

The generation of animal heat, investigated / [E. Peart].

Contributors

Peart, E. 1756?-1824.

Publication/Creation

Gainsbrough : H. Mozley & sold by J. Edwards, London, etc., 1788.

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THE GENERATION
OF
ANIMAL HEAT,
INVESTIGATED.

WITH AN
INTRODUCTION,
IN WHICH IS AN ATTEMPT TO POINT OUT,
AND ASCERTAIN, THE
ELEMENTARY PRINCIPLES,

AND
FUNDAMENTAL LAWS
OF

NATURE;

AND APPLY THEM TO THE EXPLANATION, OF
SOME OF THE MOST INTERESTING OPERATIONS,
AND STRIKING APPEARANCES

OF
CHEMISTRY.

By E. PEART, M. D.

GAINSBROUGH:

Printed by H. MOZLEY; and Sold by J. EDWARDS,
Pall-Mall, LONDON, and C. ELLIOT, in Parliament-
Square, EDINBURGH.

M.DCC.LXXXVIII.

Presented to the
Medical Society
by the Author

INTRODUCTION.

THE Cause of Animal Heat hath been much enquired after, and differently explain'd, by many Philosophers, Physicians and others, of almost every age; but hitherto, it appears to have been never rightly understood.

A great number of the Ancients, and not a few of the Moderns, have chiefly attributed it to friction or attrition, principally produced by the motion of the blood; and some have added putrefaction &c. But if friction, or motion be the cause of animal heat, why cannot an animal just killed, be preserved at the same temperature as when alive, by throwing its parts even into more violent motions than when living? But these means are totally insufficient, to keep its heat above that of the surrounding medium: there-

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fore, motion, or attrition alone, cannot be the efficient cause; neither can putrefaction, for in the most putrid state of a dead animal body, the heat is very far below the living temperature.

The generation of heat during life, and its cessation when the vital power or principle is lost, gave rise to another opinion, * that heat in animals is produced by irritability; but this advances our knowledge, very little indeed.

A Theory upon very different principles, was some time ago offer'd by Mr. Crawford, † which at first met with a very favourable reception. His principles are, that heat may exist in two very different states; one simply as a fluid, active, disengaged, and having a constant tendency to diffuse itself equally over all bodies; the quantity or degree of which is particularly evident, by its effects upon the Thermometer: this he calls sensible heat; the other where it is fixt, or combin'd

* Recherches sur differens points de Physiologie &c. par M. Fabre. page 23.

† Experiments and Observations on Animal Heat.

bin'd with different substances, and in that state producing no sensible effect upon the thermometer: this he calls absolute heat.

He next asserts, that the capacity for containing absolute heat in any body, is diminished by the acquisition of Phlogiston, and vice versa.

He therefore explains the production of animal heat in this manner: The atmospheric air contains a great quantity of absolute heat, but when it is exposed to the blood in the lungs, which blood contains a quantity of phlogiston, the air having a stronger affinity attracts the phlogiston, by which union its capacity for containing absolute heat is diminished, and a quantity of that absolute heat is deposited, proportionate to the quantity of phlogiston imbib'd. Now if this heat became sensible, the blood in the left auricle of the heart, would be much hotter than that in the right; but it is not so: therefore, this absolute heat, deposited by the air now phlogisticated, must be absorbed by the blood when it parts with phlogiston. It appears therefore, that the capacity of the air for absolute heat, is diminished in proportion to the quantity of phlogiston acquired: and that

that the capacity of the blood for containing it, is increased by the loss of that phlogiston, in the same proportion, as that of the air is diminished by receiving it.

This arterial blood then, replete with absolute heat, during its circulation through the various parts of the body, again receives phlogiston, and consequently its capacity for absolute heat must again be diminished; therefore, the more phlogiston it receives, the more absolute heat is evolved, and by that evolution becomes sensible, and thus forms the heat of animals.

But, if the attraction of Phlogiston, renders the capacity of any body for absolute heat, proportionately less: ought not the abstraction of that Phlogiston, to render that capacity for absolute heat, proportionately greater? If so, the very substances imparting phlogiston to the blood, will have their capacities for containing absolute heat, increased, in the same degree by its abstraction, as that of the blood is diminished by attracting that phlogiston; and consequently, no sensible heat will be produced; as was the case with the blood and air in the lungs.

Mr.

INTRODUCTION.

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Mr. Crawford's theory, depends upon this change in the capacities of different substances, not being in the *same* proportion to the quantity of phlogiston acquired or lost; which merely for the sake of his hypothesis, he takes the liberty to suppose *; but as he only supposes so, and as it seems more natural, and just, to suppose the contrary, 'till Mr. Crawford shall prove his supposition is a fact, his Theory must be unsatisfactory, as being founded upon laws, which are preserved or overlooked, as best may suit the author and his hypothesis.

Some time after Mr. Crawford's, Mr. Scheele's Theory of Heat &c. was published in Germany, a translation of which appeared in England †.

Though

* “ If therefore, the whole of the absolute heat, which
“ is separated from the blood, were absorbed by those parts
“ of the system from which it receives the phlogiston, it
“ would be necessary to have recourse to some other cause,
“ to account for the sensible heat which is produced in the
“ circulation.” Experiments &c. page 75.

† Chemical Observations and Experiments on Air and Fire, by Charles William Scheele &c.

Though Mr. Scheele does not particularly consider animal heat, or the manner or functions by which it is produced; yet, as heat is the same, whether generated by the animal process, or by combustion, his opinion must not be passed over unnoticed.

He supposes that heat, or Fire is a compound of Phlogiston and pure Air, and brings a number of experiments and reasonings to prove it.

But there is one circumstance, attending many of his experiments, which he overlooks, and which alone is sufficient to prove, that his Theory is imperfect; for instance, If a metal, suppose Mercury, be exposed to the action of heat and air, its phlogiston unites with the pure air, according to his opinion, and escapes in the form of heat, or fire; while the Earth of the Mercury remains deprived of phlogiston, and the atmospheric air of its empyreal air; but from whence does this calx acquire its remarkable increase of weight?

Again, If this calx be exposed to the action of heat, in close vessels, Mr. Scheele says, that the calx decomposes the heat, by uniting with its
phlogiston,

phlogiston, and again acquires its metallic lustre and properties; while the other component part of fire, the empyreal air, becomes disengaged, and in that state fills the receiver. But the mercury, now revived by regaining its phlogiston, is lighter than when deprived of it in the form of calx; how is this loss of weight to be explained upon these principles? By parting with phlogiston during combustion, the mercury gains weight; and by regaining phlogiston, it loses weight.

These circumstances are not properly accounted for by Mr. Scheele, neither can they in my opinion consist with the principles of his theory, which are therefore insufficient, and consequently at least imperfect.

The last opinion of any celebrity, which I shall mention, is that of M. Lavoisier.* He denies the
very

* “ Dans la suite de Mémoires que je viens de commu-
“ niquer à l' Académie, j'ai passé en revue les principaux
“ phénomènes de la Chimie; j'ai insisté sur ceux qui accom-
“ pagnent la combustion, la calcination des métaux, & en
“ général toutes les opérations où il y a absorption et fixation
“ d'air.

very existence of phlogiston, and makes heat, or Fire, a primitive substance, which he supposes becomes sensible, or active in the following manner.

Pure or vital air, he says, is composed of the matter of Fire or heat, with the oxygenous principle; when any body therefore, in contact with vital air, is so circumstanced, as to have a stronger attraction

“ d’air. J’ai déduit toutes les explications d’un principe
“ simple, c’est que l’air pure, l’air vital, est composé d’un
“ principe particulier qui lui est propre, qui en forme la base ;
“ & qui j’ai nommé principe oxygène, combiné avec la ma-
“ tière du feu & de la chaleur. Ce principe une fois admis,
“ les principales difficultés de la Chimie ont paru s’évanouir
“ et se dissiper, & tous les phénomènes se sont expliqués avec
“ une étonnante simplicité.

“ Mais si tout s’explique en Chimie d’une manière satis-
“ faisante, sans le secours du phlogistique, il est par cela seul
“ infiniment probable que ce principe n’existe pas ; que c’est
“ un être hypothétique, une supposition gratuite : & en
“ effet, il est dans principes, d’une bonne logique, de ne
“ point multiplier les êtres sans nécessité.” Histoire de
L’Académie Royales Sciences. Année 1783. page 505.

attraction to this oxygenous principle, than the fire hath, with which it is combined: the oxygenous principle unites with the substance thus exposed, and the fire or heat is disengaged, and becomes active and sensible.

If a metal be exposed, to the united action of heat and vital air, or atmospheric air in which vital air is contain'd, it attracts the oxygenous principle, and the matter of heat is set at liberty; and this addition of the oxygenous principle to the metal, gives it the increase of weight, and renders it a calx. Again, If a metallic calx, of mercury for instance, which is composed of mercury and the oxygenous principle, be exposed to a sufficient degree of heat in close vessels; the fire unites with the oxygenous base, and forms vital air; while the mercury thus deprived of it, is revived, and left in its original form and weight.

The acquisition therefore of phlogiston, with other Chemists, is nothing else than the abstraction of this oxygenous principle with M. Lavoisier; and he points out no other mode of its separation from other bodies, than by its uniting with

matter of fire, and forming vital air. But how are these principles to be applied, to explain the following chemical facts?

The Calx of Silver, according to M. Lavoisier, is a combination of silver with the oxygenous principle; now if this calx be exposed to the Solar light, the silver is revived, and the oxygenous principle is separated; not by combining with heat, because if the same calx be exposed to an equal, or greater degree of heat, without light, the silver is not revived. M. Lavoisier must therefore explain, why this oxygenous principle, separates from the silver to combine with light; what that combination produces; and why it would not combine with the matter of heat, which seems to be the most common form of its separation, from the metal with which it was combined. Again, from analogy, I should suppose, when silver is revived from its calx, by the action of light, that vital air is produced; If so, how does the union of Light with the Oxygenous Principle, form Vital Air?

What makes me suppose that pure, or vital air, is produced, during the revival of silver, by exposing its calx to the light, is, the production of
vital

vital air when mercury is revived by heat; and from supposing that light and heat are composed of the same principles, differently combined, or in different proportions, as will be mentioned hereafter; and consequently if so, that pure nitrous acid, becoming coloured by exposure to light, must yield pure or vital air also.

To satisfy myself whether this conjecture was well founded or not, I made the following experiment.

I kept a phial, half full of pure dephlogisticated nitrous acid, twelve hours in the dark; when introducing a small lighted taper, it was instantly extinguished. I then exposed the same acid to the light, for an equal space of time; and upon introducing the lighted taper, it burnt with a bright, enlarged flame, for a considerable time. I again repeated the experiment, and again had the same results; the acid becoming coloured, and allowing a taper to burn in the phial, after exposure to the light; but remaining perfectly dephlogisticated, and immediately extinguishing the flame, when kept in the dark. I then tried if heat alone would make any alteration, but constantly

stantly found, that without light, the taper was always immediately extinguished; let the degree of heat, to which the acid was exposed, be what it might.

If then the nitrous acid gives out pure air, by being exposed to the light: it seems natural to conclude, that silver, when revived from its calx by a similar exposure, gives out pure air also; but this I have not had an opportunity of examining.

How is this last fact to be explained upon M. Lavoisier's principles? He will say, that the nitrous acid, parts with its oxygenous principle, and becomes coloured in consequence; and that the vital air, is produced by the union of this oxygenous base, with ——— what? ——— not with the matter of fire, because it refused to unite with heat, but still adhered to the acid; — not with light, because the compound, vital air, according to M. Lavoisier, is the oxygenous principle with the matter of heat, or fire. The only thing to be said on the subject is, that Mons. Lavoisier must explain the matter himself; and

till

'till he does it satisfactorily, I shall suppose his principles are defective, and his system erroneous.

I have just mentioned these Theories, as being the most popular; and have pointed out a difficulty attending each of them, which renders the veracity, or sufficiency of their principles, at least suspicious. But the most ready way to prove their fallacy, or insufficiency, is to *give*, and *support* my own opinion upon the subject, which is considerably, and fundamentally different from all of them; consequently, if my own principles prove to be true, these as differing from them, must be erroneous.

