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Inaugural Experimental Dissertation,

BEING

AN ENDEAVOUR TO ASCERTAIN

THE

MORBID EFFECTS OF CARBONIC
ACID GAS, OR FIXED AIR,

ON

HEALTHY ANIMALS,

AND THE

Manner in which they are produced;

WHICH, UNDER THE DIRECTION OF

THE REV. JOHN EWING, D.D.

PROVOST OF THE UNIVERSITY OF PENNSYLVANIA,

BY

THE AUTHORITY OF THE BOARD OF TRUSTEES, AND
WITH THE APPROBATION OF THE FACULTY,

IS SUBMITTED TO

THE CANDID EXAMINATION OF THE LEARNED;

19th DAY OF MAY, 1794;

For the Degree of Doctor in Medicine.

BY WILLIAM BACHE, A. M. OF PHILADELPHIA,
HONORARY MEMBER AND ANNUAL PRESIDENT OF THE PHILADEL-
PHIA CHEMICAL SOCIETY, AND HONORARY MEMBER OF THE
AMERICAN AND PHILADELPHIA MEDICAL SOCIETIES.

“ Audite o mentibus æquis
“ ——— neve hæc nostris spectentur ab annis
“ Quæ ferimus.

Virgil.

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M,DCC,XCIV.

To
Dr James Woodhouse

with the respects of,

The Author.

TO

THE MEMORY OF

Andrew Adgate, Daniel Offley, and
Jonathan D. Serjeant, Joseph Infkeep.

ALSO, TO

Matthew Clarkfon,	James Sharwood,
Caleb Lownes,	John Haworth,
Thomas Wistar,	James Swaine,
Stephen Girard,	Matthew Carey,
Peter Helm,	Thomas Savery,
Israel Israel,	Jacob Whitman,
John Letchworth,	Henry De Forest,
Samuel Benge,	And
James Kerr,	John Connelly;—

THE *Philanthropic Committee* appointed by
Humanity to mitigate the sufferings of their fel-
low citizens in the hour of calamity ;

In Testimony of gratitude,

As a citizen of Philadelphia,

This *Dissertation* is inscribed,

BY THE AUTHOR.

TO

JONATHAN MEREDITH,

OF PHILADELPHIA.

*P*ERMIT me, Sir, thus publicly to acknowledge the many acts of friendship for which I am indebted to you, and which were conferred through that benevolence which has always designated itself in your disposition, whether as a Father; Brother, or Friend.

Believe me to be,

With the sincerest Esteem,

Your Obligated Friend,

WILLIAM BACHE.

INTRODUCTION.

PROBATIONARY Theses have long since been the established heralds to medical honors, these appendages to a medical education, whether the vehicles for discoveries, or dull repetitions of former knowledge, are too often regarded as just and certain criteria of the graduate's merit, the circumstances attending their production seldom being known, and never considered.

NOTWITHSTANDING the disadvantages under which the unexperienced student labors, ambition would lead him to attempt the investigation of some novel subject, did

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not the enervating dictates of fear or false shame coldly point out a beaten track and lay before him the dangerous consequences of aspiring too much, lest a failure in the endeavour should inevitably draw down upon his undefended head, the just though piercing shafts of criticism. In this dilemma he finds a difficulty in proceeding. The imputation of rashness on the one hand, sternly knits its threatening brow; whilst, on the other, foul repetition casts a galling sneer and chills him to the soul. The dangers of the former may possibly be avoided; but those of the latter are inevitable.

WITH these impressions, I have chosen for the following dissertation, a subject, which has not hitherto met with a thorough investigation, and which is of the utmost importance not only to the medical character, but to men of humanity in general.

THE existence of *noxious vapours*, disengaged from various substances has been long since known, but it was left for the united labors of a Black, a Priestley, and a Lavoisier, to

to ascertain their chemical properties, by their truly ingenious and interesting experiments.

ONE of these, *carbonic acid gas*, in various forms, has oftentimes proven destructive to man as well as other animals; and, it has long been problematical amongst physiologists whether this gas produced its morbid effects, by any *inherent positive action*, or whether it acted only negatively and brought on death, *mechanically*, by excluding respirable air.

SOME recent physiologists, particularly Goodwyn and Coleman, have imagined, that the suspension of vital action, from the noxious effects of the different gaseous fluids, was to be attributed to the same cause as that produced by submerfion in water. The extreme plausibility of Dr Goodwyn's doctrine concerning the operation of fixed air,* appears to be sufficient testimony against its possessing,

* Dr Goodwyn, page 66, asserts that fixed air may be breathed in considerable quantities, provided it is mixed with atmospheric air.

possessing, virtually, any deleterious properties, and the abstract reasoning adduced by Coleman,* tends directly to establish, that it can exert none, immediately on those organs, even did it possess any.

THE contradictory opinions of these two eminent physiologists, relative to the immediate cause of death from drowning, and submersion in noxious airs, was an additional inducement for me to pursue the subject, directing my endeavours, more especially to those points, to which they had bent the least attention, and prompting me to follow up the investigation, as little connected as possible with the hypothesis of either, differing from each only where thorough conviction has rendered it absolutely necessary.

WHATEVER may be the fact, the knowledge of the action of this aëriform fluid, necessarily involves much practical good. If it is established that its operation is purely negative, then it is obvious, that our principal

* See his introduction, page 13, &c.

principal exertions should be immediately directed to the most speedy and effectual means of conveying the sufferer from its influence; but if on the contrary, it is uncontroversibly decided, that its action is positive and direct, not only the indication necessary in the former case, but those remedies which promise most fairly to counteract effectually its letheferous effects, will be loudly called for.

I AM happy, that, in the course of the following enquiry, facts have so opened upon me, as to induce an entire revolution in my sentiments respecting this action, inasmuch as it precludes the least grounds of the imputation, that I have been biased by preconceived hypotheses, and therefore, have viewed the subject only with a jaundiced eye; and here I coincide in opinion with a celebrated professor, who is remarkable for his numerous and willing sacrifices of prejudice to the unerring dictates of truth and reason.

THE disagreeable necessity of inflicting death on so many animals, at first rendered the subject extremely irksome; but when I reflected

reflected that these immolations were absolutely necessary to a thorough investigation, and that myriads were daily slaughtered, not only to satisfy the rapacious demands of nature, but to delight the pampered appetite of the epicure, I was induced to suppress those feelings, as I was not prompted by idle curiosity, but was sacrificing at the shrine of humanity.

S E C -

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*What are the effects of submersion in carbonic
 acid gas on animal life?*

IN every investigation, and more espe-
 cially in experimental researches, that method
 is to be adopted which will comprehend pri-
 marily the most obvious traits of the subject,
 leaving the more intricate and less established
 facts, for subsequent consideration.

THE most prominent features of the pre-
 sent inquiry are, the state of the animal, vi-
 tal, and natural functions during the time of
 submersion in carbonic acid gas, the appear-
 ances of the body after death, upon dissec-
 tion, and the manner in which the gas must
 be applied to produce these phænomena.

