the ſymptoms of diſeaſes will be often varied, according to the different ſtates of the atmoſphere; by want of attention to, or knowledge of which, the ignorant practitioner muſt frequently be miſled.

The effects of winds depend on their temperature, as to heat and cold; on their moiſture or dryneſs; and on the lighter or heavier ſtate of the atmoſphere which they occaſion. And therefore they may be referred to the preceding heads.

It may be obſerved, that winds will feel cold, though they are no colder than the other parts of the air. The wind from a pair of bellows feels cold to the hand, though the thermometer ſhows it to be of the ſame warmth as before it was thus put in motion. For the air immediately ſurrounding the ſkin is warmed by the heat of the body. But this being forced away by the current of wind, the freſh air muſt needs feel colder.

Cold contracts the pores, and checks and condenſes the perſpiration of the part; and hence it

is

is that we are ſo liable to get cold when a part of the body is expoſed to the action of wind.

Winds in general however are healthful, as they drive away the ſtagnant air, tainted by exhalations from the earth, by animal reſpiration, &c. and ſupply us with that which is more pure.

Beſides heat, cold, moiſture, dryneſs, and different weight, the air may be affected by exhalations from the earth, by noxious particles brought by winds, and the like; but theſe, excepting phlogiſton, which has already been ſpoken of, we are as yet ſo little acquainted with, that we cannot ſpeak with any degree of certainty about them. It is to be hoped that philoſophy will in time throw light on this intereſting ſubject, ſince moſt of the contagious and peſtilential diſeaſes depend in great meaſure on ſuch particles abounding in the air.

CHAPTER

CHAPTER XIV.

OF THE PASSIONS.

THE paſſions influence the body, and ſome of them in a very eminent degree. They ſhall therefore be the ſubject of the preſent chapter.

The paſſions by which the body is chiefly affected are grief, joy, hope, fear, love, hatred, and anger; the others, being either akin to ſome of theſe, or of leſs moment, need not be ſpecified.

JOY is a violent and pleaſing paſſion, ariſing on the attainment of any good, eſpecially if ſudden or unexpected. This paſſion occaſions a greater determination of the nervous influence into the body than uſual; hence it ſuddenly, and remarkably quickens the circulation of the blood. A pleaſing warmth or glow is thrown upon the heart and breaſt, which are even convulſed, as it were, with tranſport; and inſtances have been known where death has been the conſequence, when the paſſion has been very violent and ſudden. In this paſſion the heart in particular ſeems remarkably lighter; owing to the greater ability with

with which it is enabled to circulate the blood, not only becauſe of the increaſed influx from the nerves, but by reaſon that the veſſels, the muſcles, and other parts, on account of the like increaſe of nervous influence, perform more than their uſual ſhare in that circulation, and of courſe greatly leſſen the labour of the heart. The ſecretions, and other functions of the body, alſo go on with a proportional increaſe of ſpirit.

HOPE, or the probability of attaining any good, is of the ſame nature with joy, only calmer, or leſs violent in its nature. The like may be obſerved of ſelf-complacency, which Mr. Hume calls PRIDE; of ſucceſsful LOVE, and of other paſſions of the pleaſing kind.

Theſe paſſions therefore might be employed by phyſicians as cordials; which they are of the higheſt kind; and much better than any that the materia medica can produce. For example, if a phyſician is capable of perſuading a ſick perſon that he ſhall recover, ſuch an *hope* will do more towards the cure, in ſome caſes, than medicinal preſcriptions; and it is well known that if a patient takes it into his head that he ſhall die, this contrary paſſion to hope will ſometimes occaſion his death.

Care however muſt be taken to prevent exceſs in thoſe paſſions, at leaſt in the violent ones of joy and love, for not only madneſs or frenzy may

may be occaſioned, but by exhauſting the ſpirits, they will often bring on a contrary diſpoſition of the ſyſtem, and the laſſitude will be productive of more ill to the body than the hilarity of the paſſion did good; and the more, as the good was only temporary, whereas the evil will be more laſting. When therefore ſuch conſequences are likely to ariſe from theſe paſſions, they ſhould be carefully moderated by a ſkilful application of paſſions of an oppoſite kind.

Grief, or that paſſion which is occaſioned by the loſs of, or diſappointment in, any *good*, remarkably decreaſes the determination of the nervous influence to the body, directly contrary to joy. Hence it cauſeth the heart to beat ſlower and weaker than uſual; and as the veſſels and other parts of the body will be equally affected, the heart will alſo have, notwithſtanding its leſſer ability, a greater ſhare than ordinary in circulating the blood. Hence it painfully labours, throbs, and is oppreſſed as with an heavy weight; and as in joy, by the greater determination of the influx from the nerves, a ſenſe of warmth was cauſed about the heart, and the ſyſtem in general, that of coldneſs or damp will now take place, for the contrary reaſon. This paſſion alſo, when very ſudden and violent, has been known to occaſion inſtant death. *Grief*, eſpecially that exceſs of it which is termed *deſpair*, is not only of longer continuance than joy, but

but productive of much worſe effects. Loſs of appetite, hyſterics, hypochondriaca, and melancholy madneſs, are often the dreadful conſequences thereof. It may be added, that in this paſſion, the ſecretions, and other functions of the body, are remarkably leſſened; and ſometimes ſo much impeded, that the fluids in a manner ſtagnate, and the ſyſtem becomes as it were almoſt inanimate.

Every means ſhould be uſed to divert the attention of the mind from the cauſe, or object of this fatal paſſion, and the introduction of objects which are likely to inſpire a contrary affection, ſhould on all occaſions be attempted. But even this paſſion may be rendered uſeful, as it may be employed to moderate the dangerous exceſſes of the contrary ones; as hath already been remarked.

Fear bears much the ſame relation to grief as hope does to joy; for as hope is a mixture of joy and grief, in which the former preponderates, ſo fear is a like mixture, in which grief has the exceſs, as Mr. Hume has elegantly ſhewn. Fear, therefore, is only a leſs perfect grief; and its effects on the body are of a ſimilar nature, but only more moderate. Hatred, envy, jealouſy, and the other diſagreeable paſſions, have alſo ſomewhat ſimilar effects.

ANGER, or RAGE, though a disagreeable passion, has an effect on the body somewhat like that of joy, I mean with respect to the increased determination of the nervous influence into the fibres; but without the pleasing sensation. What was said of that passion may be applied, with proper allowances, to this, and to others of the like kind.

The effects of the passions on the body are to be considered as produced immediately by means of the moving fibres; for it is into these that the nerves infuse their influence, according as they are affected by the mind. Joy contracts, or braces up the fibres more than usual; hence they act more powerfully, or with greater vigour; and grief relaxes, or weakens them, whence the force of their action will be less. The like may be observed of the other passions: for the vital functions of the body go on more or less vigorously according as the fibres act with greater or less power. Excesses of passion however, especially if frequent, will strain, or otherwise impair the fibres, &c. and hence those melancholy consequences which were mentioned when treating of the fibres.

It appears therefore that the passions are capable of being applied to useful purposes in medicine. But skill and address are required; and, perhaps, it will be advantageous to the practitioner if he likewise makes himself acquainted with their metaphysical theory, as delivered by Mr. Hume, and other authors.

CHAPTER XV.

OF THE SENSES.

OF VISION.

THE doctrine of vision, so far as relates to the refraction of light, was explained in the chapter on optics. The manner in which vision is caused by the rays of light shall be the subject of this section.

The different colours, like notes of sound, may be considered as so many gradations of tone; for they are caused by vibrations of the rays of light beating on the eye, in like manner as sounds are caused by vibrations or pulses of the air beating on the ear. Red is produced by the slowest vibrations of the rays, and violet by the quickest.

In the chapter on optics it was shewn that colours might be excited in the eye without the aſſiſtance of the rays of light, or merely by irritation, as is the caſe with the ſenſe of feeling. But theſe colours are the ſame with thoſe which are excited by the rays of light. For the white colour is like that which ariſeth from a mixture of all the rays; and different tones or notes of colour are ſometimes obſerved to ariſe, like thoſe cauſed by the refracted rays. Now as the rays cauſe colours by means of their vibrations, and as colours may be excited by irritating the eye, like thoſe cauſed by the rays of light, it ſeems apparent that thoſe colours are the effects of as many different vibrations liable to be excited in the retina, of the ſame ſwiftneſs with thoſe of the reſpective rays of light.

In the chapter on ſound, it was ſhewn that a muſical ſtring, when put into vibration, has the property of putting another ſtring into motion, whoſe time of vibration is the ſame with its own; or whoſe note is in uniſon with it. The ſame thing ſeems to obtain with regard to the rays of light, and the vibrations or colours liable to be excited in the retina. If the red-making rays fall on the eye, they excite the red-making vibrations in that part of the retina whereon they impinge, but do not excite the others becauſe they are not in uniſon with them. And hence it ſeems to be that the leaſt refrangible rays cauſe only a red colour. For the ſame reaſon, if the violet-making rays ſtrike on the retina, they excite all the violet-making vibrations in the part on which they fall, and thoſe only, and therefore cauſe only a violet colour, and the like may be obſerved of the rays which cauſe other colours. From hence it may be underſtood that the rays of light do not cauſe colours in the eye any otherwiſe than by the mediation of the *vibrations or colours liable to be excited in the retina*; the colours are occaſioned by the latter; the rays of light only ſerve to excite them into action. So likewiſe if blue and yellow-making rays fall together on the ſame part of the retina, they excite the blue and yellow-making vibrations reſpectively, but becauſe they are ſo cloſe together as not to be diſtinguiſhed apart, they are perceived as a mixed colour, or green; the ſame as would be cauſed by the rays in the midway between the blue and yellow-making ones. And if all ſorts of rays fall promiſcuouſly on the eye, they excite all the different ſorts of vibration; and as they are not diſtinguiſhable ſeparately, the mixed colour perceived is white; and ſo of other mixtures.

We are therefore perhaps to conſider each of theſe vibrations, or colours in the retina, as connected with a fibril of the optic nerve. That the vibration being excited, the pulſes thereof are communicated to the nervous fibril, and by that conveyed to the ſenſory, or mind, where it occaſions, by its action, the reſpective colour to be perceived.

perceived. Alſo that there are in the retina a great number of vibrations of the ſame times, or kinds, and that all the different ones are mixed equally together throughout the whole organ.

OF HEARING.

As colours may be excited by irritating the retina, ſo there are ſounds liable to be excited by preſſing or irritating the ear. The tinnitus aurium, or ringing in the ears, had long been noticed by authors. By preſſing the ear with the finger, and otherwiſe irritating it, it has been found that a regular ſcale of notes, or muſical ſounds, might be excited; and that the ear ſeems to contain all manner of them, from the loweſt, or moſt grave, to the higheſt, or moſt acute. It is probable therefore, that the vibrations of air cauſe ſounds by the mediation of theſe, in like manner as the rays of light were ſuppoſed to cauſe colours by means of the vibrations liable to be excited in the retina.