I mean not here to enter into a full explanation, and account of the principles alluded to; that I shall defer to another opportunity. The particular subject of this treatise, is Animal Heat, I shall therefore only mention the general principles and laws, upon which my opinion is founded, and so much of the theory, as will be found necessary to explain my ideas, of the nature and composition of heat.

It appears evident to me, that there is one grand principle of nature, which Chemists have entirely overlooked. It is the great principle of Elasticity and Fluidity. It is that wonderful, subtil, active, universally diffused *Æther*, hinted at by the great Sir Isaac Newton *; and by that name I shall distinguish it.

When we consider the amazing elasticity and rarity of light: the activity, and irresistible permeating power of fire: the mobility, and velocity of the electric fluid: their great similarity in many respects: their mutual action, and very constant attendance, upon each other; can we avoid supposing that they have some principle, or principles in common amongst them? Do not the operations of Chemistry prove it? Do not they all impart phlogiston to certain substances, in certain circumstances? And when we consider their general rarity, mobility and elasticity, can we refuse our assent to Sir Isaac Newton's conjecture, that there is an *Æther*, a subtil medium in nature, whose operations ought not to be unnoticed?

* Newton's Opticks. Qu. 18 &c. page 323 &c.

ted? And is it an improbable conjecture, that this *Æther*, is the great active principle in each of them; and likewise in every other combination of matter, possess'd of elasticity or fluidity?

By adopting this principle, and adding to it three others, (which none I think will deny the existence of, except the Lavoisierians,) I think it possible, to solve the phenomena of Nature, and consequently of Chemistry, in a more easy, natural, simple and satisfactory manner, than any other hypothesis hitherto offered to the world, hath done, or can do.

I therefore place *Æther* as the first principle or Element of nature; *Phlogiston* or the principle of Fixity, and Solidity, as the second; an *Acid* the third; and *Earth* the fourth.

Æther and *Phlogiston*, have an affinity to each other; and according to the proportions, or circumstances in which they unite, they form *Light*, *Fire*, or the *Electric Fluid*. Perhaps light hath a redundancy of phlogiston, and the electric fluid of æther; whilst fire, or the matter of heat, is a complete saturation of each with the other.

Æther

Æther likewise readily, and intimately unites with the acid principle; and this combination forms *Pure Air*.

Æther hath no affinity with Earth, unless the earth be already combined with an acid, or phlogiston; in which case the Æther will enter into combination with it, on account of its attraction to the acid, or phlogiston there present.

Phlogiston unites with Æther, as above mentioned; with Earth it intimately combines, forming Metals &c. but to the Acid Principle it hath no affinity, unless through the mediation of Æther, or earth.

The Acid Principle and Earth, strongly attract and unite with each other.

With these general principles, and laws, I will now endeavour to explain those chemical phenomena, which the theories before mentioned, seem'd not to do in a satisfactory manner; and I hope ere long, to be able to give so clear an explanation of many other effects and appearances in Chemistry, hitherto imperfectly or confused accounted for;

for ; as will render these principles. so clear, and satisfactory to others, as at present they are to myself.

First of all I shall consider the calcination of metals.

If a Metal be exposed to the action of heat, in the open air, or in a sufficient quantity of pure air, which is the only part of atmospheric air required ; it loses its phlogiston, and becomes a Calx, heavier than when in its metallic state ; at the same time the pure air disappears.

A Metal is composed of earth and phlogiston ; Pure Air of æther and the acid principle. By the action of heat, these four principles are so far separated from each other, and their affinities so weakened, that a double decomposition takes place ; the phlogiston of the metal combines with the æther of the pure air, and forms heat or fire ; while the acid principle, now disengaged, unites with the earth and forms a Calx, heavier than before, in proportion to the quantity of acid combined with it ; and consequently the pure air must disappear.

If now this Calx, which as before we will suppose the calx of mercury, be exposed in a close vessel, to a sufficient degree of heat: the mercury is revived, and the receiver contains pure air: which is thus easily explained.

The Calx is composed of earth, and the acid principle: Fire of æther and phlogiston. — If the heat be sufficiently great, to separate the earth and acid, beyond the spheres of their attraction: the Earth seizes upon the phlogiston of the heat and revives; at the same time, the Acid of the calx, and Æther of the fire, being both disengaged, combine, and form Pure Air; and consequently the metal, now deprived of its acid, must lose that additional weight, which it had acquired by uniting with it, when a calx.

The other experiment, where the calx of silver was reduced by exposure to Light, admits of a ready solution. The Calx contains an earth and acid; Light is formed of æther, with phlogiston either super-abundant, or loosely combined. The earth of the calx then strongly attracting the phlogiston of the light, and the æther of the light, the acid of the calx, produce a double decomposition;

composition ; in consequence of which, two new compounds arise ; the earth unites with the phlogiston, and forms Silver in its metallic state ; and I should suppose that the æther, with the disengaged acid of the calx, must form pure air ; but that I am not certain of from experience.

When Phosphorus is burnt, its acid is left, and the quantity of the acid is greater, than that originally contained in the phosphorus ; and upon these principles it could not be otherwise. For Phosphorus is composed of acid and phlogiston, with a certain proportion of æther, without which the acid could not unite with phlogiston ; the proportion of which æther, entering into its original composition, gives it its peculiar properties, different from every other acid, where the proportion of æther entering into its composition, is different. When therefore this phosphorus is burnt in contact with pure air, (without which indeed it cannot be accended) the phlogiston of the phosphorus, unites with the æther of the pure air, and forms Fire or Flame ; at the same time, the disengaged Acid of the air is deposited, and uniting with the disengaged phosphoric Acid, gives the increase of quantity and weight.

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This is all at present that I shall consider, of the Via Sicca of Chemists. I shall now apply the same principles, to explain the calcination of Mercury, Viâ Humidâ.

If Mercury be dissolved in strong Nitrous Acid, it gives a Calx of Mercury, and Nitrous Air,

I shall not at this time, enter further into the specification of the parts, of which Nitrous Acid is composed, than that it chiefly consists of the acid principle, with a certain proportion of æther, (not sufficient to enable it to take the form of pure air,) united to water; the Mercury as before intimated, chiefly consists of Earth and Phlogiston. When these substances therefore are exposed to each other, the earth attracts enough of the acid to give it the form of Calx, and at the same time its phlogiston becomes at liberty; it therefore seizes upon the æther disengaged from acid now combined with the earth, and escapes in the form of heat; but the æther combined with the acid, not being in so great a proportion as it is in pure air, is not sufficient to saturate all the phlogiston, displaced by the acid from the earth of the mercury: therefore, the remaining part
of

of the phlogiston, seizes upon the æther combined with the remaining acid ; but that acid being only partly saturated with the æther united to it, and with which it hath a strong affinity, refuses to quit it entirely, as having nothing to combine with in its place ; therefore, the æther hath its attraction divided between the acid and phlogiston, forming a close union with neither ; in consequence of which loose attraction, the space they occupy is much greater, than when the Acid and Æther were intimately combined, because they now expand themselves into the form of an Elastic fluid, to which Chemists give the name of Nitrous Air ; which therefore is Æther, having its attraction divided between Phlogiston and the Acid principle ; to both of which it hath an affinity, but cannot intimately combine with either, on account of its attraction for the other ; which must inevitably prevent a coalescence, because the Phlogiston and Acid have no attraction for each other.

If this Calx be exposed to a sufficient degree of heat, so as to separate the Earth and Acid, beyond the sphere of each other's attraction ; the Earth will attract phlogiston from the heat, while the

the

the other component part of heat, the *Æther*, will unite with the Acid disengaged from the Earth, and form pure Air, as before explained.

The whole of the Acid employed then, is contained in the nitrous air of the first process, and the pure air of the second. If these two elastic fluids be mixt together, the phlogiston of the nitrous air, will unite with a sufficient quantity, of the *Æther* of the pure Air, and escape in the form of heat: while the Acid of each uniting, and still retaining a small quantity of *Æther*, to which the acid principle hath so strong an affinity, their elasticity and bulk will be diminished, and Nitrous Acid again produced. But the quantity of nitrous acid thus recovered, is not equal to the quantity originally employed, because all the pure Air is not decomposed, and the other part remains there united with *Æther*.

I have said that the Electric Fluid is composed of the same principles as Light, and Fire, i. e. of Phlogiston and *Æther*; but either in different proportions, where the *Æther* predominates; or otherwise, in a different state of combination; in
proof

proof of which I shall offer the following experiments.

Dr. Priestley transmitted the Electric Shock, through a bubble of Air confined by Nitrous Acid, the consequence was, every spark made a considerable addition to the quantity of air, which appeared to be the purest dephlogisticated air.*

The Acid Principle not being fully saturated with æther, in the nitrous acid, attracted it from the the Electric Fluid passing through it, and then became pure Air; and I should suppose, that the phlogiston disengaged from that Æther, must phlogistificate the remaining acid.

But if the Electric Fluid be transmitted through pure air, confined by Lime-water, or Caustic Lixivium: the pure air disappears, and an Acid is precipitated.

The reason is evident: the acid principle in the pure air, hath an attraction for the earth contained

* Priestley's Experiments and Observations. Vol. 3. p. 339.

tained in the fluid by which it is confined : and therefore the attraction between the *Æther* and the Acid in the pure Air, is weakened ; in consequence of which, this *Æther* will attract the phlogiston, loosely combined in the Electric Fluid, and pass off with it in the form of heat, or light ; and the Acid will be left at liberty to unite with the Earth contained in the fluid beneath. When the Caustic Lixivium was employed, Mr. Cavendish found, that the acid combined with the alkali, so as to form a neutral salt ; which salt he found to be Nitre.

And now, though the nature and composition of *Water*, is not immediately connected with the subject of this treatise, yet as it is at present an object to which Chemists pay particular attention, permit me to give an explanation of its composition, according to the principles herein proposed.

Water is produced by a perfect saturation of the four Elemental Principles with each other ; the Acid is half saturated with *Æther*, and half with Earth ; the Earth with Acid and Phlogiston ; Phlogiston with Earth and *Æther* ; and *Æther* with Phlogiston and Acid ; so that the whole forms a
perfect

perfect neutral, where each principle is saturated, by an equal attraction to the two other principles with which it hath an affinity, in consequence of its not having a sufficient quantity of any one other principle, to enable it to take a simpler form. As for instance, the Acid Principle, hath not Æther enough to enable it to take the form of pure Air, therefore to supply the want, it attracts the Earth; and so with the rest.

If this Water be so heated as to take the form of Steam, and that steam be transmitted through a red hot iron tube, or a tube containing iron red hot, that degree of heat will separate the Earth and Acid of the Water, beyond the spheres of of each other's attraction, in consequence of which, the Earth of the Water will saturate itself with phlogiston from the Iron: and the Earth of the Iron, will unite with the now totally disengaged Acid of the Water. The Acid and Iron, will form a *Calx* or *Slag*; and the Earth of the Water now saturated with much phlogiston, and by means of that phlogiston retaining the Æther of the Water, will form *Inflammable Air*.

Inflammable Air therefore, consists chiefly of an Earthy base, united to much phlogiston; but that phlogiston retains a certain proportion of Æther, which gives it its Elasticity; and perhaps that Æther may attract a small portion of Acid; but the predominant principle of Inflammable Air is *Phlogiston*, and the base, *Earth*.

This Analysis of Water is proved by Synthesis: for if Inflammable Air and Pure Air be exploded together, the result is Water and Flame. For pure air being composed of Æther and Acid, and Inflammable Air chiefly of Phlogiston and Earth, part of the Æther and Phlogiston will unite, and escape in the form of fire, heat or flame; in consequence of which, the Acid not having a sufficient quantity of Æther, nor the Earth of Phlogiston, to saturate them, and enable them to keep in their aëriform state, they exert that power of attraction, now left unsatisfied, upon each other, and by that compound union form Water; the Acid being partly saturated with Æther, and partly with the Earth already disposed to the union, by being deprived of part of its phlogiston.

Allow me to bring one more proof, before I dismiss the subject.—When Dr. Priestley exposed Calx of Iron, in Inflammable Air, to the action of solar light, in the focus of a burning Lens, the Iron was revived, inflammable Air absorbed, and Water produced.*

The violent heat destroyed the union of the Earth and Acid, in the Calx, in consequence of which the Earth exerted its action upon the superabundant phlogiston of the Inflammable Air, with which it combined, and became Iron; at the same time, the displaced Acid, united with the Æther of the Inflammable Air: but that not being sufficient to saturate it, it seized also upon the Earth of the Inflammable Air, now disposed to that union, by the loss of the Phlogiston taken from it by the revival of the Iron; and the result of that union of the four principles, was *Water*.