1. *The appearances during the life of the animal.*

WHEN first the animal is immersed in fixed air, he makes forcible exertions to relieve himself, but almost immediately becomes apparently stupid, and so much under the effects of debility, that he lays down as if asleep, or rather in an apoplectic fit; all voluntary motion is then greatly diminished and disordered, and sensation is so far impaired, that the animal will patiently suffer to be pinched without appearing to feel any uneasiness*, and the natural heat of the body is somewhat increased† and continues so for a

* This is further evinced from an accident which is related, to have happened to L'Abbé Briquet de Lavaux, by M. Banau, M. D. In transporting him from the place infected with the vapours of charcoal he says, "Ce transport se fit avec tant de précipitation, que nous poussâmes violemment M. L'Abbé Briquet contre une porte vitrée: un carreau de vitre qui en fut cassé, fit deux profondes blessures que notre suffoqué ne sentit point, ce qui prouve qu'en pareil cas on ne doit point regarder l'insensibilité comme un signe de mort," as he recovered. Journ. de Ros. an. 1774, vol. 2. p. 464.

† Portal observes,—"Les corps des personnes suffoquées par des vapeurs mephitiques conservent long-temps leur

short time. The pulsations of the crural artery of a dog are not to be felt before submersion, without particular attention, but when the respiration becomes affected, the pulse suffers a considerable change. Slight convulsions succeed over the whole body, and particularly about the sphincter ani. Sometimes a vomiting occurs; but more frequently a copious discharge of urine and fæces. A short time, however, before these occurrences, the respiration from being carried on without much labour, is considerably accelerated, and becomes so difficult, at last, that the muscles of the abdomen and thorax take on a violent action, when the mouth, together with the nostrils, become distended.

WITH this affection of the respiration, the state of the pulse as has been already hinted at
 experiences

“leur chaleur; elle est même quelques fois plus forte immédiatement après la mort que pendant la vie et que dans la parfaite santé — mais nous en sommes convaincus principalement dans quatre personnes mortes suffoquées, trois par la vapeur du charbon et la quatrième par la vapeur du vin qui fermentoit.”

experiences a considerable revolution. From being nearly natural, and scarcely to be discerned, it is now plainly to be felt and becomes tense and violent, and, as the respiration advances to its achme, the pulse increases in strength and impetuosity. This state of the pulse is happily described, by M. Troja, in the following words; “ A mesure que la respiration devoit encore plus forte et plus genée, les pulsations devenoient aussi plus impetueuses; il sembloit que ce fut une injection de mercure poussée avec la plus grande force*.”

SHORTLY before death the respiration suffers another change; whilst it becomes still more difficult, its frequency, as well as fullness, suffers a considerable diminution, the intervals between the inspirations becoming great, and the quickness much augmented; at this time, upon the whole, each inspiration appears more like a convulsive motion, than a natural effort to draw in air. The pulse gradually becomes weaker, and very intermittent,

* See his essay on fixed air, in *Observations sur la Physique, &c.* par M. L'Abbé Rosier, vol. 1. 1778.

intermittent, and during the short period of each inspiration its oscillations are very frequent; but when the state of expiration has commenced they are more slow and feeble. The air now enters the lungs in smaller quantities during every exertion to inspire, which diminish gradually in their force; partial shiverings of the limbs supervene; the tongue of the animal is generally protruded, the pulsation of the artery fails entirely, the heart vibrates, or rather appears to thrill feebly; its action ceases and the animal expires almost instantaneously.

It is extremely difficult to ascertain, a priori, the time that an animal will exist in carbonic acid gas, and I believe that there is no subject in physiology so undeterminate, as variations in the results may arise from four causes.

1^{stly}, FROM the age of the animal. Young animals are supposed to resist the baneful influence of carbonic acid gas, longer than adults.

* See his essay on fixed air, in Observations sur la Physique, par M. l'Abbé Robier, vol. 1. p. 178.

2dly, From the species. Insects and cold blooded animals are said to live longer than quadrupeds, and these longer than birds*.

3dly, From the different degree of irritability in the same species of animal, of the same age.

4thly, FROM the different degrees in the purity of the air, as to the adventitious mixture of various gases and effluviæ †.

THE visage and neck of animals perishing in fixed air is much swollen, and the faces of men who were affected with the same gas are said to be livid †. The body remains pliant for some time after death, but at length becomes rigid, the limbs remaining stiff.

2. Phæ-

* There are however a variety of opinions on this subject. See Portal, Troja—Journal de Rosier.

† As the detail of symptoms related above may appear strange to those who have only observed the sudden effects of pure carbonic gas, it is necessary to observe, that the experiments from which they are adduced were performed in gas of various purity, and seldom without some proportion of vital air.

‡ See Portal.

2. *Phænomena on Dissection.*

UPON opening the thorax, the heart presented itself so distended with blood as entirely to fill up the whole cavity of the pericardium. The right auricle, ventricle, and both the cavæ, together with the pulmonary arteries, were completely distended with blood. The left auricle, ventricle, and pulmonary veins, not so much distended with blood as the right, but never more than half empty. The aorta generally void of blood, or, at most, containing a very slender portion of that fluid*.

THE lungs always appeared covered, more or less with livid blotches †, occasioned, I imagine by the extravasation of blood, as they became perfectly florid, and nearly the colour of arterial blood, after the lungs had been repeatedly inflated ‡.

ON

* In frogs, the heart was generally found entirely empty when the animal was completely dead.

† Troja and Haller mention the same appearances.

‡ Is there any circumstance in the mechanism of the lungs, adapted to accelerate the union of vital air with the blood?

See Portal

ON opening the abdomen, the liver and spleen were found distended with blood; upon the liver, in two cases, I observed a few spots; whilst the spleen was covered with many, particularly around the edges. The cava descendens, the veins of the intestines, and kidneys appeared as if they had been injected.

IN those cases in which I opened the cranium, the brain exhibited no remarkable appearances of a diseased state. The venous sinuses were somewhat distended with blood, the veins of the brain, little more distended than natural, and the arteries nearly empty. The ventricles of the brain were either found empty, or contained but a very small quantity of lymph. The blood found in the different cavities of the body and
vessels

blood? I imagine this to be the fact, for I have repeatedly observed that the black blood in the lungs of those animals which have been destroyed by carbonic acid gas, became florid much more rapidly than that which was poured out into the thorax, by the rupture of the pulmonary vessels, &c. in detaching the lungs from the heart, though it was equally exposed to the action of the atmospheric air.

vessels of the brain was uniformly of a darker colour than natural.

IN what manner must carbonic acid gas be applied to the body, to produce its baneful effects?

DOES it cause suspension of vital action, and lastly death, by its operation on the external surface of the body?

DOES it affect the glottis so as to obstruct inspiration?

OR does it enter the cavity of the lungs themselves, and by that means, produce its deleterious effects?

THE following experiment related by Dr Wistar in his anatomical lectures, proves that its operation upon the external surface of the body merely is not sufficient to account for the phænomena.

A CURVED tube was applied, to the trachea arteria of an animal, into which an in-

fusion

cision had been made ; so that no air could pass into the lungs but through its medium. The animal was then immersed in a vessel containing carbonic acid gas ; it remained in this situation for some time, with very little inconvenience, whilst the bore of the tube communicated freely with the open air ; but when the experiment was reversed, and the opening of the tube plunged into a vessel containing fixed air, the animal shortly expired*.

THIS point being determined we are next to enquire into the manner of its application to the organs of respiration.

COLEMAN,

* I repeated this experiment on a pigeon, by securing a silver tube in the trachea, and immersing the body and head under an atmosphere of fixed air, whilst the canula communicated with the atmosphere. It remained in this situation twelve minutes, its respiration was not affected more than before immersion, but it shewed some signs of irritation and uneasiness from the action of the air upon the schneiderian membrane, to which it had access. After this, I reversed the experiment, by removing the body and head from the fixed air and immersing the end of the tube into a vessel containing that gas, the animal immediately expired.