The pulſes or vibrations of the air beat upon the tympanum. The internal ſounds, however, or thoſe liable to be excited by preſſing the ear, do not ſeem to be in the tympanum, but in the labyrinth and cochlea, which are the inner parts of the ear. Behind the tympanum is a cavity filled with air; from its reſemblance to that inſtrument, it is called the *drum*, of which the membrane called *tympanum* is conſidered as the

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head. In the tympanum, only the ſenſe of feeling can be excited. When a ſound enters the ear it beats upon that membrane; and the pulſes are propagated thro' the drum into the cochlea and labyrinth. It there probably excites the uniſon internal vibration, and thence cauſeth a ſound, in the ſame manner as was ſhewn with regard to colours. The note of the ſound therefore, and alſo its loudneſs, ſeem to be determined by the internal ſound excited in the labyrinth; but the ſituation, and other particulars of it, are probably known by means of the other parts of the ear, in a manner not yet properly underſtood. See alſo the chapter on ſound.

OF FEELING.

Hearing and ſeeing are confined to very ſmall portions of the animal, the *eyes* and *ears:* but feeling is an univerſal ſenſe, being diſtributed throughout the whole body.

Hearing and ſeeing are capable of being excited by mere irritation, as hath been ſhewn; and they ſeem to be both occaſioned by vibrations liable to be excited in the organs of thoſe ſenſes, and carried, by the nerves to the ſenſory, or mind. Feeling is ſo liable to be excited by this means, that it is ordinarily excited by no other. And therefore it ſhould ſeem that feeling is alſo occaſioned by vibrations liable to

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be excited in thoſe parts which are endued with this ſenſe.

The whole cutis, or ſkin, is poſſeſſed of the ſenſe of feeling, and anatomiſts ſhew certain ſmall pyramidal bodies, which they call papillæ, as the immediate organs of this ſenſe; perhaps we may rather ſay, of that particular modification of it, called *touch*.

When the ſenſe of feeling is excited with an undulating motion, as by means of a feather, or the like, it yields that pleaſing kind of ſenſation called *tickling*.

When feeling is excited very ſtrongly, it degenerates into *pain*, which though diſagreeable, is of the moſt important uſe, for by it we are informed when any thing is injuring, or deſtroying the body, and arouſed to remove the cauſe.

Different parts of the body are endued with different degrees of feeling, ſuitable to their different uſes. Thus, the hair, nails, and cuticle have no feeling; the bones very little; the gums, the heart, and ſome other parts have leſs than the fleſh in general, for elſe the former would be hurt by hard food; and the labour of the latter in circulating the blood, would be continually ſenſible and troubleſome.

The difference between irritability and ſenſibility was ſhewn when diſcourſing on the fibres.

Feeling is by far the moſt uſeful, extenſive, and important of the ſenſes, and may be ſaid indeed, to be the baſis of them all. Viſion would be of very little uſe to us, if it was not aided by the ſenſe of feeling. The picture of an object, for example, is painted on the retina, by the rays of light; yet it is not merely by this picture, but by the eye tracing the boundaries of an object, that we get the idea of its ſhape, the eye only conſidering that point of an object which lies in the optic axis, at a time; ſo that it is properly by means of the ſenſe of feeling, that we get the idea of an object's ſhape. The like may be obſerved with regard to the ſituation, motion, &c. of objects. With reſpect to hearing, we probably gain an idea of the ſituation, &c. of ſounds, entirely by means of feeling. In ſhort, it is to this ſenſe that we are indebted, either immediately, or indirectly, for by far the greateſt part of our knowledge; as the reader will find by conſulting the authors who have beſt treated on thoſe ſubjects in a metaphyſical view.

To feeling may be added the ſenſations of heat and cold, which are capable of being excited wherever the ſenſe of feeling is found, and therefore ſeem to be only certain modifications of it. Heat ariſeth in a part when a ſubſtance hotter than

than that part is applied to it, and cold in the contrary caſe.

OF TASTE, SMELL, HUNGER, THIRST, &C.

Taſte, and ſmell, differ from the ſenſes of ſeeing, hearing, and feeling, in that they cannot be excited by merely preſſing, or irritating the organs, as happens with the others. The like may be obſerved of hunger, thirſt, &c.

From odorous bodies, effluvia, or very ſubtle particles, are continually flying off. Theſe particles being drawn up the noſtrils, with the air in inſpiration, act upon the organ of ſmelling, in the os cribriforme, and, according to their ſeveral natures cauſe different ſmells.

As the particles exhaled by the odorous body are in greater plenty near the body than at a diſtance from it, ſmells are weaker as the body emitting the odour is more remote, and that in a duplicate proportion to their diſtance, as thoſe who are ſkilled in mathematics can eaſily demonſtrate.

Alſo when the air is moiſt, particles exhale in greater plenty than when it is dry, and in a warm air, more than in a cold one, and therefore the ſmells of bodies are more powerful at thoſe times than at others.

TASTE is excited by ſaline, and certain other particles of bodies, which muſt either be in a liquid form, or capable of being diſſolved into a liquid by the moiſture of the tongue, for otherwiſe no taſtes are excited by them *.

The papillæ in the tongue are the organs of taſte; and on them the liquids which are capable of exciting this ſenſation act. As the particles are of different natures, they cauſe different taſtes, and taſtes of the ſame kind are ſtronger according as the particles more abound in the liquid.

THIRST is an uneaſy ſenſation in the throat, ariſing from a want of ſufficient moiſture in that part.

HUNGER is an uneaſy ſenſation in the ſtomach, ariſing from want of food. It is occaſioned by the juices of that viſcus, which not being employed in digeſting the food, ſtimulate the ſtomach.

REMARKS ON THE SENSES.

The ſenſes ſerve to inform the intelligent principle of what paſſes in, or without the body, in order that proper meaſures may be adopted for

* One reaſon why ſome ſaline ſubſtances taſte more than others, may be, their diſſolving more readily and copiouſly in the moiſture of the tongue.

The above reaſoning ſeems alſo to hold good with regard to the organ of ſmell.

for the preſervation and happineſs of the individual.

Thus, VISION gives information concerning things at a diſtance, which the other ſenſes could take no cognizance of. It alſo acquaints us with the objects immediately around, in a much quicker, better, and more accurate manner than the other ſenſes could. To this ſenſe objects appear moſt delightfully painted with a thouſand varieties of beautiful colours, all which they are deſtitute of naturally, and for which they are indebted to the eye which beholds them. Our happineſs was evidently conſulted by the Great Creator in this particular.

HEARING alſo informs us of things at a diſtance, and in many inſtances where ſight either could not at all, or much leſs advantageouſly. On this ſenſe likewiſe the whole ſyſtem of language depends, whereby we are enabled to hold converſe with one another, and from whence we derive ſuch wonderful advantages. As to the eye bodies are indebted for the beautiful colours under which they appear to us by that ſenſe, ſo the like may be obſerved with regard to muſic and the ear. Mere motions or tremors of the air, are, by means of this ſenſe, metamorphoſed into the moſt raviſhing harmony. Another very capital inſtance of our happineſs having been conſidered by the Creator. There is ſcarce a greater charm againſt the evils of life than muſic, when ſkilfully applied, and it has even been introduced into medicine, in this view, with ſucceſs.

SMELLING alſo gives us notice of certain qualities of diſtant objects which could not otherwiſe be known, as was before obſerved.

Theſe three ſenſes are, naturally, the only ones which inform us of what paſſes without the body. By theſe we are timely warned of an evil, or apprized of a good; and ſet at work to guard againſt the one, or endeavour to obtain the other. Theſe ſenſes, in conjunction with the others, inform us alſo of the qualities of bodies, of our food, and a number of other circumſtances, not to our purpoſe to relate; and hence are of infinite ſervice in the arts, as well as in the ordinary occurrences of life.

Objects of TASTE operate only by immediate contact with the tongue, and therefore do not, like thoſe ſpoken of, inform us of what paſſes without the body. Its uſe is to examine, together with ſmelling, the qualities of the food. This ſenſe, as well as that of ſmell, alſo contribute to our happineſs, by metamorphoſing the actions of mere inanimate particles into agreeable ſenſations; and hence we are led, by the mere conſideration of pleaſure, to the moſt neceſſary of our actions, that of taking food.

But

But as our bodies, from the continual waſte of fluids, have occaſion to be frequently recruited, nature has provided a ſtill more powerful ſtimulant, or incentive, to the recruiting the body, I mean the ſenſation of HUNGER. By this ſenſe, we are informed when the taking of nouriſhment is neceſſary. In health the call of appetite correſponds exactly enough with the wants of the ſyſtem in this reſpect. The gaſtric juice, whoſe uſe is to digeſt the food, being continually ſecreted, it follows that when there is no aliment in the ſtomach to employ it, it irritates the ſtomach itſelf, giving us the craving ſenſation of hunger, and thereby ſtimulating us to eat, in order to get rid of that uneaſy intruder. Nor will it be ſatisfied till a due quantity of food is taken.

THIRST is inſtituted with a ſimilar deſign to hunger. When fluids are wanting in the ſyſtem, the dryneſs of the throat in conſequence thereof produces the moleſting ſenſation of thirſt, which excites us to the act of drinking, in order to remove it; ſo that, as in hunger, our pleaſure or eaſe, and the views of nature, are, at the ſame time, obtained.

Both hunger and thirſt however, are liable to be perverted by ill habits, or by diſeaſe, from the views originally intended by them. Thus, drunkards and gluttons frequently hunger and thirſt when nature has no occaſion either for

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ſolid or fluid aliment, and the like ſometimes happens from their being vitiated by diſeaſe. The contrary of this likewiſe often takes place, eſpecially with regard to hunger; it neither giving notice when nature requires a ſupply, nor is the ſtomach, through weakneſs, capable of turning the food, if taken, into proper nouriſhment. It may be obſerved too, that when a fever takes place, nature herſelf providently deſtroys the appetite, in order to prevent an increaſe of the diſorder.

LUST was implanted in the body with a view to ſtimulate us to the propagation of the ſpecies. A turgidneſs of the ſeminal veſſels produces an uneaſy kind of ſenſation, which provokes us to the act of copulation. And by that act, as happens with regard to hunger and thirſt, we at once get rid of the importunity, and anſwer the deſign of nature. The PASSIONS might alſo be conſidered as ſo many different ſenſes; for all of them have their organs and origins in the body.