Water therefore is composed, of Earth half saturated with Phlogiston, united to the Acid Principle half saturated with Æther,

The

* Priestley's Experiments and Observations, Vol. 3, p. 82.

The only phenomenon that at present remains to be considered, is, the Phlogistification of Nitrous Acid, and production of Pure Air, by exposing pure Nitrous Acid to the action of Light.

Pure Nitrous Acid is composed of much Acid, some Æther, and Water; but as Water hath been shewn to contain an Earth partly phlogistified: Nitrous Acid may be said to contain much Acid, some Æther, and an Earth half phlogistified. When this Acid is put into a phial, where part of it can expand into the form of vapour, with heat sufficient to enable it to take that form, and thus exposed to the light, the Earth having an opportunity of acquiring its full quantity of Phlogiston from the Light, where it is loosely combined with Æther, quits the Acid, ~~and~~ and uniting with the Phlogiston, diffuses itself in the Nitrous Acid beneath, to which it gives colour; at the same time, the Acid disengaged from the Earth is left at liberty, to exert its full power of attraction upon the Æther: but not having enough already combined with it, it seizes upon that disengaged from the Light, and thus takes the form of Pure Air.

And

And now having said as much as I think necessary concerning my Chemico-Philosophical principles, and their application to the solution of some of the most common and striking Phenomena of Chemistry, to explain my idea of the *nature*, and *composition* of Heat or Fire; I shall at this time drop the subject, and immediately proceed, to the particular object of my present enquiry.

O N
A N I M A L H E A T.

S E C T I O N I.

*Living Animals have the power, or property, of
generating, or producing heat.*

IT hath long been observ'd, that many Animals,
particularly those with double hearts, forming
the two first classes of Linnè,* have a very con-
siderable degree of sensible warmth; that the de-
gree is nearly the same in the winter's cold, and
summer's heat: and consequently, that a living
animal body, in a healthy state, hath the pro-
perty, of keeping itself at nearly the same certain
natural temperature, let the temperature of the
surrounding atmosphere be what it may.

The

* *DIVISIO Naturalis Animalium ab interna structura
indicatur:*

COR biloculare, biauratum; { Viviparis. Mammalibus,
Sanguine calido, rubro. { Oviparis. Avibus,

Systema Naturæ. Caroli a Linné. page 19.

The natural heat of the human body, is about 98° of Fahrenheit's Thermometer; and that of some other genera, of these two classes, considerably higher; particularly different species of Birds; in some of which the heat is so great, as to raise the thermometer to 106 , or 108 degrees.*

But if an animal be deprived of life, it loses its temperating power, and soon becomes of the same degree of heat, with the earth upon which it lies; or the air which surrounds it.

If an Animal (which, if not otherwise express'd, is throughout this treatise to be suppos'd both living and healthy) be expos'd, to a sharp frosty air for a day, a week, or a month, its general temperature is not altered.

Sheep, oxen, horses, hares &c. are frequently exposed to frost and snow, for weeks together: when the air that surrounds them, the ground that supports them, and the food they eat, are cooled down to the freezing point, 32° , and sometimes far below it; yet at the expiration of a day, a

week

* Martine's Essays and Observations &c. p. 141 &c.

week or month, the heat of the animal is still the same, (still 98° .) 'Tis certain therefore, that the animal thus exposed, generated heat; because it was at the first to a certain degree warmer than the surrounding medium: it continually communicated heat to every thing in contact with it: and yet at the end of the day, week or month, was as warm as at first; tho' perhaps the surrounding atmosphere might have become colder. Indeed, if it had not generated heat, it must have been affected by the surrounding cold, just in the same manner, as it would, if it had been kill'd at the moment of exposure.

To offer further proofs of this property of generating heat, in the two classes of animals mentioned, (and which are particularly to be understood as the subjects meant in this disquisition), would be superfluous; as it appears sufficiently evident from what is already offer'd; and is universally allowed, by every one who hath given the least attention to the subject.

It appears evident then, that so long as an Animal retains the living principle, the functions of

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the body are duly performed, and a certain degree of heat is generated.

That as soon as the living principle is destroy'd, the exercise of every function ceases: the generation of heat is discontinued; and the body soon becomes of the same degree of heat with the surrounding medium; consequently, the living principle gives excitability to the animal solids; and one constant effect of excitement, is *Animal Heat*.

But, If an animal, perfect in the exercise of all its functions, be deprived of *Food*, or *Air*: it dies, and its heat becomes extinct; consequently, both Food and Air, are essentially necessary to the Support of animal life, and its concomitant, *Animal Heat*.

In the next Section therefore will be consider'd, why they are so.

SECTION

SECTION II.

Food and Air are essentially necessary, to the Support of Animal Life and Heat.

IN the preceding Section it appears, that the essential characteristic of life in animal bodies, is excitability; and that one invariable consequence of excitement is heat; therefore, so long as an animal lives, so long will its body maintain its natural degree of warmth; unless affected by disease, or placed in unfavorable circumstances.

If an Animal be deprived of Air, it soon dies, as is evident from experiments with the Air-pump; from drowning, hanging &c.

If it be deprived of Food, its vigour gradually abates: it consumes away: and although it may have plenty of Air—it dies. These two facts are so well known, and universally allowed, that they need but be proposed, to be granted.

May we not reason then in the following manner?

A healthy

A healthy animal, if deprived of food, or air, or both, soon dies, and its heat becomes extinct; but if supplied with food and air, for a year for instance, it will live and generate heat for a year; no unforeseen circumstance intervening. All the heat therefore that this animal generates during the year, must be composed of certain parts of the food and air employed to support its functions; for the healthy animal which dies for want of food, or air, wants not the power, or property of generating heat, but the materials wherewith to produce it; it does not die for want of excitability: but for want of a proper stimulus, to excite the due actions of the living solids; and matter proper for these different functions, to exert themselves upon,

Food and Air therefore are essentially necessary to support *Animal Heat*; and animal heat itself, is a composition of certain parts of that food and air, modified, and combined, by the proper exercise of the natural animal functions.

Animal life, seems to be a *gentle Combustion*; and an animal producing heat, in many respects, may be compared to a burning lamp; the heat in
both

both cases arising from the same cause. A living animal produces heat ; so does a burning lamp. If an animal be not supplied with air, it dies, and its heat is extinguished ; so it is with the lamp. The air that hath been burnt by the lamp, destroys animal life ; so the air that the animal hath breathed, puts out the lamp. A certain quantity of air, will support an animal for a certain time, but no longer ; so it will keep up the flame of the lamp, for a certain time only. Fixt and phlogisticated airs destroy animals ; so likewise do they extinguish the lamp. The air breathed by animals is diminished in quantity ; so it is by the burning of the lamp. A living animal, and a burning lamp, therefore exactly agree in requiring the same kind of air to support them, and producing the same effects upon the air, to which they are exposed.

But they do not resemble each other *only* in producing heat, and requiring the same kind of air : for if an animal hath not fresh supplies of food, as well as air, after a certain time it dies, and becomes cold ; just in the same manner, as the lamp dies out, if not duly supplied with oil.

Since

Since then, that part of the air destroyed by respiration, is the same, as that lost by combustion : and since the ultimate effect is the same, in both operations, that is, the production of heat ; is it not allowable to say, that the food affords to the animal, the same principle, that the oil affords to the lamp ? For since the effects are the same, the causes must be so too. Oil, therefore, affords the principle of inflammability, or phlogiston, to the lamp : and consequently, the *food* of animals, supports the functions of life, and the generation of *heat*, by supplying *phlogiston* to the *Animal System*.

The Chemical analysis, of such substances, as are proper to support animal life, confirms this opinion ; for no substance affords proper nourishment, which contains not Phlogiston in its composition ; and the instantaneous support, and refreshment, perceived by those who are much exhausted, upon taking certain inflammable substances into the stomach, such as wine, ardent spirits, essential oils &c. still further confirm it. Very different matters therefore, will support animal life, if they contain phlogiston, as an ingredient, separable by the animal process ; so likewise very different

ferent substances will support the flame of a lamp, if they contain the principle of inflammability, separable by the heat of Combustion ; such are oils, ardent spirits &c. &c.

It appears evident therefore from the preceding considerations,

1st. That the exercise of the animal functions produces heat.

2dly. That *animal heat*, as well as animal life, is supported by food and air.

3dly. That animal heat is formed from some part of the food, united to some certain other part, supplied by the air.

4thly. That the same part of the atmospheric air, that produces heat in combustion, by its union with phlogiston : is taken from it by the respiration of animals ; and consequently,

6thly. That as heat is produced both by combustion, and the vital functions of animals, it must arise from the same cause ; therefore, as the

same

same part of the air is destroyed by both, the food must furnish the animal with phlogiston, as oil does the lamp; and the combination of this phlogiston with the pure air, affords animal heat to the one, and the heat of combustion to the other.

The next thing to be consider'd is, by what function, or functions of the Animal System, this combination of the phlogiston of the food, with that peculiar part of the air, so as to form animal heat, is effected; which, will be the subject of the next Section.

SECTION

SECTION III.

The particular functions of the animal system, which combine the phlogiston separated from the Food, with a certain part of the atmospheric Air, so as to produce heat, investigated.

IT hath been mentioned, and is universally allowed, that an animal deprived of the living principle, does not generate heat; it was also intimated, that the essential characteristic of life is excitability, and heat the invariable consequence of excitation; or in other words, that heat is produced, by the action of the living solids, upon the substances which excite them.

The phenomena of life therefore, are produced, when the excitability of the parts of an animal, are rendered active, or duly excited, by the application of proper stimulants.

Since then the presence of the vital principle, is known by excitability: and heat is the consequence of excitation: it seems, that heat is produced by *action*, or *exertion*, of every kind; but,

the only parts of the animal system, which are active, excitable, or capable of exertion are the muscles, or at least contain muscular fibres in their texture; therefore it must follow, that the *muscles*, or *muscular fibres alone*, produce heat during the time of their excitation. But, if the nerves that enter into any involuntary muscle, or muscular part, be cut, or compressed, so as to prevent the communication between the muscle and the brain, or medulla spinalis, that muscle soon loses its natural excitability, and consequently can produce no heat, because not capable of excitement, by which alone animal heat is produced. Again, if the nerves extending from the Brain, or medulla spinalis, to a voluntary muscle, be cut or compressed, the muscle cannot be thrown into action, by the most violent exertions of the will; consequently it cannot be excited, or generate heat. The Nerves therefore in a quiescent state give excitability, and during the action of the brain, convey excitement to the muscles.

The involuntary muscles are distributed to those parts of the body, which perform the vital functions; which are those that support and preserve the system; as chylification, the circulation of the

the blood, secretion, excretion &c. Respiration is in a certain degree involuntary, yet subject to the exertion of the will. These muscles receive excitability from the nerves, but excitement from the influx of the nervous energy, transmitted from the brain, in consequence of the stimulus ~~of the~~ of the solid or fluid matters, applied to those nerves.

The voluntary muscles, are those not immediately concerned, in nourishing or supporting the system, and are chiefly loco-motive; the natural actions of these, are not excited by the application of stimulants, but by the determinations or volitions of the mind.

Voluntary muscles then, are thrown into action by the influx of the nervous energy, or fluid, transmitted or forced through the nerves, by the impulse of the brain: or that property of it which we call volition; the proximate cause of which transmission, arises in the brain; whilst involuntary muscles are thrown into action, by the influx of the nervous energy, transmitted through the nerves, by the impulse of the brain, the proximate cause of which is, certain sensations or feelings,

ings, communicated to the brain by the nerves, in consequence of the actions of certain stimulating substances, upon their extremities. *unintelligible*

That there is an *energy*, or *fluid*, transmitted from the brain, through the nerves, to the muscles, during their action, is evident from this, that while a voluntary muscle is in action, if its communication with the brain be interrupted, its action ceases, although the volition remains; this cessation from action, does not arise from the muscle wanting excitability, or the brain excitement: but from the excitement of the brain being no longer conveyed by the nerves to the muscle; 'tis evident therefore, that the nerves convey excitement to the muscles, and *that* muscular excitation, we call action, or exertion.