COLEMAN, as has been before observed, is of opinion, that its true mode of action is by irritating the glottis to such a degree as to cause a constriction, which is so great as to impede the entrance of the external air, whilst that which remains in the lungs from the last inspiration may be forced out, causing a collapse of those organs, totally impeding the circulation of blood through them. Not aware, however, that the same objections, which he has so lavishly offered to others, may with great propriety be applied to himself, he has attempted to explain, and account for the operation of noxious airs in general agreeably to his theory of collapse. In objecting to the hypothesis of others, on this subject, as not being supported by "*argument, experiment, or analogy,*" he has entirely forgotten that his arguments, experiments and analogies are not fraught with more satisfaction on the subject than those of his antagonists*.

INGENIOUS, however, as the speculations of all parties may appear, still an experiment

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was

* See Coleman, p. 19, &c.

was wanting to determine the fact, whether carbonic acid gas entered the lungs or not. It appeared to me probable, that if a tube could be so applied to the head of an animal, as to admit thro' its bore, a free passage of air which might be contained under a receiver, entirely excluding the entrance of any external air, the wished-for end would be obtained.

By repeated ligatures I fixed a curved tube to the end of a bladder, opposite to the neck, and made a perforation in it over the bore of the tube sufficiently large to admit a free passage of air through it. I then enlarged the neck of the bladder that it might pass easily over the head of a dog, and with a drawing string secured it round the neck. I then passed a broad strip of linen several times round this end of the bladder, sufficiently tight to obstruct the passage of the external air between the bladder and the neck, taking care to impede the circulation in the neck as little as possible. To be convinced that the ligatures alone would not cause immediate death, and thereby frustrate the intention of
the

the experiment, I suffered him to remain in this situation some time, and observed little inconvenience but what might be expected to arise from breathing through so small an aperture as the bore of the tube.

HAVING taken these precautions, I proceeded to introduce the disengaged extremity of the syphon under a receiver containing a quantity of fixed air, and could observe by the rising and falling of the water in the receiver, that the animal breathed; he died in six minutes, the carbonic acid gas being mixed with a portion of oxygenous gas.*

I ALSO invariably observed a motion of the thorax and muscles of the abdomen in every quadruped that was exposed to the fixed air. Thus it appears, that fixed air does enter the lungs, and that its sphere of action, if not confined to, is solely directed through, the medium of their cavity. †

* I repeated this experiment with pure carbonic acid gas, and found that the animal breathed it equally as in this instance.

† I also observed that expansion and contraction took place in the lungs of frogs, when exposed both to the atmospheric,

THE particular mode of operation will be the subject of the subsequent section.

SECTION II.

Whether does carbonic acid gas produce its effects, indirectly by mechanically excluding atmospheric air from the lungs, or directly by an inherent operation in those organs?

THIS very interesting part of our enquiry is by far the most intricate, as it has hitherto been but little attended to by authors; who have merely contented themselves, as it were, with half proofs and analogies, throwing but little light upon the subject through the unerring channel of experiment.

VARIOUS doctrines have been advanced at different periods to explain the phenomena produced by noxious airs, corresponding generally

atmospheric, as well as carbonic acid air, whose abdomen and thorax were laid open by a crucial incision.

generally with the then existing state of chemical knowledge, and have fluctuated continually with the rapid advances made in the speculative branch of that science.

WHILST, in the earlier ages of chemical researches, it was the opinion of many that carbonic acid air proved deleterious from a defect of an elasticity,* which was supposed to be the only necessary quality in air for the process of respiration; others on the contrary imagined, that the same effects were produced by an excessive degree of that elasticity.† The former idea was soon proven to be erroneous, inasmuch as it was found that fixed air was as capable of filling up space, and as subject to the laws of expansion as any one of the elastic æriform fluids, and the latter hypothesis was rejected when the nature of gaseous fluids became better to be understood.

THESE opinions were shortly succeeded by the idea that death or suspended vital
action

* See Hale's Vegetable Statics, p. 260—1.

† See Fontana on Poisons, Vol. I. p. 90. Morgagni, Epist. 19. art 39. Portal. Journ. de Rosier.

action was induced by suffocation. Hoffman expresses himself to this end in the following forcible terms.* “ Eadem enim horum operandi ratio est, ac si asperam arteriam suffringas; nam utroque horum aëris sufficiens introitus impeditur.”† Morgagni considers also the operation of noxious vapors to be similar to suffocation, which he imagines produces death by causing a cessation of the due circulation in the lungs.‡ This idea has been since modified, and it has been imagined that all the morbid effects were

* Hoffman, Tom. 4. and as quoted by Percival, p. 99.

† Hoffman appears to have had various sentiments on the subject, as may be observed by comparing the following passage with that above quoted. “ Vapor igitur tam tenuis et subtilis, in aërem evehctus ibique conclusus utique medianti inspiratione per nares in caput, et per asperam arteriam admissus in pulmones, propter summam suam tenuitatem partium solidarum vasorumque poris sese interne insinuat, inque minimos nervorum, cerebræ et meningum poros penetrat; ubi illud fluidum subtilissimum, quod sensibus et motibus præest; inquinando actiones sic dictas animales subito perturbare atque invertere valet. Accedit, quod aër etiam, copia horum vaporum imbutus, de vi sua elastica expansiva in expandendis vasis et vesiculis pulmonalibus multum amittat.” Hof. Tom. 4.

‡ Morgagni, Epist. 19. art 39.

were produced by an irritation on the nerves of the bronchiæ, and an universal constriction of the air-vessels of the lungs themselves*.

SINCE that time from the analogy between some of the effects of carbonic acid gas on the nervous system, and the operation of certain stimuli on that system, it was held by some† that carbonic acid gas, entering the lungs in large quantities, by its excessive stimulating power, acted primarily upon the brain and nervous system, destroying thereby the action of the moving powers, and with them all vital motion; and by others, that this same stimulant power produced its morbid effects by immediately destroying the irritability of the heart, being analogous in its operation to electricity ‡.

WHEN by the labours of Priestley the doctrine of airs began to evolve her variegated wings, from the clouds of obscurity by which it

* Fontana on Poisons, vol. I. p. 95.

† Percival's Essays, p. 101.

‡ Fontana on Poisons, vol. I. p. 96.

it had been enveloped for ages, these opinions were rejected by some chemical physiologists, and as it was imagined by them, that the efficient cause of respiration was to disengage phlogistic vapours from the lungs, and that respirable air as having an affinity for them, was by that means fitted for that function, so they explained the action of carbonic acid gas on the lungs according to this theory, and taught that by permitting the accumulation of these vapours in the lungs it was negatively noxious*.

IN the year 1788 two writers †, of distinguished talents for physiological investigation entered the lists, and endeavoured to account for the phænomena produced by noxious gases, according to preconceived hypotheses on the subject of submersion. ‡ One taking it for granted that apoplexy was the cause of death in drowning, from analogy supposed the same to be the case here; and § the other pursuing the same train of reasoning advanced

as

* Priestley.

† Kite and Godwyn.

‡ Kite.

§ Godwyn.

as a principle, that fixed air acted only mechanically by excluding vital air, and not by any inherent letheferous quality.

IN opposition to these last hypotheses in particular, the doctrine of collapse was with some amendments, answering to the improvements in scientific knowledge, again revived* by an ingenious physiologist, and sustained by various new supports; of this doctrine as far as it relates to the present subject, we have already given our sentiments in the last section.

WE have thus collected the sentiments of various authors, not with the most distant idea of entering into a minute detail of the merits of each, but that we might have in one point of view, the different sentiments which have been suggested within the present century, that they might collectively be compared with that which we shall hereafter advance.