The ſenſations by which we are provoked by the contents of the bladder and rectum, to empty theſe viſcera, may alſo be conſidered as diſtinct ſenſations, for theſe reſpective purpoſes. Theſe ſenſations however, as well as thoſe of hunger and thirſt, ſeem to be only particular modifications of feeling. Perhaps thoſe of taſte and ſmell are alſo in the ſame predicament.

CHAP.

CHAPTER XVI.

OF SLEEP.

THE difference of the ſtate of the body in ſleeping and waking is, that thoſe parts of the body which ſerve for voluntary motion in waking, as alſo the organs of ſenſation, have their faculties ſuſpended in the former ſtate. At that time, none but the vital motions, ſecretions, and other functions abſolutely neceſſary to the continuance of life, but which are wholly independent on the will, go on. Thus, the eye does not ſee nor the ear hear, nor the ſkin feel at that time, if the ſleep be profound; neither do the limbs move, though the will commands; which is frequently the caſe in dreaming, or *imperfect ſleep*. This term I give it, becauſe when the ſleep is profound, the faculty of dreaming alſo becomes dormant, the mind being aſleep as well as the body. The mind therefore at theſe times is not only unconſcious of what is going on in, and without, the body, but the whole animal, conſidered as a loco-motive being, is in a manner lifeleſs.

This alternation of ſleeping and waking is neceſſary in order to repair the waſte of the parts.

For *nutrition* is chiefly performed in ſleep; and the vital ſtrength recruited. Hence the injury which the body derives from the want of it. Hence alſo we may be enabled to underſtand the medicinal uſes of ſleep, which in caſes of long and obſtinate watchfulneſs, ſhould ſometimes be procured even by artificial means, whether the evil be occaſioned by diſeaſe, pain, uneaſineſs of mind, or other cauſe.

As ſleep is ſeldom profound, we are by the alternation of this ſtate, and waking, furniſhed with an agreeable viciſſitude, a variety of ſcene. For moſt people, during the former ſtate, dream. We are then, as it were, in a new world. The cares of life are forgot for a while, and we awake to real action with new reliſh and vigour.

Delirium, and madneſs, are alſo a kind of dreaming, the ideas in both caſes appearing to us like real external ſenſations, for which we at the time miſtake them. Theſe however are to be conſidered as *diſeaſes*.

CHAPTER XVII.

OF GENERATION.

HUMAN beings are propagated by means of ſeed as well as vegetables; and the egg is the animal ſeed. In botany we find, that male and

and female parts are neceſſary to the production of plants, as well as in animals. The ſeed itſelf is in the female part of the flower, or in the female flower, where the male and female flowers are diſtinct. But the pollen, or vivifying principle from the male part or flower, is abſolutely neceſſary to rendering that ſeed prolific, and, with which being duly impregnated, the ſeed becomes capable of producing a new plant. So in the female of the human ſpecies, the egg, the proper baſis of human ſeed is contained, but never becomes perfect unleſs quickened by the vivifying principle from the male; when that is done, the egg or ſeed is diſpoſed to produce a young animal. In oviparous animals the egg, when it arrives at a certain degree of perfection, is excluded from the body, covered with an hard ſhell to defend it from injuries, and afterwards hatched by heat. But in human beings, and in thoſe animals that are termed viviparous, the egg is hatched in the womb.

In the female of the human ſpecies a monthly diſcharge of bloody matter takes place in the abſence of pregnancy; but after conception that diſcharge generally ceaſes, it being then turned to the nouriſhment of the fœtus. The improper ſuppreſſion, or profuſion of this diſcharge, often occaſion many diſorders, eſpecially thoſe of the hyſteric kind.

CHAPTER XVIII.

OF THE PROGRESS OF LIFE, AND OF DEATH.

FROM the time of impregnation of the ovum by the male, till the birth, the young animal in the egg, is continually growing, or increaſing in ſize. From the time of the birth it alſo continues to augment in bulk till it arrives at the ſtate which we term adult; and which, in an human being, is uſually reckoned about the twentieth year. The increaſe of growth is greateſt at firſt, and is afterwards leſs and leſs rapid, till the age of puberty is attained.

The reaſon of this increaſe of ſize is, that the preſſure of the fluids is greater than the reſiſtance of the ſolids, ſo that the latter will in courſe give way, or expand*. For in youth the ſolids are ſoft; but at the age of puberty they become harder; and ſufficiently ſtrong to reſiſt any farther dilatation by the preſſure of the fluids. They afterwards become more and more hard; and at length ſo dry and rigid, that they are no longer fit for the purpoſes of the motions of the ſyſtem; whence thoſe motions, and of courſe life, which depends on them, ceaſe; and death cloſes the ſcene.

* The fluids are alſo in greater proportion to the ſolids in youth than in age.

CHAP-

CHAPTER XIX.

RECAPITULATION.

FROM what has been ſaid, the reader will perceive, that when the ſolids and fluids are in their proper ſtates, and proportions; the aliment good, taken in due quantity, and properly digeſted; and the air in the moſt perfect ſtate with reſpect to denſity, and the other particulars already diſcourſed of, the circulation, ſecretions, and other animal functions, will go on to the beſt poſſible advantage; the faculties of both mind and body will be in their moſt perfect conditions, and a general harmony will reign throughout the ſyſtem; this conſtitutes *health.*

On the contrary, when any of theſe are faulty, the harmony is deſtroyed, and *diſorder* takes place in the ſyſtem; and the diſorder is greater, according to the degree of the defect, or as more of theſe powers concur in producing it.

Diſorders therefore owe their origin either to food, the ſyſtem itſelf, or to the air: for caſualties, or the effects of external violence, are not here conſidered.

Diſorder may be introduced by food ſeveral ways; by too little a quantity thereof; by too much; by that which is too poor; by too rich food; by an over proportion of ſolid to fluid; by too great a proportion of liquid; and by improper food, either conſidered in itſelf, or varied in all the preceding caſes.

The conſequences of taking too little food, even of that which is proper, are too obvious to need pointing out. A waſte of the body, weakneſs, and at length a fever, ariſing from the gaſtric juices, which ſhould be employed in digeſting the food, getting with the little chyle that is made into the ſyſtem. An encreaſed allowance of food is obviouſly the beſt remedy in this caſe.

Food in too great quantity produces a plethora, or over fulneſs of the veſſels, and alſo crude or imperfect juices, the ſtomach taking in more than it can properly digeſt. Hence what are vulgarly called humours in the blood, and the eruptions in conſequence of theſe; gouty, and other chronic complaints, fevers, a decay of vital ſtrength, from a general weakneſs of the over-ſtrained fibres; and at length indigeſtion, and loſs of appetite; the ſtomach, from the frequent over diſtention, loſing its digeſtive power. The mere plethora may be relieved by bleeding, evacuations, and reſtriction to a due quantity

of

of food. The other complaints by the ſame means, in conjunction with thoſe uſually preſcribed for the reſpective maladies.

A poor, and rich diet produce effects ſimilar to the above; and, if taken in the ſame proportion, in a more eminent degree.

If the ſolid food be in too great proportion to liquid, the blood will be apt to be too thick, and therefore will not circulate ſo freely as it ought, and the ſecretions, and perſpiration will alſo be impeded. Hence ſtagnations of the fluids, obſtructions, and the diſorders ariſing from them. An exceſs of liquid food, I mean if too watery, will occaſion a contrary ſtate of the blood, and the diſorders conſequent thereupon.

The diſorders ariſing from improper, or bad food, will be various according to its nature. Thus, putrid ſalt proviſion produces the ſcurvy, plants of various kinds occaſion different ſpecies of diſorders, and ſome of them almoſt inſtant death, whence they are termed poiſons; and ſo of others. Philoſophy has not yet arrived at a ſufficient knowledge of the theory of aliment, to determine à priori on theſe matters, though from the improvements and diſcoveries almoſt daily making by the inquiſitive, there is reaſon to hope for greater certainty, and that this part of phyſiology will alſo in time be reduced to a

 ſcience.

ſcience. We know that the food that we take muſt, among other principles, contain a due proportion of phlogiſton in a ſtate proper for aſſimilation. And hence it ſeems to be, that animal food is in general beſt for nutrition; and next to that vegetable. There are few animals but what might be made uſe of as food. The vegetables proper for diet are far leſs numerous. But a proper mixture of animal and vegetable food is found to be moſt conducive to health.

The diſorders liable to be produced in the ſyſtem by the different ſtates of the air were ſpoken of in the XIIIth chapter, and therefore need not be repeated.

Thoſe ariſing from the ſyſtem itſelf are produced, 1. By the paſſions; of which we treated before. 2. By too violent exertion, or exerciſe; and, 3. By a ſedentary life, and too much ſleep.

The effects of over exertion, and continued fatigue on the ſyſtem are to ſtrain, wear out, and relax the fibres, and occaſion too great an hurry and irregularity in the circulation and ſecretions, and this is alſo commonly joined with an anxious ſtate of mind. From hence conſumptions, fevers, and other ſimilar complaints ariſe.

On the contrary, want of exerciſe, and an over indulgence of ſleep, eſpecially if accompanied with a tranquil mind and full diet, is apt

to

to produce plethora, crudities, and corpulency, with their consequences. But when a sedentary life is joined with hard study, and abstemious living, the opposite effects are more apt to be produced, study being a real exercise, and injures the vital powers even more than that.

Many disorders may also be called disorders of the body, which originally took their rise from irregularity with respect to food, the state of the air, or other cause. For example, when a general relaxation of the fibres obtains, we are to consider it only as a disorder of the body, without regard to its original cause, especially if that cause no longer operates; and the intention by medicine must be to restore the tone of these fibres by bracing medicines, and a proper regimen. But if the cause of the disorder remains, the first step must be to remove it. Thus, if by cold air, or otherwise, perspiration be obstructed, and a fever occasioned, we are first to remove the external cause, and then by diaphoretic and attenuating remedies, &c. restore perspiration. The like may be observed of many other diseased states of the body.