But, if this exciting power be transmissible from the brain, through the nerves, and be capable of producing such powerful effects, when communicated to the muscular fibres: it must be an *entity*, or powerful agent of some kind; possessed of vast mobility, and subtilty so great, as only to be known by the effects it produces in the Animal System; and as mobility and subtilty, are
only

only compatible with fluidity, the energy of the brain must be a *fluid*, which in conformity with custom, will hereafter in this treatise, be called the *Nervous Fluid*.

It appears then from the preceding considerations, that a muscle is thrown into action by the influx of the nervous fluid; and that one invariable consequence of that excitation, is the production of animal heat; consequently, the quantity of heat generated by an animal, will be proportionate to the quantity of muscular exertion: and that to the quantity of nervous fluid, transmitted from the brain, through the nerves, to the fibres of the muscles in action. In proof of this conclusion, the following observations and Experiments are offered.

Observation 1. If an animal, a Man for instance, in good health, be exposed to a *temperate* air, in a state of *rest*, the quantity of heat generated by the continual action of the *involuntary* muscles, will be sufficient to maintain his natural temperature of 98° ; by which the solids receive a natural stimulus, the fluids retain their proper mobility, and all the functions of digestion, nutrition,

trition, circulation, secretion, excretion &c. are duly performed, and a sufficient quantity abounds to carry off the perspirable matter, by evaporation from the surface.

Obs. 2. If a man, exposed to a *frosty air*, continues at *rest*, the *involuntary* muscles, by their natural action, *cannot* generate sufficient heat, to keep every part of the body at its natural temperature; because the coldness of the surrounding medium, carries off the heat faster than they can produce it; consequently, the solids and fluids of the extremities, and at the surface of the body, will become frigid, the fibres torpid, and the blood returning cold to the heart, will render it torpid and weak also. If these circumstances continue, the torpor gradually increasing: the circulation becoming slower and weaker: and the generation of heat diminishing, will soon render the body as cold as the air which surrounds it, and attracts its heat; and consequently, *death* must ensue.

Obs. 3. But on the contrary, when a Man exposed to a *frosty air*, perceives the coldness and torpor arising from his body being deprived
of

of its heat, faster than the involuntary muscles can furnish it, If he throws the *voluntary* muscles into action, by *exercise*, the quantity of heat generated by the *united* actions of both the voluntary and involuntary muscles, will be sufficient to warm every part, and recover and maintain his natural temperature; although the air still shall continue to attract the heat from the surface as before. The quantity of heat necessary, to keep up the natural warmth of the body, and afford a continual supply to the cold frosty air around it, must therefore be very considerable; and a great part of it must be generated by the actions of the *voluntary* muscles, because the involuntary muscles *alone*, could not keep the body from starving, and consequently soon becoming lifeless and cold as the air to which it was exposed.

But since an animal at rest, is supplied with sufficient heat by the action of the *involuntary* muscles alone, to support its natural warmth, and all its functions in a *temperate* atmosphere: 'tis evident, that if the *voluntary* muscles also be thrown into action, a *greater* quantity of heat must be produced, and thrown off from the surface in any given time, than when they were at rest,

rest, and the involuntary muscles alone were in action. To prove that this conclusion is in reality a fact, I made the following Experiment.

Experiment 1.

The temperature of the atmosphere being 63° . of Fahrenheit's thermometer, I took two pints of water from a pump, its temperature 56° . put it into a bladder, and introduced my naked hand into the bladder and water; when sitting down I remained at *rest* for 15 minutes. I then withdrew my hand, and found that the temperature of the water was 63° . so that my *hand* during 15 minutes, while my body was at *rest*, and the *involuntary* muscles *alone* were in action, had thrown off *heat* sufficient to raise the temperature of *two* pints of water, from 56 to 63° .; therefore it had communicated 7° . of heat.

Experiment 2.

I then introduced my other hand into two pints of water, from the same pump, and of the same degree of heat as the former, i. e. 56, contained in another bladder; I then threw the *voluntary* muscles into strong *exercise* for 15 minutes;

at

at the end of which time, I found the temperature of the water to be 66° . so that my *hand* during a quarter of an hour's exercise, had raised the temperature of *two* pints of water from 56 to 66° . that is, had communicated 10° . of *heat*: consequently, the exercise of the voluntary muscles in 15 minutes time, had produced so much heat, as raised the temperature of two pints of water 3° . that is, from 63° . (to which, by experiment 1st, the action of the involuntary muscles might be supposed to have raised it,) to 66° . only by the heat flowing off, from so small a part of the surface of the body as the hand, and that too one of the extremities, where the torpor at first produced, might be supposed to check the circulation, and consequently to lessen the quantity of heat it would otherwise have thrown off, proportionate to the rest of the surface,

But thinking that If I had taken more time, or less water, in trying the experiments, the difference of the results would have been greater, I made the following experiments.

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Experiment

Experiment 3.

The Thermometer being at 59° . in the open air, I introduced my hand into a bladder containing *one* pint of water, at 56° .; after the expiration of 15 minutes, during which time all the *voluntary* muscles were kept free from exertion, I found that the temperature of the water was raised to 65° .; consequently my hand had communicated to the pint of water 9° . of heat; that is, had raised it from 56 to 65° . in 15 minutes, the *involuntary* muscles *alone* being in action; for the heat communicated by the air at 59, to water at 56° , in so short a space of time, was not worth notice; but in Exp. 1st. where the air was 63, and the water 56, some allowance might have been made, if the experiment had required such nicety.

Experiment 4.

The same day I introduced my other hand into another bladder, containing *one* pint of water, of the same degree of heat with the former. i. e. 56; I then threw the *voluntary* muscles into strong exercise, which I continued during the same space of 15 minutes; when withdrawing my hand, and
introducing

Introducing the thermometer, I found the heat of the water was 73° : consequently, the united actions of *both* involuntary and voluntary muscles, during 15 minutes time, had generated so much *heat*, that besides preserving the temperature of the body at 98, in the air at 59° so much had been thrown off from the surface, that even that small part of it, the *hand*, had communicated so much *heat* to *one pint* of water, as had raised its temperature from 56 to 73° that is, 17° ; but it seems from Experiment 3. that the involuntary muscles *alone* would have communicated 9° ; consequently the the action of the *voluntary* muscles, had communicated the other 8° . If then the action of the voluntary muscles during 15 minutes, generated so much heat as raised the temperature of one pint of water from 65 to 73° by the heat thrown off from the hand: how great must have been the quantity thrown off from the whole surface, which that muscular exertion had generated!

But although so great a quantity of heat is generated by muscular action, the muscles *themselves* afford not any part of its composition, but are only the *agents*, which combine the principles of which it is composed together; and one essential
part

part is furnished by the *nervous fluid*, without which the muscles can neither act, nor produce heat.

It occur'd to me, that perhaps it might be objected, that this increase in the quantity of heat, thrown off in consequence of exercise, might not have been produced by the increased influx of the nervous fluid, but by the increased action, motion, attrition, or friction between the different particles of which the solids and fluids are composed, which must take place in great exercise of the muscles. Therefore, to convince myself whether increased muscular *motion* was necessary, to produce an increase in the quantity of heat, generated by an animal in any given time; or, not; I made the following experiments.

Experiment 5.

The temperature of the air in my room was 59° ., of the water I employed, 44° ., when I immersed my hand into one pint of it, contained in a bladder; then sitting *without* voluntary motion, or exertion, for 15 minutes, I found by withdrawing my hand, and introducing the thermometer, that the heat of the water at the expiration of that time, was raised to 57° .; so that my hand
and

and the air in the room together, had communicated to it 13° . of heat.

Experiment 6.

I then (the temperature of the air in the room, and of the water, being the same as in the former experiment) introduced my other hand, into the same quantity of the water, in another bladder; and seated myself with my back against a wall: my feet *strongly pushing* against a large book-case, firmly fixt by its weight: and my arms *forcibly stretched* out. By this exertion, the gastrocnemii, vasti, glutæi, pectorales, & tricipites brachiales muscles particularly, were thrown into *strong contraction*; in that state I kept them 15 minutes; consequently as *free from motion or friction*, as in the 5th Experiment; at the expiration of which time, by introducing the thermometer, I found the temperature of the water was 62° ; but by the 5th Exper^t. it seems, that the air in the room and the hand, by the action of the *involuntary* muscles *alone*, would in the same time have raised it to 57 : consequently, by the contraction of these few muscles, *without any motion* of their fibres, so much nervous fluid had been transmitted to, and through them, by the
brain

brain and nerves, as by that *immobile* exertion, had been converted into *heat*, sufficient to raise the temperature of *one* pint of water, from 57 to 62°, by the quantity only thrown off by the hand; which had therefore communicated to the pint of water 5°. of heat; and as the rest of the surface of the body, must have thrown off at least an equally proportionate quantity: it is evident, that the *heat* generated by this partial muscular exertion, where *neither motion* nor *attrition* were concerned, must have been *very* considerable indeed!

It appears evident therefore, that a *muscle* is thrown into action or exertion, or in other words, is *excited* by the influx of the *nervous fluid*; so that when this nervous fluid, is *not* transmitted from the brain, in consequence of volition or irritation, the voluntary muscles in the first case, or involuntary in the second, are not excited.

It is likewise evident, that this nervous fluid is a *reality* or *entity*; transmitted from the brain, by the nerves, to the muscles; so that when this communication is interrupted, and the *influx* of this

this nervous fluid to the muscle is prevented, its action ceases.

It is also equally clear, that the nervous fluid does not excite a muscle to act, by becoming *fixt* or *resident* there : but by passing through, or along the fibres of the muscles ; from this fact, that when a muscle is excited, if the *continual influx*, or *stream* of nervous fluid, passing from the brain through the muscle, be interrupted, by tying or cutting the communicating nerve, its action immediately ceases.

'Tis also as evidently proved, that the *quantity* of heat generated by a living animal, is in proportion to the muscular exertion : and consequently to the quantity of nervous fluid passing along the fibres of the muscles. And the last Experiment proves beyond a doubt, that this heat is *not* produced by *motion*, or *attrition* of the parts of which an animal is composed : but by the *nervous* fluid when, or after passing along the fibres of a muscle, or muscles.

Since

Since then the transmission of the nervous fluid through, or along muscular fibres, is necessary to excite them to action: and since the consequence of that transmission or excitation, is the generation of heat; the next thing to be enquired into, is the nature and chemical properties of this nervous fluid.

SECTION IV.

*On the Nature, or leading Chemical Principle of
the Nervous Fluid.*

FROM the preceding considerations, the nervous fluid appears to be an essential part in the composition of heat, supplied by the brain.

The Brain itself seems to be a glandular mass, supplied with a greater quantity of arterial blood in proportion to its bulk, than any other part of the body, except the Lungs, by the carotid and vertebral arteries, which are the first considerable branches sent off by the Aorta.

If the quantity of blood sent from the heart to the brain, be suddenly and greatly diminished, or interrupted, in its passage through the carotids, the brain wanting that firmness, plenitude or tension, which the blood vessels naturally support, becomes collapsed or flaccid; in consequence of which, it loses its power of impelling the nervous fluid along the nerves, to the voluntary and involuntary muscles in proper quantity; hence arise

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relaxation.

relaxation, syncope and death, as is evident from great and sudden losses of blood.

If the blood be not duly supplied with chyle, prepared by the stomach &c. from proper food or nutriment, it soon becomes impoverished by the action of the brain, the quantity of nervous fluid secreted will be gradually less and less, till at length the blood becomes quite exhausted; the Brain thus deprived of support, soon parts with its slender store to the involuntary muscles or others, and after a gradual diminution of power and action in all the functions, the scenes closes in death.

'Tis evident therefore, that the free and equable action of the brain and nerves, depends upon a proper plenitude and firmness of the blood vessels supplying the brain: the quantity of nervous fluid upon that of the nutrimental part in the blood: and that upon the food taken into, and digested and assimilated by the stomach, bowels &c. therefore, the nervous fluid is supplied by that part of the food, which after due digestion and preparation by the stomach &c. is absorbed by the lacteals, and commixt with the blood.