IT now remains more especially to proceed with the most important point in this section,

* Coleman.

fection, *viz.* Whether carbonic acid gas acts mechanically on the lungs by excluding vital air, or whether it possesses an inherent power over the animal œconomy.

As it has been generally observed by authors* that insects live longer in noxious airs than

* See Troja, Journ. de Rosier, vol. 5. an. 1778. The result of his experiments are different from mine, and most probably not without an evident cause. They point out that flies and other insects live longer in the fumes of charcoal than cold blooded animals, but it will be found that the reverse took place with me, for the frogs on which I tried them struggled under the operation of carbonic acid air between ten and fifteen minutes, which is at a medium twenty-five times longer than the flies; however an allowance must be made for the difference in the strength of the air made use of in the experiments of Troja, and that which I used in prosecuting this enquiry; Troja exposed his animals to the vapors of charcoal, obtained in a very imperfect manner, whereas pure carbonic acid, which was obtained from powdered marble, by means of the vitriolic acid, was the medium in which I operated.

The season of the year most probably had the greatest effect in influencing the results of the experiments which I have related, as they were made on the frogs immediately at the time of hybernation, and upon the flies soon after their migration from that state.

This

than any other class of animals; I shall first begin by observing the effects of carbonic acid gas upon them.

This is most probably the case, for it is to be remarked that plants in autumn are in a state of exhaustion, during the winter season, from the languid action of the different organs, the vital actions appear to be suspended: The natural consequence of the suspended action of all these stimuli, as well as that of heat, is the accumulation of irritability or mobility in the plant. When spring flow returning with its genial warmth, it proves salutary to the vegetable kingdom, but if instead of the gradual application of heat, suited to the state of accumulation in the plant, the solar influence is suddenly increased, violent effects always supersede, and the fruits, if not the plant itself, are destroyed inevitably. The same progress may be traced in the animal kingdom. In hibernating animals the effects of the summer heat, and the continual exercise of the various organs during that season, are analogous to those in plants. In the autumn, the capacity of the muscular system for irritability is diminished, by the gradual operation of the stimuli above mentioned, and during the time of hibernation the vital powers appear to be suspended. During this time the operation of stimuli being remote, the irritability consequently suffers an accumulation, and on the return of spring the animal is awakened to new and vigorous action, when all stimulating powers, having a greater field of action, will operate with increased violence. This idea receives additional support from the observations of M. Fontana, who relates, that during the
winter

UNDER a receiver filled with fixed air, obtained from powdered marble and the vitriolic acid diluted with water, I introduced several flies. Immediately upon their first entrance they struggled, but in a few seconds their limbs were affected with tremors and contracted, and they all became motionless in the space of forty seconds, and some in less than thirty. I then removed them from under the receiver, and without paying much regard to them, after I had subjected them to strict scrutiny, to observe if any visible signs of motion or life remained, I threw them into a vessel containing the water by means of which the air had been collected and retained in the receiver.

RETURNING

winter season, vipers which he had kept for his experiments, remained in a torpid state, though the thermometer was at 59° , and when he endeavoured to render them vigorous by warmth, and exposed them to a heat of 67 degrees only, in two minutes they sunk under its stimulating influence, though in summer after the irritability had suffered a gradual diminution, by a slow and steady increase of heat, and the continued action of the vital organs, they can withstand its operation to a much greater degree.

RETURNING to the vessel in the space of an hour, to repeat the same experiment with fresh caught flies, I observed some of those which I had before thrown in, so far recovered as to swim about the surface of the water, many of them, however, did not experience the same salutary effects although they had been exposed no longer to the air, and had been subjected to the same treatment with those which recovered. Upon comparing the results of many experiments made at that time, I found that flies continued to show symptoms of life when immersed in carbonic acid gas, from between twenty five to forty seconds. It may be well to mention in this place, an extraordinary change of colour which took place in the eyes of many flies, the subjects of these experiments; I was first struck with a beautiful redness of the eyes of a fly which had perished in carbonic acid gas, but could not positively determine whether it was caused by the air or was natural; after this, however, I repeatedly examined their eyes, previous to immersion, and generally found them of a dark mahogany colour, and several times this red or rather co-
 quelicot

quelicot appearance of the eyes took place after submerſion in the acid gas, though if the animal recovered, it very ſoon diſappeared, and upon a ſecond immerſion, this red colour was not ſo ſtrongly marked.

WHENCE did this alteration in colour originate?

DID the weakneſs of the coquelicot colour ariſing from a ſecond application of the carbonic acid gas, proceed from the effects of habit?

WISHING to try if effects, ſimilar to thoſe already enumerated, would be produced by merely excluding vital air from the lungs, I immerſed, at the ſame time many flies under an inverted receiver completely filled with water,* thereby cutting off all means of acceſs to the external air, and found that far from dying in ſo ſhort a time as thoſe expoſed to fixed air, they continued to move
from

* Flies immerſed under a receiver, containing inflammable air, lived generally as long as thoſe immerſed in water.

from between fifteen to twenty minutes.* By these comparative experiments, it is evident that the mere exclusion of atmospheric air, is not sufficient of itself to produce the violent and sudden effects which are the result of submerfion in carbonic acid gas, on flies, spiders and probably all other insects.

THE experiments which were instituted on frogs, perfectly coincided with those above related, though in some instances the manner of applying the carbonic acid gas was in a degree varied.

IT has been before remarked, that Goodwyn was of opinion that fixed air would not exhibit any noxious phænomena on living animals, when mixed with a due proportion of vital air, and hence he naturally concluded, that it possessed no inherent deleterious properties. The experiments above related, however, clearly evince that this conclusion has not been deduced from data sufficiently established,

* Spiders were evidently affected in the same manner as flies.

established, and those which I am about to relate as made on amphibix, directly coincide in strenghtening this opinion.

IF an animal is exposed to a given quantity of atmospheric air, suppose 25 oz. and another in similar circumstances to an artificial atmosphere,* composed of carbonic acid gas, instead of the azotic gas with the due proportion of vital air, the whole amounting to 25 oz., the result will determine whether or not the aëriform carbonic acid possesses any hurtful power.

ON Wednesday the twenty-ninth of October, I immersed a frog under an inverted receiver

* This idea of constituting an artificial atmosphere, I first learnt from Dr Wistar in a conversation I had with him on the subject. I afterwards met with it in a treatise on dephlogisticated air, by Count Morozzo, who says. "Après avoir observé que la respiration des animaux mephitise tres peu le gas dephlogistiqué, et que l'on parvient à lui rendre sa première bonté, j'ai éprouvé d'agréger le meme gaz avec tous les gaz meurtriers, et avec l'air vicié par les differens procédés phlogisticans, pour observer s'il auroit la propriété de leur oter la qualité meurtrière et de les rendre respirables." Journ. de Ros. Ann. 1784, Vol. II. p. 113.

ceiver filled with an artificial atmosphere, composed of seven ounces of vital air, and eighteen of carbonic acid gas, making the compound in the proportion of twenty-eight parts of vital air in the hundred, the quantity of that gas ascertained to exist in the atmospheric compound.

AT the same time I confined another frog in twenty-five ounce measures of atmospheric air, this being necessary as a standard of comparison.

THE frog which was placed in the factitious atmosphere was taken out perfectly dead in two hours and thirty-five minutes. On removing the sternum, the lungs were found partly distended, the heart entirely void of blood, and deprived totally of irritability.

THE frog which had been confined in the atmospheric air remained in that situation eighteen hours without having suffered much apparent uneasiness or inconvenience.