The science of medicine is not yet arrived at such a state of perfection as to enable us to reason about the manner of operation of medicine in general, any more than we can about the causes and progress of diseases in many cases; so that much muſt be left to accurate obſervation; and our conduct muſt be regulated by the paſt experience of others, and our own; hence the great uſe of practical writings in medicine. Yet our knowledge in this way is very conſiderable, and in moſt caſes ſufficient. Thus, when from a knowledge of the cauſe of a diſeaſe, we know alſo that any particular evacuation will cure it, we can, in general, with certainty produce that evacuation, even as a mechanic can produce a deſired effect by a known adequate cauſe. If, for example, we would purge, we not only know what medicines will procure that evacuation, but have our choice of a variety of them, which are known to produce different effects in that way, according to the end to be anſwered. Thus, manna is merely ſolutive, but jalap powerfully evacuates alſo the vaſcular ſyſtem, and ſo of others. The like may be obſerved of emetics, diuretics, ſudorifics, and thoſe which encreaſe other evacuations. So likewiſe we can leſſen one evacuation by encreaſing another. If tonics are wanted, we have our choice of a like variety. And the ſame may be obſerved of attenuants, and thoſe for other intentions. We even know the *manner* in which ſome of theſe remedies act; Thus, an emetic acts by vellicating the fibres of the muſcular coat of the ſtomach, thereby exciting it into contraction, whereby the contents of that viſcus are expelled. A cathartic acts in a

ſimilar

ſimilar manner on the guts, and alſo, by irritating their ſmall glands, occaſions an encreaſe of their ſecretions; whence the liquid part of the diſcharge. The operations of other medicines have alſo been rationally accounted for by medical writers. But yet to know *how*, or *in what manner*, theſe medicines produce theſe effects, would be of little other avail than to gratify curioſity; all that we have occaſion to know is, that they *will have theſe effects*; and our knowledge in this reſpect may be conſidered as real ſcience. The ſkill of a phyſician conſiſts in acquiring a knowledge of the cauſe and ſtate of a diſorder; and that will point out to him the remedies proper to be adminiſtered, at leaſt in caſes which are relievable by medicine.

We are even more perfect in this branch of the medical art than in that of the knowledge of the diſeaſes themſelves, many of which ariſe from cauſes that do not fall under the nature of our ſenſes; as from qualities of the fluids, the air, &c. which philoſophy has not yet enabled us to aſcertain. In theſe caſes, till we are better informed, experience, and attentive obſervation muſt be our chiefeſt guides. But there are a variety of caſes in which we are able to acquire a knowledge of the diſorder with ſufficient certainty. Thus the cauſes of diſeaſes with reſpect to plethora, fever, and the like, are diſcoverable with accuracy by the pulſe. A relaxed ſtate of the fibres, by the weakneſs and laſſitude of the body; a diminiſhed perſpiration, by the uſual ſymptoms of a cold; and if any doubt ariſeth with regard to the ſtate of the blood, the opening a vein will uſually ſatisfy us. In many other caſes alſo the like certainty may be obtained. But I meant only to inſtruct the reader in *philoſophy*; whereas I am now treſpaſſing on the bounds of the *practice of phyſic*; I ſhall not therefore any longer detain him on that head.

APPENDIX.

APPENDIX.

APPENDIX.

OF LIGHT.

IN a former treatiſe, I gave ſome obſervations concerning light, the ſubſtance of which will be found at the end of the chapter on Optics in the preſent work. The following particulars on the ſame ſubject have ſince occurred to me. I have ſubjoined them to this Treatiſe, becauſe I do not know when I may have leiſure to appear in print again.

The Motion of Light is ſwifteſt in Bodies of the leaſt refractive Denſity.

In the 10th propoſition of the third part of the ſecond book of Sir Iſaac Newton's Optics, it is ſuppoſed that light is ſwifter in bodies than in vacuo. The following conſiderations will, I preſume, ſhew this to have been a miſtake.

In the 12th and ſubſequent propoſitions, the illuſtrious author ſhews that the rays of light are in fits of alternate reflection and tranſmiſſion,

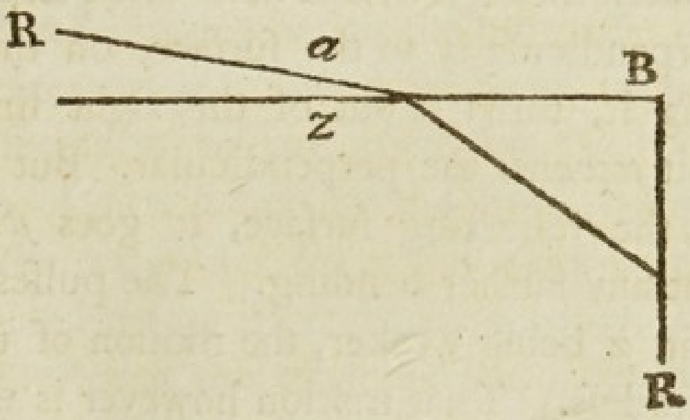
ſion, which may be termed *a vibration of the rays*. It is now generally underſtood, that on this vibration of the rays viſion depends; the different rays having different times of vibration, and thereby cauſing the different colours, in the ſame manner as different times of vibration of the air cauſe different tones, or notes of ſound. Now as the ſame ray, however reflected or refracted, always excites the ſame colour, its time of vibration muſt always be the ſame; for if it was either quicker or ſlower, the colour would be altered. For example, if the green-making rays were made to vibrate more quickly, they would no longer cauſe green, but blue, indigo, or violet; and if they were made to vibrate more ſlowly, they would cauſe yellow, orange, or red; in the ſame manner as when a muſical ſtring is either tightened, or ſlackened, ſo as to alter the time of its vibration, the note yielded thereby is proportionably higher or lower than before.

The times of vibration of the rays therefore, being always the ſame, it follows, that if the velocity of light be encreaſed, each fit of a ray will take up a proportionably *greater* ſpace than it did before. But that if the velocity of light be diminiſhed, the ſpace of each fit will be proportionably *leſs*.

Now

Now it appears from the ſecond book of the Optics, but particularly from the table in page 206 (3d edition) that the *greater* the refractive denſity of the body, the *ſhorter* are the ſpaces occupied by the fits of the rays. Thus, to take an example from the table in round numbers, the ſpace in glaſs, is to the ſpace in air, as 9 to 14. Therefore, inſtead of light being ſwifter in glaſs than in air, as the propoſition referred to ſuppoſes, it is ſwifter in air than in glaſs, and that in the proportion of the two numbers juſt mentioned, as is evident from what has been ſaid; ſo that the very reverſe of that propoſition is the truth: light moving *ſlower* in bodies than in vacuo, in proportion to their refractive denſities.

That this is the truth, will appear from the hypotheſis which Newton himſelf propoſes for explaining refraction. Let R be a ray paſſing



out of a rarer into a denſer or more refracting medium. He ſuppoſes his æther to be denſer in rare bodies, and rarer in denſe; and by this ſubtle elaſtic fluid he conjectures that the ray is refracted. At the ſurface where the two æthers meet, a ſmall condenſation of each may be ſuppoſed; and the author imagines that pulſes or waves are excited in the medium, which are ſwifter than the ray, and therefore overtake it in its paſſage, and urge it forward. If a cannon-ball be ſhot obliquely through air into water, it will be turned, by the reſiſtance of the water, *from* the perpendicular. But a ray of light is refracted *towards* the perpendicular; and this I ſuppoſe has led opticians to imagine that the motion of the ray is encreaſed, contrary to what happens to the cannon-ball. If the æther be denſer in *a*, the rarer medium, than in *z*, the denſer, the pulſes or vibrations of it muſt be ſtronger; and therefore the ray muſt be urged on with greater velocity in *a* than in *z*. When the ray arrives at the ſurface, the medium of *a* being condenſed there, the ray meets with reſiſtance. But having broken through it, that ſame denſe æther, acting perpendicularly to the ſurface, on the ray's quitting it, turns it out of the right line, and bends it *towards* the perpendicular. But having paſſed the refracting ſurface, it goes *ſtrait on* without any farther bending. The pulſes of the æther in *z* being weaker, the motion of the ray becomes leſs. That motion however is uniform during its whole paſſage through *z*, as is evident from the fourth part of the ſecond book of the Optics; in which reſpect it differs from the cannon-

non-

non-ball, which not only has its motion continually aſcend in the water, but is turned into a *curve line*; ſo that in neither reſpect are the inſtances parallel.

When the ray paſſes out of a denſe into a rare medium, as from *z*, into *a*, the bending of the ray *from* the perpendicular is performed by the condenſed part of the denſer æther in *d*. But having broken through that confine, the ray, now acted on by the ſtronger pulſes of the æther in *a*, moves on ſwifter than before.

When light paſſes from a denſe into a rare medium, it is reflected entirely at a certain obliquity; but in paſſing from a rare into a denſe medium, it is tranſmitted, though the obliquity be much greater; which may be underſtood from the greater condenſation and reſiſtance of the ſurface of the æther in *a*, than of that in *z*.

Alſo reflection, whether the ray paſſes through the denſer towards the rarer body, or the contrary, ſeems to be performed by the condenſed ſurface of the æther in the rarer body. For when the ray comes from the rarer medium, it is reflected before it can break through this condenſed æther at the confine; and when it comes from the denſer medium, it is reflected by ſtriking againſt the ſame condenſed ſurface of the æther in the rarer body *a*, as well as by its own.

And hence it appears, why reflection out of the denſe medium into the rare, is even weaker than out of the rare into the denſe; the former being produced but by one power, the latter by two.

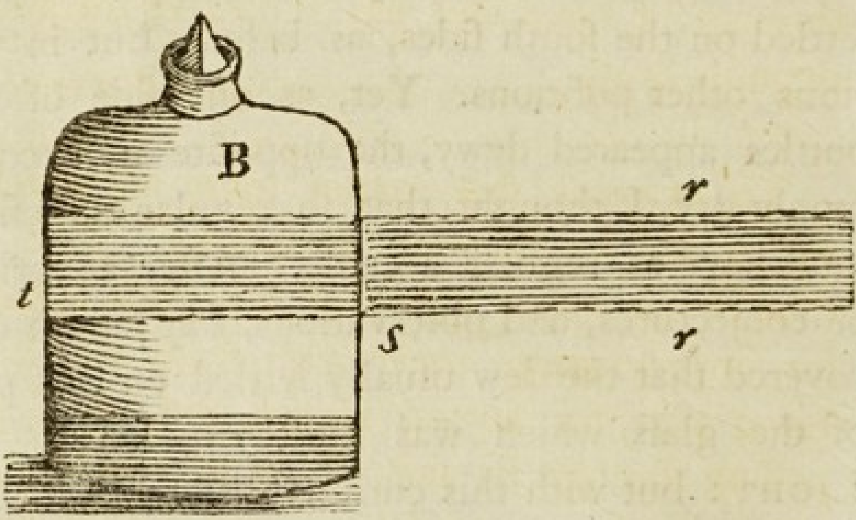
We have hence alſo the reaſon why there is firſt an attraction, and then a repulſion, at the ſurface of a body; and why, in proceeding from the denſe body, the attractive force is weaker, the repulſive ſtronger; and the contrary as we proceed from the ſurface of the rarer. From this repulſive force, ariſing from the condenſation of the medium at the confine, the inflection of light may likewiſe be underſtood.