Now,

Now, as was before intimated p. 38, all those substances which afford proper nourishment, contain *phlogiston* as one necessary ingredient; and as in case of great exhaustion of the nervous fluid, by violent muscular exertions &c. the most sudden refreshment and reinvigoration, is obtained from those matters which contain much *phlogiston*, in the most detached state, as wine, ardent spirits, &c. it is natural to conclude, that the *nervous fluid* contains *phlogiston*, as one of its essential parts; therefore, the food supplies the brain with *phlogiston*, as certain inflammable matters do the lamp; as was before hinted from analogy, p. 39.

If then, as is presumed from the preceding considerations, the nervous fluid be of a *phlogistic* nature: and heat be produced by the combination of *phlogiston*, with a certain part of atmospheric air: and the respiration of air be as necessary to the continuation of animal life, and the generation of animal heat, as it is to the support of the flame of a lamp, and the production of the heat of combustion, it will follow, that the air during respiration, must communicate this essential part of its composition to the animal body; or rather, to the *blood*, by that natural and necessary action
exposed

exposed to its influence; and if it be a fact, that blood does imbibe this essential part of the atmospheric air, when exposed to its action in the Lungs, during respiration, and part with it again, in consequence of the generation of animal heat: it will be a convincing proof, that a *nervous fluid* does in reality exist: that it is of a *phlogistic* nature, and by communicating *excitement* to *muscular* fibres, is left in such a state, as to readily combine with the *essential* part of the *air*, contained in the *blood*, and thus form the *heat of animals*.

The subject of the next Section, will therefore be an attempt, to prove that this essential part of Atmospheric Air, is really absorbed by the Blood in its passage through the Lungs, during respiration.

SECTION

SECTION V.

On the change produced in the Blood, by its exposure to the action or influence of Atmospheric Air in the Lungs, during respiration.

ONE observation worthy of attention is, that the same quantity of blood passes through the lungs, in any given time, as through the rest of the body; because no blood is transmitted from the heart by the aorta, but what is received from the pulmonary veins, immediately after it hath been exposed to the action of the air in the lungs.

If the blood in the vena cava, or pulmonary arteries be examined, it is found to be of a *dark red*, or *blackish* colour; but after having been exposed to the influence of the air, it is returned by the pulmonary veins to the heart, of a *bright red* colour, to be conveyed by the arteries, to support the functions of every part of the body.

The same change of colour, is also produced by *exposing* blood taken *from* the veins of an animal, to the atmospheric air ; therefore 'tis evident, that this change of colour is effected by the action of the air.

But, if this venous blood, be exposed to air that hath been respired, or burnt 'till it would no longer support life or combustion, it does not acquire this florid red colour, but still remains black ; or, if this black or venous blood, be exposed to a proper quantity of common air, that quantity will be diminished, and the residuum unfit for either respiration or combustion.

It appears then, that a certain part of the atmospheric air is destroyed, decomposed or absorbed by respiration, combustion, and by exposing to it, a quantity of black or venous blood ; and that it is the *same* kind of air that is destroyed, or absorbed in each process ; and to this part of the common air, Philosophers have given different names, as Empyrean Air, Vital Air, Dephlogisticated Air, Air eminently respirable &c. but the shortest and perhaps as good a name for it as any,

any, is that of *Pure Air*, which I shall therefore make use of through the remaining pages.

Dr. Priestley and others, have supposed, that the change produced by exposing venous blood to the air, is in consequence of the air, by its superior attraction, depriving it of phlogiston, which gives it the dark colour; therefore the air attracting this phlogiston, leaves the blood of its natural florid colour. If this be the only use of respiration, 'tis evident that the only change which ought to be produced in the air respired, or exposed to venous blood, must be, that it hath received a quantity of phlogiston, without parting with any thing to the blood; and the only change in the blood, its having parted with phlogiston, to the air, without having received any thing from it; But, as air suffers the same change from combustion as from respiration, it is evident, that if respiration renders air impure only by imparting to it phlogiston; combustion also must render it foul by communicating phlogiston, without taking any thing from it. But M. Lavoisier from experiments boldly asserts
directly

directly the contrary. He says * that if Mercury be calcined in vital air perfectly pure, it may be absorbed to the last particle; but if the operation be interrupted before all the vital air be absorbed, the residuum is not in the least altered, that is, it contains no more phlogiston than was contained in the original quantity of air employed.

If so, and so I have not a doubt but it is, as the change produced in the air by combustion and respiration

* “ Les partisans de la doctrine de Stahl, sont perpétuellement dans de semblables embarras: si on leur demande ce qui se passe lorsque l'on calcine du mercure dans l'air vital, les Physiciens anglois répondront qu'à mesure que le phlogistique se dégage du métal, il se combine avec l'air dans lequel on opère, & qu'il le change en air fixe ou en air phlogistique; mais cette assertion est encore absolument contraire aux faits. Lorsque l'on opère sur de l'air vital absolument pur, on peut l'absorber jusqu'à la dernière goutte, & si l'on interrompt l'opération avant que l'absorption ait été complète, la portion d'air vital qui reste n'est nullement altérée, elle ne contient exactement que la même quantité d'air méphitique qui étoit contenue originairement dans la totalité de l'air qu'on a employé.” Histoire de L'Académie &c. Année 1783. p. 519.

respiration is the *same*, it will naturally follow, that the *Blood* does *not* impart phlogiston to the air in the lungs; that the alteration produced in the nature of the air, is the *loss* of its pure air; and that the change of the colour of the blood from *black* to *red*, is effected by this *Pure Air*, which it hath *absorbed* during its passage through the lungs.

As a further proof that the change produced in the air by respiration, is not the accession of phlogiston, but the loss of its pure air, I shall borrow some experiments from my much esteemed Friend Dr. E. Goodwyn, published in his valuable Thesis at Edinburgh, 1786.*

He took a quantity of air containing by analysis, phlogisticated air 80 parts, pure air 18 parts, and fixt air 2 parts, the whole making 100 equal
 I parts.

* Differtatio medica inauguralis, de Morbo morteque Submerforum investigandis.

parts. From repeated trials he found, * that the whole received and returned by one respiration, gave of phlogisticated air 80, pure air 5, and fixt air 13 parts, the whole 98 equal parts; so that $\frac{1}{50}$ th part of the whole bulk was lost. It appears therefore, that the air by one respiration had suffered a loss of 13 parts of pure air, and had gain'd 11 parts of fixt air, the quantity of phlogisticated air being the same. The pure air therefore was either absorbed, or changed into fixt air; but that it was absorbed and not changed into fixt air, his 4th Experiment seems clearly to prove †: Four ounces of blood from the vena cava

* Totus aër, una respiratione, receptus, constabat ex partibus:			Totus aër, una expiratione, redditus, constabat ex partibus:		
Aëris phlogisticati	80		Aëris phlogisticati	80	
Aëris puri	—	18	Aëris puri	—	5
Aëris fixi	—	2	Aëris fixi	—	13
	—			—	
		100			98
	—			—	

p. 40.

† “ *Experimentum quartum.*—Quattuor unciae sanguinis, e vena cava ovis, in vas vitreum receptae, illico, actioni centum partium aëris atmosphaerici jam explorati, objiciebantur :

cava of a sheep were exposed in a glass vessel to 100 parts of the preceding kind of air: the dull dark colour was presently changed to red: the volume of air diminished, and about $\frac{1}{30}^{\text{th}}$ part of the whole was absorbed, while the phlogisticated and fixt airs were not in the least altered, consequently the part absorbed was pure air.

When the same experiment was repeated with eight ounces of blood, $\frac{1}{20}^{\text{th}}$ part of the whole was absorbed, and that was pure air, the phlogisticated and fixt airs being in no respect altered.

These Experiments prove, that *no* phlogiston is absorbed by the air from the blood during respiration, as was supposed by analogy from M. Lavoisier's observations on combustion; and consequently,

bantur: ecce subito, color sanguinis e fusco in rubeum vertebatur: volumen totius aëris decrescebat; ipsiusque circiter trigesima pars (scilicet quae purus aer erat) evanescebat; dum nec fixus aër, nec phlogisticatus, vel minimum immutarentur.

Idem experimentum instituimus, octo unciis venosi sanguinis utentes; tuncque pars totius aëris molis vigesima, sub puri aëris forma abiit; caeteris aëris portionibus haud mutatis." p. 45, & 46.

frequently, that the florid *red* colour given to the blood, by exposing it to the air, is *not* produced by its parting with phlogiston to the air, and therefore, its *black* colour is *not* owing to the superabundance of phlogiston contained in it. It appears likewise evident, that the blood circulating through the lungs, does not produce *fixt air* by decomposing the pure air; because when it absorbs pure air, and acquires its florid, red colour, *out* of the body, no *fixt air* is produced. Perhaps this *fixt air*, is secreted by the exhalent vessels of the lungs, and thrown off as an excrementitious matter: upon the same principles, as the vapour of perspiration is thrown off from the surface of the body,

From the preceding experiments &c. it seems at least very probable, that the opinion of Dr. Priestley, and others, who suppose the *chief* use of *respiration* is to *free* the blood from a redundant phlogiston, is erroneous; and that the *real* use is, to *supply* the blood with pure air.

The cause of *death* then in animals exposed to impure air, is *not* the *phlogiston* retained in the blood, for want of pure air to carry it off: but
the

the want of a *proper supply* of that pure air to the blood, which by circulating through the muscles &c. hath been deprived of it. For if the retention of phlogiston in the blood, be the cause of death, on account of its sedative power, why does it not produce the same deleterious effects upon the *right* auricle and ventricle of the heart, as it is supposed to do by passing unaltered to the *left*? but there it shews no such effects: therefore, the cause of death in this case, *cannot* be the sedative power of phlogiston, retained in the blood.

The Pure Air therefore, absorbed by the blood, seems to act as a stimulus, or to be some way or other necessary to excite and support the action of the heart; and if of the heart, that also of every other involuntary muscle; in proof of which I shall borrow another of Dr. Goodwyn's experiments, which for the conviction it carries along with it, I esteem as a most beautiful, though cruel experiment.*

* "*Experimentum septimum.*—Cani super mensam religato sternum sustulimus; tunc pulmones eodem pacto, quo in experimento sexto, ope follis, aëre atmosphaerico inflavimus. Dum

Exp^t. 7. " The Sternum of a Dog tied down upon a table was removed, and the lungs by means of a proper pair of bellows were inflated; whilst air was thrown in, and the blood circulated through the pulmonary veins red and florid, the left ventricle of the heart and the arteries continued to beat with their usual force. A proper quantity of atmospheric air being thrown into the lungs and there confined, the blood circulating in the pulmonary veins began to grow black, and

in eos inspirabamus, et sanguis, per pulmonum venas transibat rubeus et floridus, sinister cordis ventriculus, et arteriae, more et vi naturae solitis, pulsabant. Totum aëra atmosphericum in pulmones injectum, ibi cohibuimus: tum sanguis, qui pulmonum venas circuibat, nigrescere; cor et arteriae minus crebro debiliusque micare; donec tandem, sanguine, in pulmonum venis, jam nigro et penitus venoso evadente, cor tardius movebatur, arteriarumque pulsus sensim evanescebant. Sed tunc, aëre incluso exire permissio, inspirationes, ope follis, redintegrabamus; et sanguis, qui per pulmonum venas ibat, gradatim colorem floridum resumere: cor, eadem ratione, reviviscere; omnesque arteriae magis et magis crebro validiusque pulsare coeperunt; donec, redeunte rubro colore, cor et arteriae, naturae solito more, pulsare videbantur,&c."

and the motion of the heart and arteries became less frequent and powerful, till at length the blood in the pulmonary veins becoming black and like venous blood, the motion of the heart became still more slow, and the pulsation of the arteries gradually became imperceptible. The included air being then permitted to escape, air again repeatedly thrown in by means of the bellows, and the blood passing through the pulmonary veins gradually regaining its florid colour, the heart again began to recover its power, and the arteries to beat quicker and stronger, till at length its red colour being restored to the blood, the heart and arteries seemed to beat with their natural force." &c.

All these experiments and observations being considered, it seems allowable to draw the following conclusions :

1st. That the *florid red* colour of *arterial* blood, is produced by its *absorption* of *pure air*, whilst exposed to the atmospheric air in the lungs, during respiration.

2nd. That

2nd. That the *black* colour of *venous* blood, is owing to this *pure air* being *decomposed*, or otherwise *destroyed*, or *taken from* the arterial blood, as it circulates through, and gives support to the various parts of the animal system.