NOT having any thing of the nature of an eudiometer whereby I could possibly ascertain

tain with any degree of precision the purity of the vital air used in the foregoing experiment, and not being perfectly satisfied that it might not have influenced the experiment, and accelerated the death of the frog by some noxious impurity, I determined to try what effect the pure oxygenous gas alone would have on frogs, endeavouring in this way to detect any hurtful matter that it might be impregnated with.

I IMMERSED, therefore, a frog under a receiver containing seven ounce measures of vital air, obtained at the same time with the former, (from the black calx of manganese by means of concentrated vitriolic acid), and whilst I remained observing him, which was for several hours, I observed no change to take place in him except that his respiration was rendered more slow and tranquil than before submersion; after continuing exposed to the vital air sixteen hours I permitted him to escape, which he did with alacrity, as what I had already seen had sufficiently satisfied me of the purity of the vital air which had been used in these two experiments.

REFLECTING upon the experiments which had been instituted, I found that one objection might be advanced against the justness of that which had been tried in the artificial atmosphere; viz. that the carbonic acid gas had not been accurately mixed with the vital air, and consequently, retaining, by its gravity, the bottom of the receiver, it would surround the frog and thereby exclude entirely the vital air from his lungs. That it will form an aggregate if proper care be taken, cannot be doubted from the following observation of M. Fourcroy*; speaking of carbonic acid gas, he says, “ Il se mêle a l’air vital, mais sans
 “ alteration, et il forme un mélange que l’on
 “ peut respirer pendant quelques tems, pourvu
 “ qu’il n’en fasse que le tiers.”

To obviate the above objection, the following day I procured a large bottle, and having filled it with water, introduced 7 oz. of vital air, and added to this 18 oz. measures of carbonic acid air, then making a mark on the outside of the bottle correspond-

C 2

ing

* Fourcroy Elemens d’Histoire Naturelle, &c. T. 1.
 p. 440.

ing to the volume of the air in it, and carefully securing the mouth with a ground stopper, I agitated the two airs together, thereby producing a complete mixture of them. This agitation consequently caused a considerable absorption of the fixed air, which I supplied, knowing what quantity to add, from the mark on the outside.

AT forty minutes after one o'clock, I exposed a frog to 25 oz. measures of atmospheric air.

TWO minutes after a second frog was put into the factitious atmosphere, in which it was suffered to remain three hours and an half, when it was taken out dead, having been without motion ten minutes before it was removed.

THE frog in the atmospheric air lived till the noon of the following day when it escaped.

THESE experiments were repeated on frogs several times, and always with a similar result, some sustaining the action of the fixed
air

air longer than others, generally however from between two and an half to four and an half and five hours.

A FROG was exposed to an atmosphere of fixed air alone, he made some exertions when first submersed, but soon became motionless; his thorax moved equably at first and without much apparent alteration, but soon took on irregular contractions and expansions, which entirely ceased after he had been immersed eight minutes and an half, when he expired. On opening the thorax and abdomen the heart was found distended with a black coloured blood, and was excited into action by the puncture of a lancet, and the lungs were devoid of air. This frog was amongst many the most susceptible of the impressions made by carbonic acid gas; others lived thirteen, some fifteen minutes before they expired, and in many the lungs were in a great degree distended with air.

AT the same time, a frog was immersed under water, which had stood some time to deprive it of any air which might have been
diffused

diffused through it. It exhibited after some time all the phenomena of a drowning animal, but in a moderate degree only, and did not expire until fifty-six hours had elapsed*.

THIS

* As it might probably be objected to this experiment, that the frog being amphibious had a power of decomposing water, and by that means of supplying itself with a due quantity of oxygene to carry on the various functions of the system, to this protracted time, with a degree of regularity, I made a vacuum as to oxygenous gas in two ways; 1. By immersing them in mercury, and 2. By preparing an atmosphere of light inflammable air from diluted vitriolic acid and iron filings, by these means avoiding even the most trifling grounds of suspicion as to the validity of the experiment.

I placed a frog in a vessel two-thirds full of mercury, and with a sufficient weight restrained him from rising to the surface, to which the gravity of the fluid naturally urged him. After half an hour had elapsed I removed the weight, the frog was still alive but considerably injured by the excessive pressure of the mercury.

I immersed a frog in an atmosphere of hydrogenous gas, he appeared not to suffer the least inconvenience during the space of thirty minutes, when being fully satisfied with what I had observed, coinciding with the experiments made upon frogs in water and mercury, I released him. These two last experiments were often repeated with the same result.

THIS last spring, I renewed some of the experiments upon frogs, especially those in which they were exposed to the action of pure fixed air, and found that they were not capable of resisting its action so long a time as they did immediately before hibernation.

THE first frog I immersed in the spring, survived the operation 9 minutes, but all the others did not survive its effects 5, and some not two minutes and an half; whereas, in the fall they proved to be much less affected by the air, as they were sometimes found to survive 15 minutes, generally ten or twelve, and only one who had been exposed to this air appeared to die in 8 minutes and an half, and his heart on dissection had not lost all irritability, and was distended with blood.

THESE experiments coincide with the idea held out in the note of page 28, and support the doctrine of Girtanner relative to the accumulation of the irritability of animals and plants during the winter.*

HAVING

* By experiments instituted in the spring and Fall, may we not be able to ascertain the relative quantity of irritability an animal gains during the period of hibernation.

HAVING established that carbonic acid gas exerts a positive influence on insects and amphibious animals, we shall next relate some experiments, to prove the same relative to quadrupeds.

I EXPOSED a mouse to a factitious atmosphere measuring twelve ounces and an half, the oxygenous gas of which was obtained from nitre by means of a gun barrel. That it was pure I now satisfied myself by the eudiometer.

AT first, upon submersion it appeared very uneasy and struggled much, but in the space of a minute was bereft of all voluntary motion and fell down, exhibiting most of the symptoms already mentioned as occurring to animals when exposed to fixed air: at the end of ten minutes it expired.*

* The purity of this atmosphere, when tried in the eudiometer, by the test of nitrous air, after the animal had perished, appeared equal to that of the atmospheric air made use of in the following experiment, even allowing largely for the absorption of carbonic acid gas by the water, which could not be great, as the nitrous air was poured in immediately after the admission of the factitious atmosphere,

ANOTHER ready to die with fear was immersed in an equal quantity of atmospheric air; it continued to breath during an hour when I removed it, and put an end to its miserable existence. Another mouse lived in an equal quantity of atmospheric air half an hour, when its breathing became a little laborious, and upon being removed returned immediately to its natural vigour, shewing its unconcern by eating.

I THINK it unnecessary to relate any experiments which I have made upon birds, as those which have been already mentioned, as instituted on insects, amphibiæ and quadrupeds are sufficient to establish the fact we are in pursuit of. That fixed air does act on the inhabitants of the aërial regions, we learn from the poet * who says—

atmosphere, and the diminution suffered to take place, which it did almost instantaneously, without agitating the two airs together, thereby avoiding, as much as the nature of the experiment would admit, all grounds of error.

* This has been considered as more properly applying to inflammable air, as fixed air could not rise in the atmosphere

“ Spelunca alta fuit, vasto immanis hiatu,
 “ Scrupea, tuta lacu nigro, nemorumque tenebris
 “ Quam super haud ullæ poterunt impune volantes
 “ Tendere iter pennis; talis sese halitus atris
 “ Faucibus effundens, supera ad convexa ferebat.*

WE conclude this section, by declaring that which we are authorised, both by facts and experiments; viz. that carbonic acid gas does not produce its effects indirectly, by mechanically excluding atmospheric air from the lungs; but that it acts directly by an

atmosphere on account of its gravity, but when mixed with atmospheric air, it will prove destructive to birds as well as other animals, as we see in the note just quoted from Morozzo, and when mixed in this way it will doubtless penetrate the air to a considerable distance above the place from which it is generated.