I muſt aſk pardon for dwelling ſo long on an hypotheſis; but it is becauſe it was Newton's, and that it was made uſe of by himſelf to explain the phenomena of refraction. But though it overturns the ſuppoſition that light is ſwifter in bodies than in vacuo, yet the general ſcope of the propoſition in queſtion will not be affected thereby; the ſquare of the line B R, in the ſcheme, being ſtill the meaſure of the refractive force of the body, as mathematicians will eaſily underſtand.

Light is capable of receiving Heat from Bodies, as well as of communicating it to them.

I have long ſince obſerved, that if a bottle or vial with an aqueous liquid in the lower part of it be ſuffered to ſtand for a conſiderable time, a dew will be ſeen condenſed in the ſides of the glaſs, above the ſurface of the liquid. Some time ago, I obſerved caſually, that this dew appeared only on one ſide of the bottle; and I have ſince found, that if the bottle be not too full, and heat does not intervene, this is generally the caſe. The bottles in which I firſt noticed this phenomenon either ſtood in, or faced, a window that looked almoſt full ſouth; and therefore ſpeculating concerning the cauſe, it firſt occurred to me, whether the motion of the magnetic fluid might not determine the vapour to the ſouth ſides of the glaſſes? But making like obſervations on bottles that ſtood in another window which faced the eaſt, and on others which I purpoſely placed in different ſituations, I found that the dew in theſe caſes by no means ſettled on the ſouth ſides, as before, but in various other poſitions. Yet, as one ſide of the bottles appeared dewy, the oppoſite moſt commonly dry, I thought that ſo regular an effect muſt have as regular a cauſe. After a variety of conjectures, and obſervations, I at length diſcovered that the dew uſually ſettled on that part of the glaſs which was moſt expoſed to the Light: but with this curious difference, that it were not the ſun's direct light, ſo as to occaſion an unuſual heat in the ſide of the veſſel expoſed to it; for then, as might naturally be expected, the reverſe of the phenomenon took place; the ſide next the ſun being dry, the oppoſite one dewy.

As light is uſually conſidered as connected with heat, I was at a loſs how to reconcile this fact to the received philoſophical theory of theſe matters. As the vapour riſes alike into the whole cavity of the bottle, if its ſides were every where equally warm, it ought to condenſe uniformly on every part. But ſince it is found to condenſe only towards the light, and, on the contrary, to evaporate from the oppoſite ſide if it be already wet, (as I have tried,) it ſhews that the ſide next the light is *colder*, and the oppoſite ſide *warmer*, than the other parts of the veſſel: and this difference muſt be occaſioned by the paſſage of the light through it.



Let *r r* be rays of light reflected from the clouds, walls, or &c. and incident on the bottle B at *s*. The rays, on entering and paſſing thro' *s*, occaſion the glaſs there to become colder than before.

before. In B is a quantity of vapour, which will now condenſe rather about this colder part *s*, than any other; and, if the effect be great enough, a dew will appear there. The rays, on leaving the glaſs, enter the air and ſteam in the bottle; and whereas *s* was made colder, theſe will be made warmer than before; and therefore if any dew be already on *t*, it will now be diſſipated. This is the ſtate of facts as deduced from obſervation; from whence the following concluſions ſeem naturally to follow.

1. The reflected light of the clouds, &c. in paſſing from a rarer and leſs refracting medium, into, and through, a denſer and more refracting one, abſorbs heat from that medium.

2. But in paſſing out of a denſer, into, and through, a rarer and leſs refractive medium, it depoſits heat.

To examine this matter more accurately, I varied the experiment as follows. The bent tube of the upper veſſel of my glaſs apparatus for impregnating water with fixed air, has its lower part, for ſeveral inches, cut, by a plane paſſing through its axis, ſo as to repreſent only the half of ſuch a tube. In the middle veſſel I put ſome water; and placed the apparatus in ſuch a poſition, that a right line paſſing through the centres or middle parts of the flat and convex ſides of the tube, was at right angles with the light from the window. Examining the apparatus the next morning, I found that the dew had not collected on the inſide of the veſſel as uſual, but about the tube. As the tube ſtood with reſpect to the light, there were four ſurfaces of the glaſs. On the firſt ſurface, or that next to the light, dew was condenſed; the ſecond ſurface was dry. The third ſurface was dewy, the fourth dry. The reaſon of this difference, from the uſual appearance of dew on the inſide of glaſſes, was, that in the latter caſe only the inſide of the glaſſes are expoſed to the vapour; whereas the tube, being confined in the glaſs, the vapour ſurrounded it, without, as well as within. And this alſo ſhews that the heat or cold is generated more powerfully at the *entrance* of the light into the medium, than in its paſſage thro' it, as will alſo appear in the ſequel.

It has uſually been thought that light and heat are one and the ſame principle. But it appears from the above obſervations, that heat is only one of the principles of light; and that common reflected light at leaſt, is capable of retaining a greater or leſs quantity of it, according as it paſſes through a more or leſs refracting medium.

Speaking of the foregoing obſervations to a friend, he referred me to a fact mentioned by the late ingenious Mr. Bewley, at the end of one of

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Dr. Prieſtley's volumes, of a ſimilar evaporation and condenſation of quickſilver in his barometer; which evidently proceeded from the ſame cauſe; and may be conſidered as a confirmation of the facts ſtated above.

That light is capable of being combined with more or leſs heat, is alſo evident from ſome curious facts related by Mr. Sheele, though that gentleman did not apprehend the cauſe; conſidering light, and what he calls *radiant heat*, as different things. Thoſe for whom this paper is written, I ſuppoſe to have read Mr. Scheele's excellent work on air and fire; and to them I ſuppoſe it will appear, after what has been ſaid above, that what Mr. Scheele calls radiant heat, is nothing more than light combined with a greater quantity of heat. From the facts related by that gentleman, it alſo appears, that by paſſing the light through different mediums, the ſuperabundant heat may be taken from it. Thus, by letting the light paſs out of the air through glaſs, into air again, the ſuperfluous heat is in great meaſure left in the glaſs; the cooled light (if I may ſo call it) alone entering into the air. By reflecting this heated light with a glaſs mirror, the ſuperabundant heat is alſo in great meaſure left in the glaſs. But if the reflection be made by the firſt ſurface of a body, as a metallic mirror, the light rebounds undecompoſed, the medium in that caſe not being changed, becaufe the reflection is made by the *air*, not by the *metal* itfelf, as hath been fhewn.

It feems to appear from hence, that light, like air, water, gold, &c. is capable of being heated or cooled; and that it may either communicate heat to, or receive it from, bodies, according to the temperature, or other circumftances, of thofe bodies. And hence it may be confidered only as a more fubtle body than air, in the fame manner as air itfelf is rarer than, and different from, water, or gold.

I will bring a few inftances to illuftrate this matter.

The fun's direct light is hotter than the ordinary reflected light of the clouds; and fo far refembles Scheele's radiant heat of coals. In paffing through the air, it depofits part of this heat. Hence we have lefs folar heat, in proportion to light, in winter, than in fummer. For the light, in paffing through a larger and denfer portion of air in its greater obliquity in the former cafe, depofits a greater portion of its heat.

So the fun's direct light, inftead of condenfing the dew in bottles on the fide next the fun, diffipates it from thence by its heat; contrary to what happens with the reflected and *colder* light of the clouds.

If

If the ſun ſhines on a common culinary fire, 'tis well known that it either puts it out, or makes it burn leſs vigorouſly than before. For though the ſun's direct light is hotter than common reflected light, yet it is much colder than the fire, and therefore ought to abſorb heat from thence. And though light be vaſtly more rare than flame, yet as it moves with ſuch prodigious velocity, a great quantity muſt paſs through it in a ſhort time, and therefore 'tis no wonder if it has a ſenſible effect on the heat of the flame. Perhaps too the light abſorbs the heat in its *naſcent* ſtate.

After bodies are made red hot, they are found not to become hotter in proportion to the heat applied. For the light emitted, like evaporation, abſorbs, and carries off, part of their heat. So likewiſe in combuſtion, part of the heat is abſorbed and carried off by the light. Heat, when ſufficient, volatilizes, and expels light from bodies, as it does fixed air, or water.

Water ſtanding in a veſſel expoſed to the light, (not the ſun's direct light,) is ſenſibly colder than the air around it. Part of this cold proceeds from evaporation. But part of it alſo, I imagine, proceeds from the cauſe aſſigned in the firſt of the foregoing concluſions. So glaſs bottles filled with watery liquids, and placed in the ſhade, are more apt to have moiſture condenſe on on their outfides, than when they contain only air.

Many years before this doctrine occurred to me, I obferved, that after having fat writing feveral hours in cold winter's mornings by candle-light, as foon as the fervant had opened the window-fhutters, though the windows themfelves remained clofe, I felt myfelf colder. I then thought it might be owing to the affociation of ideas, (for the cold could not have entered the room fo foon from without in the ufual way;) but I now rather attribute it to the admitted light of the clouds, &c. which, being colder than the air of the room, leffened the heat around me *.

Two fimilar pieces of glafs being equally heated, and one of them placed in a dark room, the other at the hole of a window-fhutter of the fame room, through which the reflected light of the

* On this fubject, the printer has furnifhed me with the following obfervation; which I think worthy of being inferted.

" Obferving what you fay, that on opening your window-" fhutters of a winter morning, you have felt it colder than be-" fore—the writer hereof hopes you will not deem him imper-" tinent (though his remark fhould be ufelefs) if he takes the " liberty to fay, that he has many times obferved, when he has " either been up all night, or hours before day-light, that the cold " about break of day, and till broad day-light, has more affected " him, (fo as to occafion fhivering, and an undefcribable difa-" greeable fenfation,) than either before or afterwards; though " he has feldom or never then been fituated where window-" fhutters were in ufe."

the clouds paſſed, the latter was cooled ſooner than the former.

To theſe may be added the old obſervation, that light reflected from a plane glaſs quickſilvered, becomes brighter; and that the ſun, ſhining through clear glaſs windows, feels hotter, than before. And other examples will probably occur to the reader.

The equilibrium of heat, diſturbed by light in the manner deſcribed, is reſtored by the known tendency of bodies to preſerve an equality of temperature; and this is done independent of the action of light. Hence it is that the foregoing effects of light are not uſually more ſenſible than we find them.

Light is a very ſubtle body, or fluid, the particles of which are made repulſive by means of heat.

It has already been ſhewn that light may contain a greater or leſs quantity of heat; and yet it is light in the one caſe, as well as in the other: for viſion is cauſed by the reflected light of the clouds, the moon, &c. as well as by the ſun's direct light: ſo that heat is not the *principal* ingredient of light.