3rd. That the existence of a *detached* or *superabundant* phlogiston in the blood, communicable to the air, is *doubtful*, or at *most* very *inconsiderable*.

4th. That if it does exist in that state, it does *not* shew any *deleterious* or *sedative* effects upon the heart, while in the *right* ventricle or auricle, and consequently is *not* the cause of death, when it circulates in the same state to the *left*.

5th. That the *florid* colour of the blood in the pulmonary veins, left auricle and ventricle of the heart, and in the arteries, is the only criterion by which we *might* judge, that it is in a *proper state* to support the phenomena of life; that this colour depends upon the presence of *pure air*, and consequently, that the cause of death, when animals are deprived of this pure air, is the *want* of

of a proper *supply* of it, to the Blood by the process of animation deprived of it.

Since then the nervous fluid is of a phlogistic nature : pure air is absorbed by the blood : heat is produced by the combination of phlogiston and pure air, and this combination in animals is effected by muscular exertion or excitation, the next thing to be explained is, how the nervous fluid by the exertion of the muscles, is so combined with the pure air in the blood, as to form the heat of animals.

It is also as certainly known, that if the nervous fluid is absorbed by the blood, it must be combined with the pure air in the blood, as to form the heat of animals. The nervous fluid is absorbed by the blood, and the pure air is absorbed by the blood, and the combination of phlogiston and pure air is effected by muscular exertion or excitation, the next thing to be explained is, how the nervous fluid by the exertion of the muscles, is so combined with the pure air in the blood, as to form the heat of animals.

SECTION VI.

*The manner in which Animal Heat is generated
by muscular Exertion.*

IT hath been shewn, that no muscle can act without an influx of nervous fluid, nor be kept in action, without a continual stream of that fluid through or along its fibres.

It is also as certainly known, that if the *artery*, or *arteries*, supplying a muscle be compressed, or cut, so as to interrupt the influx of blood from the heart to the muscle, it becomes flaccid, cold, and at length paralytic ; therefore 'tis evident, that the *action* of a muscle, and its *power* of *generating heat* in consequence of that exertion, in a certain degree depends upon the *influx* and *circulation* of a proper quantity of *arterial blood* through its vessels, as well as upon the influx of nervous fluid ; and that if it is not duly supplied with both, it becomes paralytic, and loses its power of generating heat.

It appears sufficiently evident therefore, that animal heat is generated in the following manner.

When certain *Ideas* or *volitions* are excited in the *brain*, or when certain *feelings* or *motions* are produced there, by the actions of certain *stimuli* upon the extremities of the *nerves* extended to the involuntary muscles, and by those nerves communicated to the brain, it determines, impels, or transmits along the nerves, a proportionate quantity of the nervous fluid; this fluid passing along the muscular fibres, excites them to contract; that is, increases the attraction, or approximation of the particles of which the muscular fibres are composed, to each other.

But, from the preceding considerations, it appears that this attraction between the component particles of which the muscular fibres are composed, is not produced by the nervous fluid becoming fixt, stationary, or combined with the fibres of the muscle, but by *moving* or *passing along* them: therefore, after having passed the fibres, and excited them, it must pass into the *fluids* contained within the body of the muscle. It is evident therefore, that the nervous fluid, after having excited

cited the muscular fibres, must pass into the *blood*, contained in its proper vessels, every where forming so large a part of the bodies of the muscles. This *nervous fluid* therefore, received into the *blood*, unites with the *Pure Air*, contained there, and forms *heat*. Perhaps it suffers some change in the mode of combination of its principles, by exciting the fibres of the muscles, which renders its phlogiston more detached, and ready to combine with the pure air in the blood, than it would be without passing along the fibres. The *Blood* thus deprived of its pure air, in the extremities of the arteries, by its union with the phlogiston of the nervous fluid, becomes *black*, and is returned by the veins to the right auricle and ventricle of the heart, to be transmitted by the pulmonary arteries through the lungs, there again to receive from the atmospheric air, a fresh supply of pure air, by which it again becomes fit for the purpose of receiving phlogiston from the nervous fluid, when commixt with it in the muscles during their action; and consequently again becomes fit, to support all the functions of the living animal body, which depend upon motion and heat.

From all then that hath been advanced in the preceding

ceding part of this tractate, it appears allowable to draw the following conclusions.

1st. That the *Brain* separates from the *Blood*, a subtile elastic *fluid*, of a *phlogistic* nature.

2nd. That this fluid by the *action* of the *Brain*, in consequence of *volitions* arising, or *feelings* excited there by the action of stimulating matters upon the nerves and by them communicated, is *propelled* or *transmitted* along the nerves to the *muscles*.

3rd. That the *Fibres* of muscles, by the nervous fluid thus passing through or along them, are *excited* to *contract*, owing to the attraction between the solid particles of which the muscles are composed, being *increased* by the energy of the nervous fluid passing through them.

4th. That the nervous fluid does not remain *fixt*, or *united* with the fibres of muscles, but *passes* into the *Blood*, contained in the vessels of the muscles.

5th. That

5th. That the *principles* of which the nervous fluid is composed, are so disposed after giving excitement to muscular fibres, that the *phlogiston*, which forms one essential part of it, is capable of forming an *union* with the *pure air*, contained in the *Blood* with which the muscles are supplied by the *arteries*.

6th. That this combination of the phlogiston of the nervous fluid, with the pure air contained in the blood, forms *heat*; and consequently

7th. That the *quantity* of heat generated by a living animal, must be *proportionate* to the quantity of nervous fluid thrown into the Blood: and *that* to the degree of muscular exertion; and therefore

8th. That the *quantity* of muscular exertion, and heat produced in consequence thereof, must require a quantity of *pure air*, *proportionate* to the quantity of nervous fluid. Therefore it must follow,

9th. That the degree of *quickness* of the *circulation* of the *Blood*, or the *number* of *contractions*
of

of the *heart*, must be *proportionate* to the quantity of nervous fluid passing into the Blood : to the quantity of heat generated : or to the exertion of the muscles ; and consequently,

10th. That the more quickly the blood circulates thro' the arteries of the muscles, and becomes deprived of its pure air as such, the more quick must be its return to the *heart*, and *circulation* through the *Lungs* ; and the more frequent must be the *respirations*, to *restore* to it the quantity of pure air that is lost, by the formation of heat by its union with the phlogiston of the nervous fluid.

The first seven conclusions appear to me to be already sufficiently proved, and the 8th. 9th. and 10th. to arise naturally from them. If therefore in the next Section these last conclusions be shewn to be *not false* : it will be a proof that the *former* are *just*, and the *principles* from which they were drawn, *true*.

SECTION

SECTION VII.

The degree of muscular exertion being increased or diminished, is always accompanied with a proportionate increase or diminution of action, in the Heart and Lungs.

ANIMAL Heat being a compound, produced by the mixture of the nervous fluid with pure air, and that combination the result of muscular exertion, it must of necessity happen, that the more the muscles are exerted, the greater must be the quantity of nervous fluid thrown into the blood contained in them; and consequently the quantity of pure air necessary to form heat by saturating, or combining with that increased quantity of nervous fluid, must also be proportionately greater: therefore a greater quantity of blood must be required to supply it. But as the quantity of blood contained in the muscles, is perhaps nearly the same during their contraction as when relaxed, the only means of increasing the quantity supplied to the muscles, in any given time, is by quickening or accelerating the motion of the blood through them.

That

That this accelerated motion of the Blood, should *exactly* correspond with the degree of excitement in the muscles, 'tis necessary, that the motion or exertion of the *Heart*, should *always* bear a *certain proportion*, to the *united* exertions of the other muscles. — And as the quantity of pure air destroyed or decomposed in the Blood, is proportionate to the quantity of nervous fluid thrown in by muscular exertion, 'tis evident, that to *supply* this *loss* of pure air to the Blood, as *fast* as it is destroyed, the exertions of the Lungs, or *number of Respirations*, must also be *proportionate* to the exertions of the muscles of the other parts of the body.

To satisfy myself of the truth of these conclusions, I made the following observations and experiments.

At the time of trying the 5th Exp^r. Sect. 3. p. 52, I observed that the temperature of the air in the room was 59, the number of the pulsations of the heart were 70, and the respirations 18 in a minute, when I began the experiment; and as my body remained at rest all the time of that experiment, I repeatedly found the number

of pulsations and respirations remain'd the same, and so continued 'till I began with Expt^r 6. — But soon after my muscles were thrown into that state of contraction, or exertion, there mentioned, I found the number of respirations in the minute, was augmented to 36, and of the pulsations of the heart to 101, and there continued till the experiment was finished, and the muscles were relaxed. So that to form the quantity of heat capable of raising one pint of water 5° that is, from 57 to 62, by being only exposed to that small part of the surface of the body the hand, so much *pure air* had been destroyed in consequence of the exertion of those voluntary muscles, as had required an addition of 18 *respirations* per minute, for 15 minutes, to *restore* it to the Blood; and to *supply* it *fast enough* to combine with the nervous fluid, necessarily flowing into the blood, after giving this degree of excitement to the voluntary muscles, the *heart* was excited to *contract* 31 *times* in the minute, more than was necessary when the *voluntary* muscles were at rest, and the *involuntary* only in action.

I soon convinced myself that *this increased* action of the heart and lungs, was not produced in consequence

consequence of the quantity of heat generated, or any increased motion of the solids—for examining the number of respirations and pulsations when sitting still, I found that in a moment, by violently grasping the arms of my chair, or even stretching out my legs with force, the number of respirations and pulsations were greatly increased; and that always in proportion to the degree of muscular exertion. This *increased action* of the heart and lungs, or muscles subservient to respiration, being produced at the *same instant* in which the muscles began to be excited, must have arisen from the *same cause*, that is, an *increased quantity* of *nervous fluid* transmitted to them by the Brain, *proportionate* to the quantity sent to the other muscles at the same time; and *this increased quantity* is transmitted to the *Heart and Lungs*, *so long* as it continues to flow to the *other muscles*.

The Lungs and Heart therefore agree in this respect, that *each* receives a quantity of nervous fluid from the brain, *proportionate* to the quantity transmitted to *all* the other muscles of the body; by which, their motions are so regulated, that the *Blood* is always supplied with *pure air*, in proportion

proportion to the demand for it in the system, by the action of respiration; and *that* Blood is always *sent* to the muscles in *such quantities* in any given time, by the action of the Heart, as is necessary to supply a quantity of pure air, *sufficient* to *saturate* the nervous fluid flowing into it, from the excited muscular fibres; and this saturated combination forms a proportionate quantity of heat.

But besides this, it is necessary that the heart be possess'd of *another* property, that is of being *sensible to*, and *stimulated by* heat, and that in proportion to the *quantity of it in the system*, whether generated there or not. For if there were no provision in the Animal Œconomy, for the expulsion of heat, in proportion to its generation, 'tis evident, that the heat during violent muscular exertions, would be *accumulated* to a great degree; but it appears from the preceding observations and experiments, that it is *not*, but flows off from the surface in an increased quantity, therefore 'tis equally evident that there is such a provision in the animal œconomy; and that heat is *never* accumulated, but when its evaporation from the surface is *obstructed*, by spasm, or some other cause, when

when the functions of the body are disordered; and that then the accumulation of heat forms Fever, or inflammation.

The Heart must therefore have the property of being *stimulated* by heat, in a remarkable degree; and its action must *always* bear a proportion to the quantity of heat in the body; and the quantity of *blood* thrown by the heart to the *surface*, will therefore be proportionate to the quantity of heat it contains; and the quantity of *evaporation* or *perspiration*, form'd by the union of that heat with the fluid part of the blood, or perspirable matter, will again be in proportion *to that*. — That this is in reality the case, we need only consider the *evident increase* of evaporation from the surface, during violent exercise, to be convinced. For in a temperate air, while the body remains at rest, this evaporation is *insensible*; but by violent exercise it becomes so *evident*, as to run in streams down the surface of the body, and render the substances in contact with it, evidently *wet*.

The degree of moisture thus communicated to the air, might easily be determined by confining the

the hand in a bladder, containing a certain quantity of air, in the same manner as I employ'd the water, and after a certain time of rest, and of exercise, examining the degree of moisture in each case communicated to the air, by an Hygrometer — but not having one convenient for this purpose, and being fully satisfied of the fact from the preceding observations, and considerations, I never have tried the experiment.