* Since writing the above, I have found a fact related by Morozzo, Journ. de Ros. Vol. II. Ann. 1784, p. 114, which though tried in the investigation of another point, tends directly to corroborate the opinion held out in this dissertation. He says, “ Dans tous les mélanges ou il y
 “ avoit partie égale de gas déphlogistiqué, la durée de la
 “ vie des animaux a été considérablement plus longue
 “ que dans l’air atmosphérique, si l’on excepte cependant
 “ l’air vicié par la vapeur du charbon, dans lequel la vie
 “ d’un moineau n’a été que de 24 minutes, et l’air fixe,
 “ dans lequel elle a été de 38 minutes.”

an inherent power on the animal œconomy, and particularly through the medium of the lungs.*

* We should not be surpris'd that carbonic acid gas should operate so hurtfully on the animal œconomy, when accumulated in too great quantity. Being generated in the system, and constantly thrown out from the blood in the process of respiration; may it not be looked upon as a fecal matter of the vascular system? and, in this point of view, when accumulated there in excess; why should it not prove as universally hurtful to the system at large, as the preternatural retention of any other fecal excretions? It may be objected that the retention of fecal matters in general do not produce hurtful effects with such great precipitation; but nature having ordained that a constant and complete evacuation of this gas should be kept up from the blood, is it not perfectly agreeable to the dictates of sound reason to suppose, that when this quantity is accumulated to any great degree, and in a rapid manner, that ill effects should be produced thereby much more suddenly, than from the gradual accumulation of those excretions to whose influence the animal œconomy is much more accustomed.

I have here considered the carbonic acid gas, which is discharged from the system by respiration, as being generated in the blood, and not immediately by the combination of carbon and oxygenous gas in the vesicles of the lungs; for this obvious reason: any two substances, not actually under the influence of the animal œconomy, cannot enter into any combinations, otherwise than agreeably

WHAT the nature of this action of carbonic acid gas is, together with the most obvious methods of relieving its destructive effects, will be considered in the following section.

ably to the unerring dictates of the established rules of chemistry. The oxygenous gas in respiration, cannot enter into any combination with carbon whilst in the vesicles of the lungs, as it then may be considered as external to the influence of the system, and the heat is not sufficient to effect a combination; fixed air being produced only by a red heat. The cause of the formation of this air must, therefore, be referred to a law of the animal œconomy, which implies the combination to have taken place within the precincts of its organs. This opinion is further corroborated by our knowledge of the fact, that carbonic acid gas is discharged by the perspiring pores.

Dr Rush in his lectures mentions a fact which puts this beyond the possibility of a doubt, viz. If in the morning a lighted candle is placed under the cloaths of a bed in which a person has lain all night, so great is the accumulation of this gas, that the flame is immediately extinguished.

SECTION III.

On what part of the general system, and how does carbonic acid gas produce its effects?

Does it act more immediately upon the nervous system? Or,

Is life affected more particularly by its operation on the blood and muscular system? And

Lastly, What is the most obvious method of rescuing animals from a state of suspended vital action, brought on by its noxious influence?

THAT carbonic acid gas makes some impression on the nervous system, cannot be denied; indeed the results of some of our experiments, the sensations, as related by the unfortunate Pilatre de Rosier,* with which he was affected immediately upon plunging
into

* See Chaptal's Chemistry.

into an atmosphere of that fluid, prepared by fermenting beer, and the analogous manner in which it affects our schniderian membrane* when disengaged from our drink, all unite in testifying the truth of this position.

BUT although we hold that it acts in some measure upon the nervous system, producing symptoms differing in violence according to its strength, we are nevertheless far from imagining that all the direful consequences resulting to animals exposed to its influence, arise from this action. An opinion embracing so much would doubtless far exceed the boundaries of truth, as is evinced by experiment; for, as has been before observed, animals will live a long time in fixed air, provided there is an ample flow of atmospheric air into the lungs.

IT would be wrong here to pass over in silence an experiment related by Landriani, which without strict examination might appear to advocate the contrary doctrine. He observed that a fowl would die in a short time, when confined in a bladder filled with carbonic

* It was supposed by a celebrated physiologist, that its principal seat of action was on this membrane.

nic acid gas, though the head was protruded out of the bladder : provided the edges were so secured round its neck by repeated ligatures that all communication between the external and internal air was cut off.

HOWEVER plausible this may appear, we are disposed to doubt, that death in this instance was produced by the operation of the carbonic acid gas on the external surface of the body, but trust that it will not be wrong to attribute it solely to the pressure of the ligatures round the neck ; more especially as the same experiment has been repeated, paying attention to this circumstance without producing such direful effects.

BEFORE I enter into the consideration of the second quere, it may be proper to premise some ideas respecting the blood.

THE intimate connection between muscular action and vital air has long since been recorded by Fontana*, though from the state of

* Fontana, vol. 2. p. 141-2, relates the following experiment.—“ I pierced the fore-foot of a land turtle that

chemical knowledge at that time he could not be expected to give an ample and satisfactory history of the relationship. It has been since

“ weighed a pound and an half, with an American arrow.
 “ In eight minutes it could scarce move, and in a quarter
 “ of an hour was dead. When the feet and neck were
 “ stimulated, they discovered a slight degree of sensation.
 “ Having opened the thorax I found the heart and au-
 “ ricles quite motionless. I touched the heart, and it con-
 “ tracted itself once each time. On freeing it from its
 “ membranes, it began to move very briskly, and conti-
 “ nued to do so for several hours. I covered it with the
 “ inner shell, and in twenty-four hours found it again
 “ motionless. I pricked it once with a needle, it con-
 “ tracted a single time; I pricked it again, it contracted
 “ afresh, and continued to do so once every time I pricked
 “ it; I left it exposed to the air for three minutes, and it
 “ then began to move of itself, continuing a very brisk
 “ motion for several hours. I covered it afresh with the
 “ shell, and on uncovering it in four hours after, found
 “ it motionless. I left it in the air for a few minutes, and
 “ in a short time, and of itself, it recovered its oscillations,
 “ which continued for six hours. I again covered it with
 “ the shell, and on uncovering it two hours after,
 “ found it without motion. I then covered it with
 “ water, which I kept on it for ten minutes, without
 “ its producing any change. I drained off the water, and
 “ the heart was scarcely left in the air a minute, when it
 “ began to move briskly, and continued to do so for feve-
 “ ral hours. Lastly, I put it in the sun, where it soon
 “ dried. The auricles likewise dried in a degree, and all
 “ was then still. I now wet both heart and auricles; the
 “ former

advanced (by Girtanner and Beddoes) that oxygenous gas, absorbed during respiration is subservient to the generation of irritability

“ former continued always motionless, but the latter began to move, and continued their motion for eighteen hours, when becoming dry they lost it forever.” The contractions here produced cannot be accounted for merely from the stimulus of the air, as, this being the case, they would have commenced immediately on contact with it, and at that time would have been the strongest: Hence, it is evident, that the atmosphere must have imparted some degree of irritability to the heart, which was necessary to be accumulated before the feeble stimulus of the air could excite motions.