A ray of light therefore may be conſidered as a ſeries of particles, combined with a ſufficient quantity of heat, ſo as to give them a repulſive power; and in this reſpect they may be reſembled to particles of air or vapour, which are alſo made repulſive by heat. It may likewiſe be preſumed, that when light is hotter, its particles are more repulſive, or its elaſticity is greater, than in the contrary caſe.

What the particles of light conſiſt of cannot perhaps at preſent be ſhewn. I have formerly ſuppoſed them to be phlogiſton; and Mr. Scheele and others ſeem to have adopted a ſimilar idea. But there are arguments that militate againſt this opinion.

That electricity is, in ſome manner or other, connected with light, has long been noticed. If quickſilver paſſes over a table, it does not adhere. But if water be ſubſtituted for quickſilver, part of it adheres to the table, or the table is *wetted*; and this water, by combining with the heat of the table, flies off by degrees in the form of *vapour*. Electricity, like the quickſilver above, paſſes over a non-electric without any of it adhering. But when it paſſes over an electric, light is ſeen. Does it not ariſe from hence, that part of the electricity, or ſomething contained in it, like the water on the table, adheres to the ſurface; and is volatilized into *light* by the heat of the electric, as the water was into *vapour* by the heat of the table? This point

might

might perhaps be determined by nice thermometrical experiments, the thermometer itſelf being uſed as the electric. If it be true, then light, as it exiſts dormant in bodies, is to viſible light, what water is to vapour. By ſuch trials the quantity of *latent heat* in light might poſſibly be diſcovered, eſpecially as this heat is depoſited when light is ſtopped and ſtifled in opake and dark ſubſtances. Perhaps alſo phlogiſton will be found in future to be the *other* component principle of the electrical fluid. For light ſtopped in inſulated opake bodies does not electrify them; and yet it is well known that ſeveral phlogiſtic proceſſes may be performed by means of electricity.

Light does not move on of itſelf, but its motion depends on the medium through which it paſſes.

For if light paſſes out of air into glaſs, and from thence again into air, its velocity in the latter caſe is the ſame as in the former; and yet, as its paſſage was ſlower in the glaſs, if its motion did not depend wholly on the medium, it ought to have leſs velocity in the air after having left the glaſs, than before it entered it.

Agreeably to this idea, Newton explains the fits of the rays, by ſuppoſing them to be occaſioned by the vibrations or pulſes of his ethereal medium.

It may farther be obſerved, that a ray of light, while in the *ſame medium*, paſſes on with an uniform motion, in a right line. But if the ray moved on of itſelf, it would be bent into a curve, either towards, or from, the perpendicular, according as it was accelerated, or retarded, provided that it entered the medium obliquely; as may be collected from the hypotheſis at the beginning of this article *.

I have, for my own amuſement, carried theſe ſpeculations concerning light and heat, to much greater lengths. For example, I make it appear probable that the ſubtle medium which cauſes the repulſion of particles of light, is not of itſelf *heat*, but that to become *heat* it muſt be combined with particles in the form of repelling atmoſpheres; ſo that though that medium be the *cauſe* of heat, yet heat itſelf is a *quality*, and the reſult of the combination juſt mentioned.— That the vibration of light has no connection with its heat, any more than the vibration of air for cauſing ſounds has with the heat of that air. —That the heat in combuſtion, mixture, &c. is

* This ſeems to favour the hypotheſis, that light conſiſts in motion propagated through a medium; but preceding obſervations are againſt this opinion.

is produced merely by chemical means, and depends on the fire already combined with bodies; but that that produced by friction, and the like, is *factitious*, and *made at the time*, by combining the free medium, with the body, as above.—That tastes and smells are probably caused by the different particles of light; and that acidity, in particular, seems to depend on some of the less refrangible rays.—I have also extended these speculations to other subjects connected with them. But it would not be proper to publish them without more experiments than I have either leisure or conveniences to make; and even what I have here given is offered rather to excite others to take up the subject, than as demonstrated truths. I should not have joined them to a work like this, but that I do not know when I may again have an opportunity of appearing in print; and that some of the facts seem worthy of being known. For the same reasons I have added the following.

OF

OF LIME TREATED WITH INFLAMMABLE AIR.

IT has lately been difputed, whether inflammable air is phlogifton alone, or phlogifton combined with water ?—I thought that if the latter opinion was true, there might poffibly be methods of feparating either the phlogifton, or the water; fo as that the inflammable air might be decompofed. And, as quick-lime attracts water ftrongly, I tried the following experiment.

Into a vial capable of holding three ounces, I put fome weak fpirit of vitriol, and iron filings; and after they had effervefced a while, fo as to expel the common air, I tied over the mouth of the vial a bladder, containing about two or three ounces of lime, but out of which I had fqueezed all the common air. And though inflammable air enough was generated to more than fill the bladder, as I afterwards purpofely tried; yet, after the effervefcence was entirely over, the bladder was nearly as empty as at firft, and had continued fo during the whole operation, though none of the air had efcaped.

I then tied the fame bladder and lime over another quantity of fpirit of vitriol and iron filings, and the whole of the air was again abforbed; and I repeated the procefs a third time with the fame refult. Probably much more air would ble o

Pl
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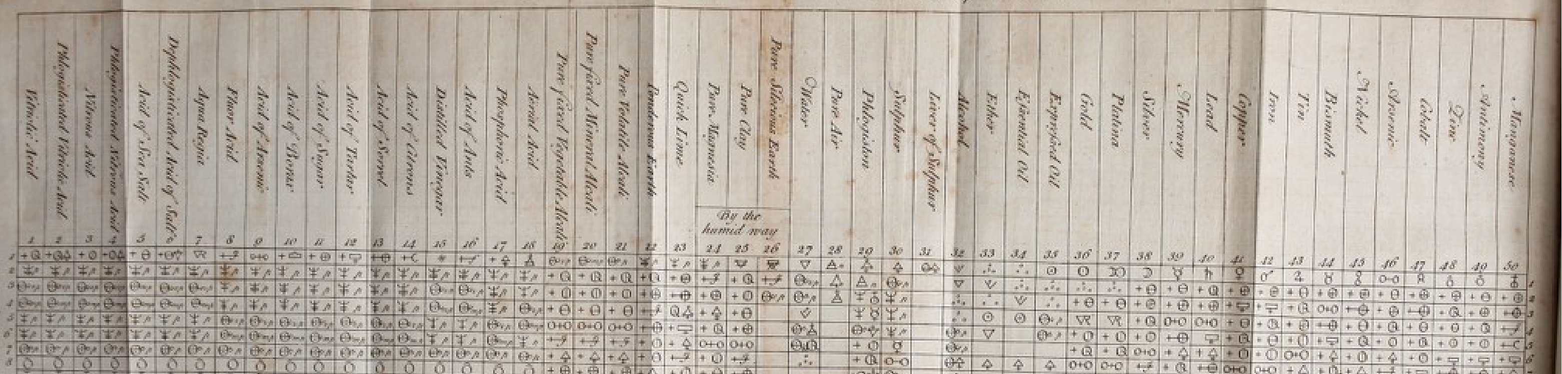
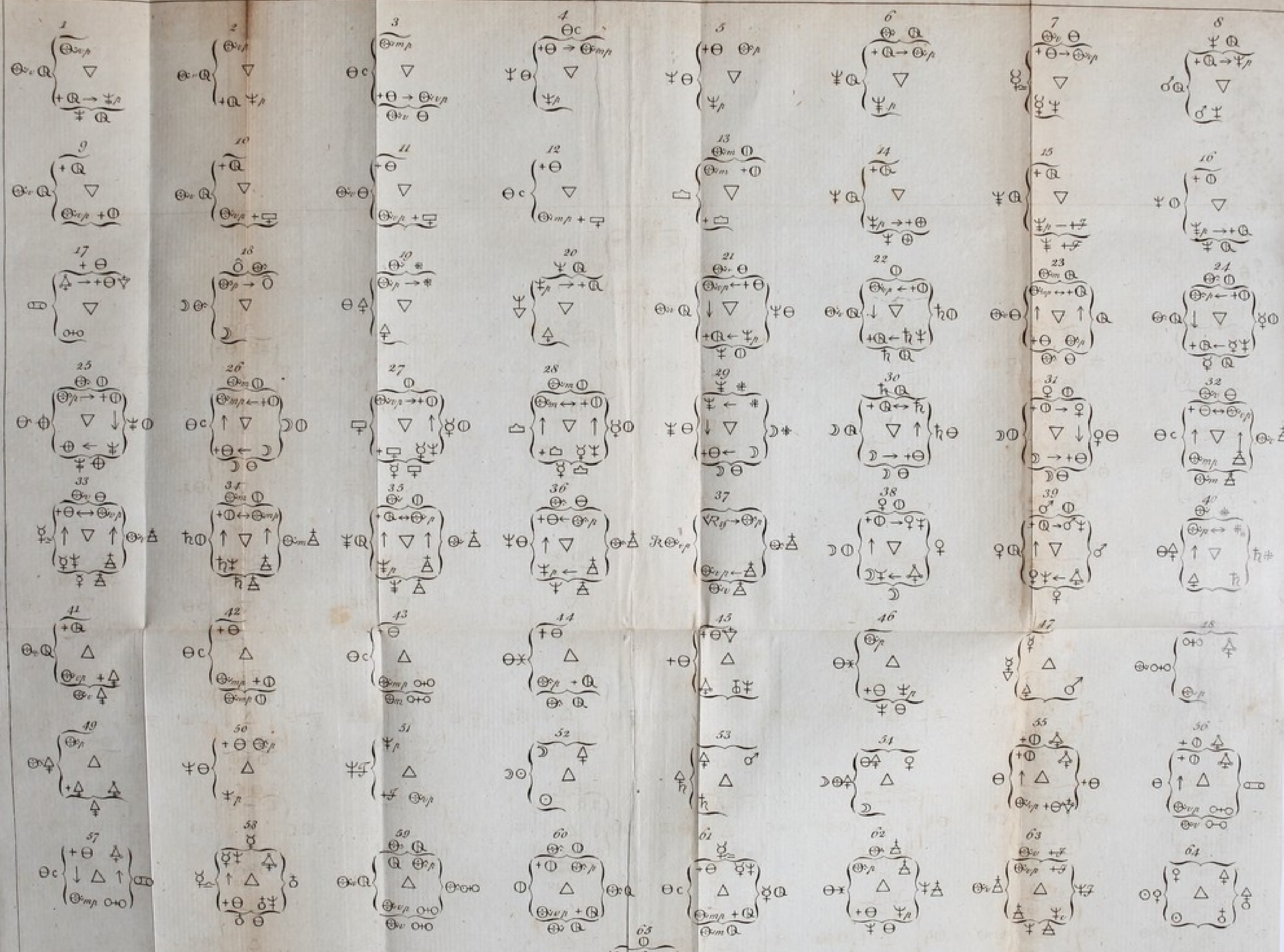
V

Bergman's Table of Simple Elective Attractions, with improvements.