However, to satisfy myself that the Heart is *stimulated* by heat, *independent* of muscular exertion, in an *eminent* degree, I made the following experiment.

The temperature of the air which I inspired, in my room, was 60° . the number of pulsations of the heart in a minute, were 63, and of respirations 18.

I then placed myself so *near* the Fire, that the heat communicated to my skin was 112° . and by holding the thermometer at the same *distance* from the fire, and of the same *height* with my mouth, I found the air I inspired was also heated to 112 — after sitting in this manner some minutes exposed

exposed to the heat of the fire, I examined the state of my pulse, and found the number of pulsations were increased to 100, but the number of inspirations were *scarcely* 17 in the minute—the perspiration was now so *greatly* increased, as to become *sensible* under the form of sweat. 'Tis evident therefore, that the number of the contractions of the heart were increased 37 in a minute, by the *stimulus* of heat alone; by which the determination of blood to the surface, and consequently the evaporation of heat from it, were *increased* to preserve the temperature of the body, as near as possible at its natural standard.

But, tho' the heat had so *evidently* increased the frequency of the contractions of the heart, the number of respirations were *rather diminished* than increas'd; the reason of which perhaps may be, that the *degree of heat* necessary to support the animal functions, requires a continual supply of nervous fluid from the brain, and pure air from the blood to support it, by the actions of the involuntary muscles; but, in this case, a sufficient quantity of heat was supplied by the fire to support those actions, whereby a less expence of pure air became necessary, and fewer respirations,

respirations were required to supply the loss. But be that as it may, 'tis evident that the number of *respirations*, is always *proportionate* to the quantity of pure air destroy'd in the blood, by the generation of heat, and consequently to the *degree* of muscular exertion in the system; while the number of *contractions* of the *heart* depends upon the *degree* of muscular exertion, and the *quantity* of heat *also* present in the body.

For in the preceding experiment, the heat independant of motion, had increased the contractions of the *heart* from 63 to 100, because it is stimulated by heat; but the *Lungs* are not stimulated by heat, and there was no *increased muscular action* to diminish the quantity of pure air in the blood; therefore there was no necessity for any increase in the number of respirations. But had the number of pulsations of the heart been increased to 100 by *exercise*, the expence of pure air in consequence of that muscular exertion, *must* have required a *quicker respiration* to have supplied the loss; to convince myself of which, I threw my muscles into strong action, 'till the number of pulsations were 100 per minute, as in the former case; when I found the number of
respirations

respirations was increased to 25——tho' when the *pulsations* were increased to the *same number* by *heat*, the *number of respirations* was only 17.

From these considerations, it appears then that the conclusions in the last chapter, are *true*; and the principles from whence they were drawn, are further confirm'd thereby. The same observations likewise point out these following *invariable Laws* of the Animal Œconomy.

1st. That whatever be the quantity of nervous excitement, energy, or *fluid*, sent from the brain to the other muscles voluntary, or involuntary, a quantity always bearing the *same* proportion, is sent at the *same* time to the Lungs, or muscles subservient to respiration; by which means, the quantity of pure air communicated to the Blood in the lungs, is always proportionate to the quantity destroy'd by forming heat with the phlogiston of the nervous fluid, united with it in consequence of muscular exertion. For if the quantity of nervous fluid sent to the respiratory muscles, be in the *same* proportion with that sent to all the other muscles: 'tis evident, that the degree of their action, will also at all times bear the *same*

ratio, to the quantity of the *united actions* of all the other muscles.—Therefore the more the muscles are exerted, the more quick will be the respirations—and vice versa.

2nd. That the quantity of nervous fluid sent to the *Heart* also, bears always the *same* proportion to the quantity sent to all the other muscles ; therefore the degree of exertion of the other muscles, is always accompanied with an *equal* degree of action of the *heart* ; by which means, the quantity of *arterial* blood, and consequently of *pure air* sent by the *Heart* to a muscle, or muscles, in any given time, is always proportionate to the quantity of muscular *exertion*, and *nervous fluid* evolv'd by that exertion.

3rd. That the *Heart* is peculiarly *sensible* to the action of *heat*—that the quantity of heat in the Body, always produces a correspondent degree of action of the *heart* ; by this means, the quantity of *blood* thrown to, and *heat* evaporated from the surface, is always in a healthy animal *proportionate* to the quantity of heat in the *system*—and by this property of the heart, the even, natural temperature of the animal body, is constantly preserved ; and

4th. That the action, or number of contractions of the heart, are always in a *compound ratio* to the degree of muscular exertion; and to the quantity of heat present in the system.

And now perhaps it will not be improper to give one general, comprehensive, or Synoptical View of the whole, and then conclude the subject.

1. Whilst an animal body retains the *living principle*, its moving solids, or muscular fibres possess *excitability*.

2. So long as an animal is capable of *excitement*, so long can it *generate heat*, but no longer.

3. *Excitability* of the muscular fibres, is the great characteristic of *Life* in animals.

4. *Excitation*, or muscular exertion, is the efficient cause of animal heat.

5. *Food* and *Air* are both essentially necessary to the support of animal life, and animal heat.

6. *Food*

6. *Food* by digestion &c. supplies *Chyle* to the *Blood*, and from that a *phlogistic fluid* is secreted by the *Brain*.

7. *Atmospheric Air* during respiration, supplies the blood with *Pure Air*, which being absorbed, changes the black colour of the blood to a florid red.

8. The *nervous fluid* secreted from the blood by the *Brain*, is propelled by it along the nerves whenever the *Brain* is excited, to the *muscles*; where by its *influx* and *motion*, it excites them to action, or exertion.

9. The quantity of *Blood* sent to the muscles in any given time, is proportionate to the quantity of *nervous fluid* sent to them; and consequently

10. The quantity of *Pure Air* also sent to the muscles, is always proportionate to the quantity of *nervous fluid*.

11. The quantity of *heat* generated, is always proportionate to the degree of *muscular exertion*; that to the quantity of *nervous fluid* sent to the muscles;

muscles: and that again to the quantity of *pure air* sent to them.

12. The nervous fluid and pure air sent to the muscles, by exciting them *lose* all their distinguishing properties, and can be no longer found in their original forms; but

13. At the same time that the nervous fluid and pure are commixt in the blood, during muscular exertion, and *lost* as such, the quantity of *heat* in the blood is *increased*; therefore

14. The *Heat* generated by animals in consequence of muscular exertion, is formed, by a combination of the *nervous fluid*, with the *pure air* contained in the Blood; and consequently

15. The quantity of nervous fluid and pure air destroy'd as such, by their union, must produce a proportionate quantity of *heat*; therefore

16. The *heat* produced is always proportionate to the *muscular exertion*, by which the nervous fluid is supplied; and

17. The

17. The *action* of the heart is always proportionate to the *exertion* of the *other* muscles ; by which action a proportionate quantity of pure air, is supplied to unite with the nervous *fluid*, to form this heat ; and

18. The number of respirations, or degree of action of the muscles serving to move the *Lungs*, must bear the *same* proportion to the exertion of the other muscles, that *pure air* may be supplied to the Blood in the Lungs, as fast as it decomposed in the *muscles*.

19. The Heart is very *sensible* to the stimulus of *heat*, and its motion always bears a *proportion* to the *quantity* of it present in the system ; as well as to the degree of *muscular exertion* ; by which means, the quantity of heat sent *to*, and evaporated *from* the *surface*, is always proportionate to the quantity present in the *body*. And to these we may add the following observation, as the 20th.

20. That as the quantity of *nervous fluid* sent to the Heart, and muscles of respiration, is always proportionate

proportionate to the quantity sent to *all* the *other muscles*; and consequently *their actions* proportionate to the *exertion* or *excitement* of the *Brain*; 'tis evident, that the quantity of *pure arterial blood* sent to the *Brain*, to support its functions, and supply it with *materials* whereof to form the nervous fluid, is always proportionate to the quantity of *nervous fluid* sent from it, to support the animal functions of *every other part* of the *system*. For as the *Brain* always sends a quantity of *nervous fluid* to the heart, proportionate to the degree of excitement: the *heart* must always send to the brain a quantity of *arterial blood*, proportionate to that excitement, in consequence of its action being always proportionate to the excitement it receives.

And the quantity of *pure air* sent to the brain, must always be proportionate to the *excitement* of the brain, because the quantity of *arterial blood* is so; which arterial blood always contains a *certain proportion* of pure air; because the quantity of it exposed to the action of atmospheric air in the Lungs, is always proportionate to the quantity of pure air decomposed by the nervous fluid in the muscles; on account of the quantity of
energy,

energy, or nervous fluid, transmitted to the lungs to excite their action, by which pure air is absorbed, being *always proportionate* to the quantity sent to the other muscles, by which *that pure air* in the blood is decomposed, to form *animal heat*.

And now, having brought my subject to a conclusion, I can only add, that upon an impartial review, *each part* seems to be consistent with *every other*, and the *whole* with what *every one* may observe, *invariably* to take place within himself.

If I walk slowly along, for the space of one hundred yards upon even ground, my breathing and pulse are but little accelerated, and the heat of my body remains nearly the same as before. But if I walk at the *same speed*, up a *steep hill*, or bearing a *heavy burthen*, for the *same distance*, my breathing becomes *full and frequent*: my heart beats *strongly and quick*: and the quantity of heat thrown off from the surface of my body, is so *greatly increased*, that the perspirable fluid with which it unites and evaporates, cannot be taken up by the air in contact with my body,

so

so fast as it is thrown off; therefore it is condensed, and runs in streams down the surface.

What is the cause of this *difference*, when the *space*, the *speed*, and the *actual motion* of the muscles are the *same*? Certainly the *quantity* of *muscular exertion*, or *nervous energy* transmitted from the brain to the muscles in the *latter* case, where the body was *raised* on high, or where a *weight* was carried, being *much greater* than when the body was *only moved*, without being lifted up, or without any additional weight upon it.

For though the *motion* of the muscles was the *same* in both, yet the *increased weight* to be moved, required the *muscular power* or *exertion* to be much greater in the *latter* case than in the *former*; and that exertion was produced, by the *volition* or *determination* of the *Mind*, propelling a *greater quantity* of *Nervous Energy*, or fluid, from the brain to the muscles employed; therefore to the *increased quantity alone* of nervous fluid, transmitted from the brain to the muscles, to give them the necessary increase of power, are the *accelerated pulsations* and *respirations*, and *increased*

N production

production and evaporation of *heat*, to be attributed.

And indeed how could it be otherwise? The mind or brain *cannot* throw a *distant* muscle into action, without transmitting *some power, energy, or fluid* to it, to increase the attraction or approximation of its parts. This fluid of the Brain after exciting the muscles, being *something*, must pass *somewhere*, and have *some effects*; therefore it passes into the *blood*, where meeting with *pure air*, it forms *heat*. But, as the quantity of nervous fluid thrown into the blood, depends upon the degree of exertion of the muscles, it is necessary, that the quantity of pure air taken into the blood in the lungs, and the quantity of that blood propelled by the heart through the muscles, should *always* be *proportionate* to *that* quantity of *nervous fluid*, that it may be *saturated*, and form a proportionate quantity of *heat*; for which purpose, that *grand Law* of the Animal Œconomy was instituted, that the quantity of nervous fluid sent from the brain *to*, or degree of action excited in the *Heart* and *Lungs*, should always be proportionate to the quantity of nervous fluid sent

sent to, and degree of exertion of all the other muscles. And the *Heart* is also endowed with a *sensibility* to the action of *heat*, that it may transmit to the surface a quantity of *blood*, proportionate to the quantity of *heat* in the system, that the *redundant heat* may be thrown off, and the *body preserved* at its *natural temperature*.

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A P P E N D I X.

*In which the Chemical Effects, produced by the
Nervous Fluid uniting with Pure Air in the
Blood, are more particularly consider'd.*

IN consequence of what hath been advanced in the preceding parts of this treatise, I will suppose it granted me, that the nervous fluid determined to a muscle by the brain, produces a contraction of its fibres; and afterwards passing into the Blood contained in the muscle, and meeting there with the pure air absorb'd during the passage of the blood through the lungs, the phlogiston of the nervous fluid unites with some part of the pure air, and forms *that heat*, which is the immediate object of this enquiry.