This is further illustrated by an observation of *Monf. Troja*. “ *Le cœur étoit pâle, et avec un forte irritation on excitoit a peine un légère irritabilité dans l'oreillette droite seulement: cependant, elle s'est manifestée davantage dans le ventricule droit, lorsque le cœur eut resté quelque-temps exposé à l'air.*” The count *Morozzo* observes, also, that when he opened sparrows and rabbits who had perished in oxygenous gas their hearts exhibited marks of irritability a long time, the heart itself ceasing to move spontaneously after two hours, but the auricles continued to move a considerable time longer. These observations have the more weight as they were made by men of sound understanding, and who held no theory on the subject by which they could possibly have been biased. *Girtanner* relates the following experiment, which establishes this idea without leaving a shadow of doubt. “ A considerable quantity of very pure oxygene air was injected
D “ into

in the animal œconomy; and that in some animals such is the volatile nature of this irritability, that a constant supply is called for, to sustain the functions of the different vital viscera, whilst in others, the tenacity of the moving powers for this principle is so great, that the necessity of so very constant and regular a supply is not so urgent. That this oxygenous gas when poured into the lungs by the ordinary efforts of respiration, is through their medium conveyed into the blood vessels with which that viscus copiously
abounds,

“ into the jugular vein of a dog. The animal raised most
 “ terrible outcries, breathed very quickly, and with the
 “ utmost difficulty; by little and little his limbs became
 “ hard and stiff, he fell asleep and died in less than three
 “ minutes. Upon opening the thorax and the pericar-
 “ dium, the heart was found more irritable than ordinary,
 “ and its alternate contractions and dilatations continued
 “ upwards of an hour. The right auricle of the heart
 “ was vermilion, and it contained as well as the right
 “ ventricle, a great quantity of blood of a bright vermilion
 “ colour, frothy and not coagulated. The blood con-
 “ tained in the left ventricle, in the aorta, and the arteries,
 “ was of a rose colour, and was mixed with bubbles of
 “ air. All the muscles were more irritable than ordinary.
 “ After the blood contained in the heart and veins was
 “ discharged, the irritability of the heart and the muscles
 “ sensibly diminished.”

abounds, and that uniting with the blood, it is thence conveyed, imparting heat and life even to the most remote parts of the body, so requisite for the adequate performance of their functions. That it is by oxygene alone that the moving fibres are supplied with that irritability, so absolutely necessary to their contractions; and that the production of this principle is wholly unconnected with the nervous system*. So great is the validity of the facts advanced in support of these opinions, that I have adopted them, as it is only by deducing reasons from firm data, that speculative researches can be of importance to true science †.

DOES carbonic acid gas affect the blood?

D 2

SOME

* The functions of the nervous system may be considered as wholly distinct from those of the muscular. The nerves are more particularly confined to sensation, and the muscles to motion. The nerves serve to convey the electroid fluid as demonstrated by Valli, &c. which acts as a stimulus, producing motion. The muscles prepare the irritability from the blood without which the action of stimuli would be abortive.

† I must refer to Beddoes observations for a further detail of facts, &c.

SOME experiments of Girtanner* would lead to the idea that its influence on blood was not great, for he allows it to possess no action on that contained in the arteries. But on the other hand he found, that its influence on venous blood was very great †, rendering the colour blacker than ordinary. Allowing that this position was just, even with respect to the action of this air on the blood in the animal œconomy, I attempted to account for its full effects.

CONSIDERING the arterial blood as imbibing oxygenous gas from the atmosphere in respiration, and after having distributed this gas in the round of circulation, becoming venous and black on its arrival at the right side of the heart, it was evident, that when the communication between the lungs and vital air was cut off, that all the blood of the system after one circulation would be entirely venous, and leave ample room for the carbonic acid gas to exert its most energetic influence.

ONE

* Beddoes Observations, 229.—Arterial blood from the carotid artery of a sheep was received into a bottle filled with carbonic acid air, no change on the vermilion colour.

† Beddoes Observations, p. 244.

ONE very great difficulty however, started up against this opinion, and demanded, why carbonic acid gas inevitably produced the same effects, though in a slower degree, in the factitious atmosphere, when there was sufficient oxygenous gas, to render the blood in the lungs arterial, and to answer all the purposes of respiration ?

IT was to no purpose to explain away this objection, by imagining, that the slower effects were produced by the diluted state of the carbonic acid air, and that this gas operated on the lungs by entirely excluding the absorption of vital air, because in this case animals in general would have perished in the factitious atmosphere sooner than they would have drowned, but this was not the case with quadrupeds. It was necessary then to hold that its operation was not confined solely to venous blood, but that it also had an immediate influence upon the blood of the arterial system ; throwing aside the consideration of any power that the arterial blood might possess, when out of the body, of resisting the action of fixed air, as no conclusive argument against its action on this blood in the living body,

body, and as not coincident with our knowledge of the animal œconomy, in which combinations and decompositions daily take place, which are not functioned by external chemical affinities, but subject to the reigning laws of the animated organs*.

Is this action, whatever its nature and effects may be, dependant on the acidity of the carbonic acid gas, or must it be explained on other principles?

As the question has been amply discussed by M. Troja, I shall relate two experiments
which

* This last opinion I am the more inclined to adopt, as it accords with facts which cannot be entirely explained by the former. The following experiment related by Girtanner is conducive in strengthening the probability of the latter hypothesis. “A small quantity of carbonic acid gas was injected into the jugular vein of a dog. The animal became sleepy, and died in about a quarter of an hour. The right auricle and ventricle of the heart was filled with thick blood, and in part coagulated. The blood contained in the left ventricle and auricle was of a deeper colour than ordinary. The heart and muscles had lost all their irritability.” This I think proves, that the whole sanguiferous system can be affected by the carbonic acid gas,

which he made on the subject, preferring his own words, though all his ideas on the subject are not consonant with our opinion.

“ MAIS la vapeur du charbon est elle nuisible par son acidité ? Par l’air phlogistique comme air phlogistique, ou par quelque autre principe dont elle est composée ? C’est un question très difficile à discuter, et je la regarde supérieure à mes forces ; cependant, elle ne peut pas être meurtrière pour être simplement acide. Je desirois avoir un moffette toute acide pour remarquer séparément, et sans composition d’autre substance, les effets qu’elle produiroit sur les animaux. J’ai cru devoir me servir de l’air acide découvert par M. Priestley. A cet effet, je mis presque une livre de sel marin dans une grande cornue, et j’y versai une bonne quantité d’huile de vitriol concentrée. Ensuite, je fis passer son gout par un trou fait exprès, dans l’intérieur de ma grande caisse, en laissant son corps en dehors pour placer par dessous une grosse lumière.

“ LA

“ LA caisse fut remplie presque dans l’in-
 “ stant de fumée, qui étoit l’air acide. J’y
 “ avois renfermé un chat. Il se porta très
 “ bien pendant quatre heures, à l’exception
 “ qu’il touffoit de tems en tems par l’irritation
 “ de la vapeur dans le poumon : il rendit
 “ aussi par la bouche une quantité prodigieuse
 “ d’eau, en partie tres-fluide et limpide, et
 “ en partie comme le blanc d’œuf. Ennuyé
 “ de poursuivre plus long-tems mon ope-
 “ ration, je mis en liberté l’animal. Il étoit
 “ un peu malade, verfoit de l’eau en grande
 “ quantité par la bouche, par le nez et touf-
 “ soit fréquemment ; au bout de deux jours,
 “ il étoit bien remis.