Bergman's Second Table.



would have been abſorbed by the lime; but I did not make any farther trial with it.

In attempting however to repeat the experiment with freſh lime ſome time after, I did not ſucceed; and I ſeveral times met with the like diſappointment. At laſt however I ſucceeded again, and found on examination, that the ſucceſs ſeemed to depend on the following circumſtances; at leaſt theſe were the circumſtances in which I ſucceeded beſt.

The lime had lain in the air, in a room where the rain could not affect it, till it was become quite light and ſpungy, and I put the pieces into the bladder without powdering them. The lime was alſo white or cretaceous. The ſpirit of vitriol was ready made, and cold; and was in the proportion of one part oil of vitriol, to about four of water. Whenever I uſed freſh lime, the experiment failed; neither did ſlacked lime always anſwer.

Taking the lime out of the bladder, I dropt ſome of the pieces of it into a baſon of water, and immediately a quantity of air ruſhed out in bubbles, as the water was abſorbed by the lime. But on adding an acid afterwards, I could not perceive any efferveſcence, at leaſt when *good lime* was uſed.

But I alſo found, that if the lime, *before* it had abſorbed inflammable air, was thus dropt into water, air-bubbles alſo ruſhed out; and ſeemingly in as great quantity as afterwards.

I had no conveniences at hand for trying this air, only I did not find it inflame by holding the flame of a candle in it. And any one that ſhould chuſe to take up the ſubject would do well to examine,

1. Whether the air contained in the pores of the lime *before* it had abſorbed inflammable air, was the ſame mixture of phlogiſticated and dephlogiſticated air as that of the atmoſphere, or only one of theſe?

2. Whether the air which was expelled by the water *after* the lime had abſorbed inflammable air, was the ſame as the above, or inflammable air alone, or a mixture, or *new combination* of theſe?

To place this experiment in another light, I put into the middle veſſel of Blades's glaſs apparatus, over night, ſome *lac calcis*; and in the under veſſel ſome ſpirit of vitriol, and iron filings; then left them to operate till the next morning. On drawing off ſome of the clear liquor, I found that it had not the leaſt taſte of lime-water that I could perceive, or indeed any taſte at all.

The lime therefore had been precipitated from the water.

Shaking the powder up, ſo as to mix it with the water, and then taſting it, I found that it taſted ſtrongly of lime; but on letting the powder ſettle, the clear liquor was as taſteleſs as before: which again proves that the lime had been precipitated.

On adding an acid to the mixture, a very ſtrong effervеſcence inſtantly aroſe. In this reſpect, this latter experiment differs from that in which dry lime was employed. Of what nature the air was that was thus expelled, ſome future enquirer would do well to examine. Was it inflammable air? Or fixed air formed by the union of the inflammable air with the dephlogiſticated part of the common air in the apparatus? Or was it volatile vitriolic acid, which in theſe caſes uſually riſes with the inflammable air? — I obſerved, that though the mineral acids raiſed a great effervеſcence, diſtilled vinegar did not occaſion any.

On the whole, the ſubject ſeems to deſerve farther examination.

OF CHEMICAL AFFINITY.

BERGMAN has divided his table of elective attractions into two parts, viz. by the moiſt, and by the dry way. The following experiment ſhews, that in the moiſt way the menſtruum itſelf is capable of varying the affinity.

I mixed olive oil with ſlacked lime into a paſte, by which means a calcareous ſoap was formed. I then added a quantity of mild fixed alcali, with water ſufficient to render the whole fluid, and ſet it over the fire till it boiled. I did this to try, whether the calcareous ſoap would be decompoſed by the alcali; the alcali itſelf uniting with the oil, the fixed air with the lime? but found that this was not the caſe. I then repeated the experiment with rectified ſpirit of wine inſtead of water. In this caſe the calcareous ſoap was decompoſed; and on filtering the liquid, and evaporating it, a perfectly pure alcaline ſoap was obtained.

If I added the ſpirit of wine to the calcareous ſoap *without* the alcali, the ſoap did not appear to be acted upon. By throwing in mild alcali, the ſoap began to be diſſolved, and decompoſed. But when the alcali was all combined, the ſolution was again at a ſtand. On adding ſufficient alcali, the ſolution was renewed, and continued till the whole of the calcareous ſoap was decompoſed, nothing but the lime, in a *mild* ſtate, remaining. If more alcali than enough was put into the mixture, the ſuperfluous quantity remained undiſſolved with the lime.

This is a very expeditious method of making ſoap, and it is perfectly pure at the firſt operation; for common ſoaps are purified by diſſolving them in ſpirit of wine. It is alſo free from rancidity. Except however for medicinal uſes, the experiment is more curious than uſeful. For ordinary purpoſes, a ſoap loaded with alcali is deſired. Alſo in the large way of manufacture, a prodigious quantity of ſpirit of wine muſt be employed; and though it might be drawn off by diſtillation, and the ſame ſpirit uſed repeatedly, yet I ſuppoſe more ſpirit would be loſt, than the ſaving in fuel would make good.

My reaſon for inſerting this proceſs is, to ſhew that affinities are capable of being varied in the moiſt way, merely by varying the menſtruum. The reaſon that the calcareous ſoap was not decompoſed by the alcali when water was uſed, was, I ſuppoſe, that the alcali was ſtrongly attracted by the menſtruum; whereas rectified ſpirit of wine has no affinity to fixed alcali. It might likewiſe be added, that the ſpirit was capable of acting on the oil of the calcareous ſoap, (for by uniting an expreſſed oil to any ſubſtance with which it can form a ſoap, it is rendered ſoluble in vinous ſpirit,) whereas water has no action on ſuch oil *.

Perhaps a number of other curious exceptions would be found by uſing vinous ſpirit, or other liquid, inſtead of water; and each menſtruum might poſſibly require a diſtinct table. I have myſelf a remarkable inſtance of this kind, in a method of decompoſing ſea ſalt: which however I cannot produce, becauſe I mean, as ſoon as I can make it convenient, to put it in practice; the alcali being obtainable by it in a cheaper, and far more expeditious manner, than by any method at preſent employed.

* I found that this decompoſition would not take place in the *dry* way.

The following Obſervations reſpecting Heat were ſubjoined to the firſt Edition of this Work.

" HEAT has hitherto been generally conſidered as an *agent*. Ought it not rather to be conſidered as a *principle?* For example, when we find that *cold* water will not diſſolve cream of tartar,

tar, but that *hot* water will, ought it not to be ſaid that water alone is incapable of diſſolving that ſalt, but that it is rendered capable of it by the intervention of a ſufficient quantity of heat or *fire** ? —So water will not unite with oil; but if an alcali be added, it will; the alcali, being attracted by both, acting as an intermedium. If the alcali be withdrawn from the compound, the union is diſſolved, and the water and oil ſeparate. So if the above ſolution be expoſed to the cold, the fire, or heat, which ſerved as an intermedium, being attracted away by the ſurrounding bodies, the water, and ſalt, ſeparate. In ſome caſes the heat is ſo ſtrongly retained, or fixed in the compound, that no decompoſition takes place on expoſure to cold, the ſurrounding bodies not having power to attract away the heat or *fire* ſo fixed. The like may be obſerved of bodies not burning but in a certain degree of heat; and of many other inſtances to be met with in chemiſtry. Again, heat or fire decompoſes many compounds. Is it not becauſe one of the ingredients has a greater affinity to it than to the principle it is already united with? The fire or heat, in ſome caſes, is attracted away by the neighbouring bodies on expoſure to cold, and the body is again capable of uniting with the principle that was expelled by the heat; but in other caſes this does not happen.

* Fire, or the cauſe of heat, when *free*, is, perhaps, that ſubtle medium by which Newton explains the refraction of light.

pen. Heat or fire therefore ſeems to act in the ſame manner as other chemical principles.— If vitriolic acid be combined with water, its activity is very great. If it be transferred to metals, earths, &c. its activity becomes leſs and leſs, till at length it is imperceptible. If the ſame quantity of *fire* be transferred from ſome bodies, to others, in a like ſucceſſion, according to their capacities for containing *heat*, the activity of this principle is, in like manner, decreaſed. For *fire* to appear as *heat* therefore, muſt it not be *diſſolved* in bodies, or combined with them in the form of *atmoſphere?* And is not its activity more reſtrained, in proportion as bodies attract it more ſtrongly? The diſpute "whether heat be a *quality*, or a *ſubſtance*," may, perhaps, be ſettled by proſecuting theſe conſiderations."

"The doctrine of phlogiſton leſſening the capacities of bodies for containing heat, as ſtated by Dr. Crawford, has been oppoſed by Mr. Morgan, and others, who cannot find that the capacities of bodies for containing heat are ſo greatly altered by means of phlogiſton as Dr. Crawford pretends to have found by experiments. Perhaps the following conſiderations will tend, in ſome meaſure, to clear up this matter.

"I am inclined to think that the heat in combuſtion comes from the air, as I formerly ſuggeſted;

ſuggeſted *; but yet I think that we muſt conſider heat, or fire in *two different ſtates.* When it is ſet free, it then manifeſts itſelf as heat; becomes ſenſible to the feeling, and the thermometer; and different bodies have different capacities for containing it, the ſame as they have for containing *moiſture.* A ſpunge, for example, has a greater capacity for containing water, or *moiſture,* than ivory or wood. But when fire is *chemically combined* with bodies, it then, I think entirely loſes its property of *heat,* even as water does that of *moiſture* when combined in quicklime, or guaiacum wood. It is then no longer ſenſible to the feeling, or the thermometer, any more than moiſture in like circumſtances is to the hygrometer, and of courſe is by no means diſcoverable by the methods of finding the capacities of bodies for containing diſengaged fire, or *heat.* This difference is ſo very obvious, that I wonder it had not occurred to me before.

" A body therefore may contain an immenſe quantity of fire, in a *fixed,* or *combined ſtate,* and yet its capacity for containing *heat* may be very little

* Though phlogiſton (or the inflammable body) may extricate heat from *air* and *ſome other ſubſtances,* it may not from *all.* The fixed alcali extricates the calcareous earth from many ſubſtances; but there are others to which it has a leſs affinity than that earth; and there are other inſtances of the kind to be met with in chemiſtry. On the following theory alſo the capacity of a body for containing *heat,* does not depend on its quantity of phlogiſton.

little. When that fire is disengaged, and set loose by the addition of phlogiston, or otherwise, it shall then occasion a very intense *heat*, and yet its capacity for containing heat shall not be found to be lessened; it may even be increased.