In the *Introduction* to this dissertation, I gave a general explanation of what I suppose to be the Elemental Principles of Nature, and consequently of Chemistry. I mentioned *Æther* and *Phlogiston* as the two grand *active*, and an *Acid* and *Earth*

as the two *more passive* principles. Likewise, that the only immediate attractions, are 1st. between Æther and Phlogiston forming Light, Fire, or the Electric Fluid, according to the quantity of each entering the composition; or mode of their combination; 2^{ly}. between Æther and Acid, forming Pure Air,

3^{ly}. Phlogiston and Earth, forming metals, &c.

4^{ly}. between Acid and Earth, forming saline substances.

It was intimated also, that Æther was the grand, or general Cause of Elasticity and fluidity; and Phlogiston, of fixity and solidity.

If from these principles, a conjecture may be hazarded concerning the *composition* of the nervous fluid, I should suppose, that it contains Phlogiston with an *Earthy base*, but intimately combin'd with a certain proportion of Æther. — Its mobility and fluidity, point out the presence of Æther: its phlogistic nature hath been investigated already, partly from the materials of which it is form'd, and partly from the effects it produces;

duces; and as the quantity of phlogiston, which it must contain to produce the effects it does, must be very considerable, and most probably in much greater proportion than the *Æther*: and as it is different from Light, Fire, and Electricity, it must have some *base* to give it its degree of fixity; consequently, as Phlogiston hath an attraction to *Earth*, but none to Acid, it is most natural to suppose, that *this base* is an *Earth*. The *Earth* attracts the phlogiston, so as to give it a degree of fixity: while the Phlogiston having an affinity both with the *Earth* and *Æther*, hath its attraction so divided, that its intimate combination with either is prevented, and a certain degree of elasticity and fluidity is preserved.

The nervous fluid secreted from the blood by the brain, then is supplied with Phlogiston and *Earth*, by the aliments taken in as food; and it seems to acquire its *Æther* from the blood; a great quantity of *which* is sent to the Brain by the heart, immediately after it hath been impregnated with pure air, (containing *Æther*) in the Lungs. And the quantity of blood carried by the carotid-arteries to the Brain, saturated with pure air, and returned by the Jugular Veins, deprived
of

of it, altho' there is no great muscular exertion carried on there, seems to confirm the idea.

These conjectures, making the principles of which the nervous fluid is composed, the *same* as those forming Light, Fire, and the Electric fluid, *excepting* the small quantity of *Earth* contained in the nervous fluid, seem to acquire a degree of probability from considering the *Torpedo*, which hath the power of giving a *shock*, *similar* to that of Electricity, by the nervous fluid transmitted in consequence of volition. But in the *Torpedo*, the nervous fluid seems to contain a *greater* proportion of *Æther*, than of Phlogiston; and if so, perhaps the base is Acid, or the mode of combination between the *Æther* and Phlogiston, is somehow different from what it is in other animals, not possess of that peculiar property, or power.

Supposing therefore that the *nervous fluid* consists of an *Earth*, united to much Phlogiston, along with a certain *smaller* quantity of *Æther*; the next thing to be consider'd, is the effects that must ensue, from its *meeting* with the *pure air* in the blood.

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The nervous fluid then consists chiefly of an Earth and Phlogiston; the pure air of an Acid and Æther; consequently a double attraction and decomposition must take place, and two new compounds arise; for the Earth of the nervous fluid, will unite with the Acid of the Air: while the Æther of the Air combining with the Phlogiston of the nervous fluid, will form heat.

But the quantity of the phlogiston contained in the nervous fluid, being in an *over proportion*; the æther of the pure air combines with a *sufficient* quantity of it, to form heat, and leaves its acid disengaged; while the *redundant* part of the phlogiston, remains still united with the earthy base of the nervous fluid. This phlogisticated Earth therefore, will combine with the disengaged acid of the pure air, in a certain proportion, and take along with it a part of the Æther, with which it was originally combined, and form *Volatile Alkali*. This volatile alkali therefore is produced, from the intimate union of the *Earth, Phlogiston, and Æther* of the nervous fluid, with as much of the disengaged *Acid* base of the pure air, as the Earth and Æther could attract; their quantity of attraction being necessarily diminished

by the portion of phlogiston already combined with them.

The whole of the nervous fluid therefore is now disposed of: part of its phlogiston forming heat, with the æther of the pure air; and the other part of the phlogiston remaining united with the Earthy base, and Æther entering into its original composition, combining with so much of the disengaged acid of the pure air, as they can *intimately* unite with. For the Earth and Æther of the nervous fluid, being deprived of a great part of their phlogiston by the formation of heat, will eagerly attract any thing they can meet with of a phlogistic, or acid nature, to supply its place; meeting therefore with the disengaged acid of the pure air, to which both the Æther and Earth have so strong an affinity, they seize upon it, and saturate themselves with so much as they can take into an intimate combination; and this compound, is distinguished by the name of *Volatile Alkali*.

We have then volatile alkali, and the remaining part of the disengaged acid, left. But, tho' the Earth and Æther, could not *intimately* combine

bine with a greater quantity of Acid, yet in this compound state, they retain a *less* intimate degree of attraction for it; and although that degree is far less, than what they have for that portion of Acid essential to the existence of the compound, yet it is *greater* than for most other substances; therefore, this alkali and acid will unite and form an *Ammoniacal salt*.

But, from the circumstances to which this acid is exposed, during its separation from the *Æther* with which it was combined, and to which it hath so strong an attraction, a small portion of *Æther* is retained; and perhaps by means of that *Æther*, a minute portion of *Phlogiston* also; and and these small additions, are sufficient to give it properties *different* from those of pure acid, and of every acid produced under different circumstances, and consequently retaining these additional principles in different quantities and proportions; therefore this Acid thus produced, is of a *peculiar* nature; and is known to Chemists, by the name of *Phosphoric Acid*; and consequently, the neutral formed by its union with the Volatile Alkali, will be a *Phosphoric ammoniac*.

But,

But, whether the base of the nervous fluid be an Earth or not, I am fully convinced in my own mind, that volatile alkali is composed of those principles, which I have hinted at; and likewise, that it is generated, or produced, by the mixture of the nervous fluid with pure air, in the blood, in consequence of muscular exertion. If therefore, the Earth be not supplied by the nervous fluid, the residuum of the phlogiston of the nervous fluid (after saturating the Æther of the pure air, and passing off in the form of heat,) meets with *this Earth* in the blood, and superphlogisticates it; and in that state enters into an intimate union, with so much of the disengaged Acid of the pure air, as enables it to take the form of Volatile Alkali. But from what hath been said, and from other considerations, not immediately connected with my present subject, therefore not mentioned, I am inclined to adopt the *former* opinion, that the Earth is supplied by the *nervous fluid*.

'Tis likewise not very material at present, to determine whether the portion of Æther necessary to form Volatile Alkali, be supplied by *that* entering into the original composition of the nervous

nervous fluid, and perhaps still combined with the earth and remaining phlogiston; or by a small quantity, obstinately retained by the acid of the Pure Air, to which it has so great an affinity, as not to be easily instantly separated; or by both.

This opinion, concerning the nature and composition of Volatile Alkali, and its production by the Animal process, seems to be confirmed by the Chemical productions of it. For when a quantity of Earth, hath an opportunity of combining with a *large* proportion of Phlogiston, with the interposition of a *small* portion of Acid, and Æther, the result is volatile alkali; for instance, Dr. Priestley * found, that Iron exposed to Nitrous Air, gave evident signs of the production of Volatile Alkali. In this case the Iron furnishes Earth, and a quantity of Phlogiston; while the Nitrous Air, consisting of Acid, Æther, and Phlogiston, gives the proper quantity of Acid and Æther, and supplies a sufficient quantity of Phlogiston,

* Priestley's Experiments and Observations. Vol. 3. p. 203.

giston, to complete the proportions, and form Volatile Alkali, or Alkaline Air.

From this account of the composition of Volatile Alkali and Alkaline Air, it appears that this Air is formed of the *same* principles, nearly in the *same* proportions and mode of combination, as Inflammable Air is; for in the Introduction p. 26, Inflammable Air is said to consist chiefly of an Earthy base, united to much Phlogiston, with a certain proportion of Æther to give it Elasticity, and perhaps a small portion of Acid. And I am of opinion that both accounts are just, and perhaps the chief difference between the two Airs is, that Alkaline Air, or volatile alkali in the form of Air, contains a greater proportion of Earth, and more Æther, than inflammable Air does. And this opinion, of the *similarity* of the principles and mode of combination of these two Airs, explain, and are greatly confirmed by Dr. Priestley's experiments, * when by means of the Electric spark, or by heating bits of dry crucibles &c. in it, Alkaline Air was expanded to

twice

* Experiments and Observations, Vol. 3. p. 197.

twice or thrice its original bulk, and become inflammable Air; for both by the action of the Electric fluid, and heat, its component principles were to a certain degree separated, and the Earth had an opportunity of acquiring more phlogiston; but that phlogiston being attracted by the Æther, as well as the Earth of the Alkaline Air, could not intimately combine with either; therefore, the phlogiston divided its attraction between the two; and the Earth and Æther having no affinity, were *by it separated* from each other; consequently the *bulk* of the air must have been increased, and that acquisition of *Phlogiston* rendered the whole Inflammable; the proportions of the principles, being then the same as in Inflammable Air; unless there might have been some *little* difference, in the proportions of the Acid principle, contained in the two airs.

A general *Chemical* View of the *whole*, therefore may be given in a few words.

The nervous fluid is composed of an *Earth*, united with *much Phlogiston*, and a quantity of
Æther,

Æther, sufficient to give the due degree of Elasticity and mobility.

The pure air contained in the blood, consists of *Æther* and the *Acid Principle*.

When a muscle is excited, a quantity of the nervous fluid passes along its fibres, and is afterwards received into the blood supplied from the heart, and contained in the arteries of that muscle; which blood is saturated, with the pure air imbib'd during its passage through the lungs.

A quantity of this phlogiston of the nervous fluid, unites with the *Æther* of the Pure Air, sufficient to saturate it, and form that heat, which is called *Animal heat*: and the acid now disengaged, still retains a small portion of *Æther*, and perhaps acquires a small quantity of Phlogiston, by which it becomes possess'd of peculiar properties, different from pure acid, and from every other Acid, produced under different circumstances, and containing *Æther* and Phlogiston in different proportions; and to this peculiar acid, Chemists give the name of *Phosphoric Acid*.

At the same time, the *Earth* of the nervous fluid being deprived of a great part of its phlogiston, but still retaining a considerable proportion, with all or part of the *Æther* entering into its original composition, acquires new properties; and the attraction it exerted upon the phlogiston, now taken from it, is transferred to a portion of the disengaged *acid* of the pure air; with which it forms an intimate union, and acquires those peculiar properties, which are distinguished by the name of *Volatile Alkali*.

This Volatile Alkali, formed by the intimate union of Earth and Phlogiston, with a small proportion of *Æther* and Acid; as a *compound* hath still a general attraction to the Acid: with which it now unites, and forms a salt, distinguished by the name of *Phosphoric Ammoniac*.

Thus I account for the production of *Heat*, *Phosphoric Acid*, and *Volatile Alkali*, by the *Animal Process*. Many other little circumstances may arise, during this combination of the nervous fluid with pure air, which may give origin to *other* productions at the same time; but those

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being of lesser moment, at this time are passed over unnoticed; my present intention being, only to give a *general view*, of the principles I have been led to adopt, and their application to the explanation, of the *more evident* productions of the Animal System.

F I N I S.

E R R A T A.

- Page 16, bottom line read confusedly.
— 17, line 2, dele . after principles.
— 39, line 3, from the bottom read 5ly.
— 43, l. 8, dele of the
— 58, l. 13, read scene.
— 93, l. 9, after pure, add Air.
— 95, l. 12, after heart for . put ,
— 103, l. 6, for Electricity, read the Electric fluid.
— 109, l. 6, dele instantly.

A. T. A. T. A. T. A.

- Page 16. Bottom line read carefully.
- 17. Line 2. Note. After principles.
- 18. Line 3. From the bottom read 24.
- 19. Line 4. Note of this.
- 20. Line 5. Read 100.
- 21. Line 6. After 100, add 10.
- 22. Line 7. After 100, add 10.
- 23. Line 8. After 100, add 10.
- 24. Line 9. After 100, add 10.
- 25. Line 10. After 100, add 10.