"The capacity of *nitre*, for example, is much less than that of water; yet when nitre is mixed with a combustible body, and fired by a spark which may be considered as nothing (for the least spark will equally fire an 100 weight, and a grain,) a very great degree of heat indeed is generated. I cannot find however, that the capacity of the residuum, of the Clyssus, or of the air generated, is, on the whole, less than that of the mixture was before the conflagration; and that no heat was absorbed from the neighbouring bodies is evident, because the conflagration happened almost in an instant; and bodies are a long time in imbibing heat from the surrounding substances, as is evident from a mixture of spirit of nitre, and snow; the capacity of which being increased, does not become saturated till after a very considerable time.

"No one, however, will dispute that the heat in the above instances came from the mixture of the *nitre* and the *inflammable body*; and I account for it by *supposing* that the latter displaces the fire *chemically combined* in the acid (or dephlogisticated air) of the former; all of which (except perhaps what the inflammable body absorbs in

lieu

lieu of its phlogiſton) becomes then diſengaged fire, or ſenſible *heat*, agreeable to the theory above premiſed; and which I was led to by the conſideration of the analogy of water or *moiſture* in like circumſtances.

"Though therefore Mr. Morgan, and others, have found that *phlogiſticated* and *dephlogiſticated* airs have not their capacities for containing *heat* ſenſibly different, the latter may nevertheleſs contain a very great quantity of fire in a ſtate of *chemical combination*; and its being extricated by the inflammable body may be the principle on which the *heat* in combuſtion depends. The like may be obſerved with reſpect to *animal heat*, &c."

It may be added, that the fire, extricated as above, probably combines with the bodies in form of atmoſphere around their particles, and thereby conſtitutes *heat*. But the ſubject requires to be further inveſtigated by experiments.

THE END.

ERRATA.

Page 305, line 2, for *aſcend* read *leſſened*.
306, line 17, for *phenomenon* read *phenomena*.

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To be placed at the End, after Bergman's Tables.

E

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er to ourse, the above Table is calculated.

l, Mr. Kirwan's ingenious papers in the
r 1782.

SHEWING the Appendix to a philoſophical friend (my old worthy ſchool-maſter) after it was printed off; and mentioning to him ſome other hints that had occurred to me reſpecting Light, I have, at his requeſt, inſerted the following, *verbatim*.

DEAR SIR,

Your diſcoveries concerning light, and particularly that it is a quite different thing from heat or fire, I was ſo much ſtruck with, that I could not help catching the enthuſiaſm, and engaging in ſo delightful a ſpeculation. I am much miſtaken, if light will not be found a very important chemical principle, and of extenſive uſe in nature. The chapter on this ſubject in your *Philoſophical Obſervations*, ſhews that light exiſts in a ſtate of chemical combination in bodies; and hence you explain very ingeniouſly the blue light in *combuſtion*. I think, however, that this light comes not from the *inflammable body*, but from the *air*; and I think I can point out how it came there.— Light ſhining on vegetables, occaſions them to form dephlogiſticated air. I ſuppoſe that the light unites as a *chemical principle* with the impure air, and the phlogiſton of that air with the plant. Horn lead, and horn ſilver, are blackened by light: I ſuppoſe the light unites chemically with the acid, the phlogiſton of the acid to the calx. So air, ſtanding on dephlogiſticated ſpirit of nitre, phlogiſticates the acid when expoſed to the ſun; the light I ſuppoſe uniting to the air, the phlogiſton of the latter to the acid; (or is it the *water* that is decompoſed?) In combuſtion, therefore, this light is expelled from the air by the phlogiſton of the inflammable body. Blue light blackens luna cornea ſooner than the other rays, being more eaſily abforbed; but red light is hotter than blue, as Dr. Franklin's experiments shew. 'Tis known that metallic calces attract phlogiston stronger, as they are more heated. This has hitherto seemed strange to me, as it is different from what happens to other principles. But your discoveries enable me to explain this matter. You shew that light is expelled from bodies by heat, like fixed air, or water.—Now, as light expels phlogiston from calces, when the attraction of the light to them is weakened by heat, they become of course more capable of receiving phlogiston.

Light thrown on charcoal, or a white heat being given to it, it becomes (with the heat) inflammable air. Light, therefore, is probably an ingredient in inflammable air: accordingly we find that it makes its appearance during its combustion. So metals at the instant of their reduction fulgurate. Where re-compositions of this kind take place without heat and visible light, I suppose the light is transferred *silently* (as chemists say) just as also happens to fixed air, &c. in like circumstances. I don't know whether light is not the intermedium between the particles of bodies, and fire (the subtle medium which causes heat); for if fire and Newton's æther be the same, bodies *repel* that.—But light *attracts* it, and thereby condenses it atmospherically around its particles, whence their repulsion: and it seems to me that 'tis particles of light *with these repelling atmospheres*, uniting to the particles of bodies, that give the *latter* their repulsive power *; and not merely the fire, which, if alone, would be *repelled* by them. You shew that light can combine with more or less of this fire, and so become more or less hot, and more or less repulsive; and I imagine that bodies become hotter or colder only by the light united in them receiving more or less fire; and the like of the repulsion of the

* Dr. Fordyce finds, that latent heat lessens the gravity of bodies.

particles

particles of these bodies*. I think, with you, that electricity is either condensed light, or light *and something else* (though perhaps *not* phlogiston). Your idea that light is the cause of acidity, &c. is probable from what I have already said; for calces of metals, and pure air, are now reckoned acids. By some trials I have made, I think the light that causes the dew next it in bottles, is only that of the clouds; for the clouds are cold; but the walls, earth, &c. being warmer, the light reflected by them is not so cold as that from the clouds. *A-propos*—You shew that the sun's direct light is hot—a proof that the sun itself is so, contrary to what some have supposed. Again, say you, light is an elastic fluid. If so, it must either gravitate upon some body or bodies, or else the world must be *bounded*; for otherwise, the particles of light would recede from each *ad infinitum*. If the former, then, like the air, it is not every where equally dense. (I speak not of *rays*, but of *particles* of light). But I am rambling from chemistry to a very different subject. I shall conclude these rambling observations therefore (most of which, however, I have picked up from your own conversation) with suggesting, whether light may not be the cause of the polar, or crystallizing virtues of particles of bodies combined with it? and (since vinous æther is kept in a liquid form by the mere pressure of the air, and camphire, &c. may be rendered liquid, and the boiling point of liquids may be protracted, by encreasing that pressure) whether the *solid* cohesion of the particles of bodies is not caused by the pressure of a more subtle elastic fluid, which, when heat has sufficiently severed

* When the capacity of a body for heat is increased, I suppose it is by augmenting its quantity of *light*; the body, with the *same temperature*, then retaining more fire. Hence vapour absorbs *electricity*, as well as *heat*: and (*vice versa*) when it condenses deposits them.

thoſe particles, at length intercedes them; and whether their *fluid* or *liquid* coheſion is not cauſed by the preſſure of a fluid groſſer than the other, but which, when heat has ſufficiently ſeparated the particles, alſo intercedes them; when they become elaſtic, unleſs hindered by the preſſure of a ſtill groſſer fluid, as air, or the like; which, however, is at laſt, when the heat becomes ſufficient, alſo able to intercede them?

Hoping that the *chemical* doctrine of light will be ſpeedily improved by the diſcoveries of others, and wiſhing you all ſucceſs and happineſs, I remain,

Your hearty friend,

and well-wiſher,

NATHANAEL JESSE.

P. S. The following methods of procuring an equal temperature, occurred to me ſome time ago. I firſt thought of this ſubject, with a view to prevent the effects of heat and cold on time-keepers; but it is no leſs uſeful in ſome chemical, and other proceſſes.

The veſſel containing the ſubſtance required to be kept in an equal heat, is to be incloſed in another, ſo as to be every where at a ſufficient, and *equal* diſtance from its ſides; and into this outer veſſel is to be poured ſpermaceti melted, and cooled to juſt above the congealing point. It will then congeal all over the inner veſſel. This apparatus is then to be placed in a water-bath, ſand-bath, or the like, ſo as not to touch the ſides or bottom; and a lamp with ſeveral wicks, to be lighted or extinguiſhed occaſionally, or other well-regulated gentle fire, is to be applied, ſo as to keep the outſide of the ſpermaceti melted, the inner part, or that next the veſſel, remaining congealed. As long as there is part of the ſpermaceti remaining unmelted all over the ſurface of the inner veſſel, whether the thickneſs or diameter of that ſolid portion be greater or leſs, the heat in the veſſel itſelf will remain the ſame, or the variation will not be worth mentioning, as they who are acquainted with Dr. Black's celebrated theory of latent heat, will eaſily perceive.

Or the ſpermaceti in the ſecond veſſel may be juſt above the congealing point; and a veſſel with a wire bottom, containing ſpermaceti in ſmall pieces, may be ſuſpended, ſo that the wire bottom may be a little under the ſurface of the liquid ſpermaceti. The act of ſolution will keep the liquid ſpermaceti from becoming hot. As the liquid accumulates, it may run out by proper openings; and being hardened, and reduced to ſmall pieces, will ſerve for the ſame purpoſe repeatedly. This method will perhaps require leſs attendance, though the temperature will not be ſo exactly preſerved as by the preceding method.

If the temperature be required to be different from the melting point of ſpermaceti, wax, ſuet, oil, or other animal or vegetable fat, may be uſed; or any other ſubſtance whoſe congealing point anſwers to the heat required. If a cold temperature be wanted, ice may be employed; and if a very hot one, melted metals, or the like; the apparatus being properly varied.

As liquids boiling in the open air always remain of the ſame heat, theſe might be uſed inſtead of melting or congealing ſubſtances, in proper caſes. Spirit of wine, water, quickſilver,

quickſilver, oils, &c. may be employed for this purpoſe, according to the degree of heat required, a due alteration being made in the apparatus.

To what was ſaid in page 324, &c. relative to the decompoſition of calcareous ſoap by mild alcali in ſpirit of wine, I beg to add, that I have ſince found that many other decompoſitions will take place in ſpirit of wine, which will not at all in water, nor in the *dry* way. Among others, I have a method of making ſoap in ſpirit of wine, in a cheaper manner than with calcareous ſoap and mild alcali, which I had thoughts of putting in practice. But I have ſince found a method of doing it in a much more eligible way, *without* ſpirit of wine. As ſome of theſe experiments are ſtill depending, I cannot at preſent give an account of them, but muſt wait till ſome future opportunity.

J. E.

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