“ SI cette moffette n’avoit pas produit son
 “ effet avec la mort de l’animal, je ne pour-
 “ rois pas en accuser l’absence de l’air acide
 “ qui est immédiatement absorbé par l’eau et
 “ par l’humidité : il en sortoit toujours du
 “ nouveau de la cornue, dans laquelle j’avois
 “ remis plusieurs fois du sel et de l’huile de vi-
 “ triol, et la caisse avoit été toujours remplie
 “ de fumée. La quantité de cet air étoit si
 “ considerable, qu’elle avoit trempé, sous
 “ forme

“ forme d’esprit de fel marin, tous les parois
 “ de la caisse, pénétré la substance du bois
 “ même, s’étoit fait jour à travers quelques
 “ commissures des planches qui étoient cal-
 “ feutrées avec du papier et de la colle, et a-
 “ voit tout mouillé le corps de l’animal.

“ CEPENDANT, je n’avois pas accompli
 “ le but de mon expérience. Je calfeutrai
 “ mieux les commissures de la caisse ; et je
 “ recommençai la meme opération et j’y ren-
 “ fermai un gros chien. Je fournis de l’air
 “ acide pendant quatre heures, j’en eus
 “ précisément le même resultat. Alors, j’otai
 “ le feu de dessous la cornue, et je laissai le
 “ chien renfermé jusqu’au lendemain matin.
 “ Il y resta 14 heures. Quand j’ouvris la
 “ caisse, l’odeur acide étoit si forte, que mes
 “ dents s’en ressentirent toute la journée. Je
 “ m’attendois à trouver l’animal presqu’ex-
 “ pirant ; si ce n’est, disois-je, la vapeur
 “ acide qui l’a maltraité, ce sera la moffette
 “ excitée par sa respiration : point de tout, il
 “ se portoit très-bien, et il me paroissoit me-
 “ me plus vigoureux.” Thus it appears, that

it

it is not by its acidity that carbonic acid gas acts.

WHENCE, then, do these effects proceed ?

I WILL hazard a conjecture on the subject, though it may hereafter be found far from coinciding with the fact.

I SUPPOSE an inherent property* in carbonic acid gas, inducing when combined in too great quantity with the blood, whether arterial or not, such changes in its nature, as to banish from its dominions all oxygenous gas, according to its state of concentration ; causing it to combine with the moving parts of the animal œconomy to which it is more particularly destined, thereby producing a great accumulation of excitability, which when acted on by the ordinary stimuli then existing in the system, produces all the phenomena incident to submersion in that fluid. †

* Probably its stimulating property.

† It may possibly act only indirectly on the blood, by exhausting the irritability of the muscles, thereby causing a rapid demand for the oxygenous principle which would
be

THIS view of the subject enables us to account, in a satisfactory manner, for the symptoms which have been related as taking place, whilst the animal was alive, during the time of submerfion in carbonic acid gas.

IT has been observed that the heat of animals, whose vital action has been fufpended by carbonic acid gas is confiderably encreafed. This Phenomenon I conceive cannot be accounted for, unlefs from the fudden converfion of oxygenous gas, exifting in the blood, into the principle of irritability or at leaft into a ftate of combination with the folids; and the more than ordinary black colour of the blood, from the entire expulfion of oxygenous gas from that fluid.

THE encreafed action of the heart and arteries during the firft ftage of fubmerfion, may be explained fatisfactorily from the rapid generation of irritability, and the continued action of the various ftimuli upon it;

as

be confequently exhausted from that fluid; or there may be a compound action, as it may act both directly and indirectly.

as well as the subsequent feebleness, fluttering, and total decline, from its as rapid decay.

ANY further enlargement on this hypothesis would render the length of this dissertation unusual, I shall therefore, leave it thus but imperfectly sketched to the judgment of the candid.*

* It has been already observed that the carbonic acid gas was considered as an excretion, and that it was formed in the blood vessels by the combination of oxygenous gas with carbon. It seems to have been intended by the all beneficent hand of nature that this excretion should not be formed and evacuated in vain, for agreeably to our hypothesis, it must act as a balance to the system, in great measure curbing, in common circumstances, the immoderate accumulation of excitability, so often productive of dreadful consequences.

When oxygenous gas is poured into the system in excessive quantities, carbonic acid gas is thereby more abundantly generated, and thence acts on the blood &c. lessening the influence of the oxygene, keeping the system in great measure at the natural standard: on the other hand, when the quantity of oxygenous gas is deficient, the production of carbonic acid gas is consequently diminished, and its action on the blood is therefore more restricted, keeping in a negative manner, the sources of irritability from falling too low. Nevertheless, there
doubt-

WHAT is the most successful method of relieving animals, whose vital functions are suspended by carbonic acid gas?

FROM the various observations which I have made, respecting the diseased state induced by carbonic acid gas, I am inclined to believe that the effects produced by it are much more serious in their nature than those arising from submersion in water; nor am I singular in this opinion. M. Troja who made many ingenious experiments on the subject in the year 1778, and whose name has often appeared in the course of this enquiry held the same opinion. The reasons, however, which seem to have induced him in a great measure to adopt this idea, I must confess, are such as do not point out to me the propriety of the opinion, not that I think they would be without weight, did the facts from which they are adduced really exist*.

doubtless are cases wherein by the excessive quantity, or by deficiency of oxygenous gas, this equipoising quality of the carbonic excretion cannot be of the least avail, when highly morbid effects are thereby inevitably induced.

* What we allude to here more particularly is, the idea which he held concerning the rupture of the lungs, which

The want of authenticity, nevertheless, of his facts, cannot materially affect the doctrine, provided more substantial proofs can be marshalled in its support.

THE following comparative experiments were instituted to determine the justness of this hypothesis.

I IMMERSED a mouse under a receiver of water, and suffered it to remain until no motion was to be observed, except very faint movements of the heart.

AT the same time, I immersed another mouse of equal vigor, under a receiver containing 7 oz. of the factitious atmosphere, and did not remove him until he had become

much

he imagined invariably took place in animals who had perished in carbonic acid gas. I could never observe, that any rupture had intervened in these cases, though I repeated his experiment several times, except in one case in which by a carelessness in dissecting, my knife had effected an artificial aperture. His experiments in attempting recovery after the pulse had stopped, was a further inducement; but we have facts which evince, that so general an induction as he draws from his experiments in our present state of knowledge, would be not only very unjust but inhuman.

much enfeebled, his respiration at considerable intervals, and the movements of the heart, irregular and frequent.

UPON removing the mouse which had been submersed in water, into the air, it lay a short time without making any efforts to breathe, and without any sign of remaining irritability, besides the slight motion of the heart already mentioned; however, in the space of forty seconds, or a minute, some slight strugglings occurred, a spontaneous breathing commenced, and it recovered in a short time so far as to crawl, when I put an end to its sufferings.

THE latter mouse, though it still continued to respire after I had removed it into the atmospheric air, did not recover from its stupid state, all the efforts in respiration were to no purpose, and it ceased to live in the space of five minutes. No endeavours were made to expedite the recovery of either.

A DOG also, who had been exposed to carbonic acid gas, expired after he had been removed

moved from its influence, though he breathed three times, after he had been conveyed to the atmospheric air. In this case I made no efforts to recover the animal*.

THOUGH candour forbids that I should omit giving my sentiments on this delicate point, I am far from wishing in the least to influence the practical exertions of any man, and whatever may be my opinion, I think it highly criminal, not to seize upon with avidity every opportunity of being of service to our fellow creatures, who have suffered in this way as well as in any other. There is always a possibility † of effecting a recovery, even where appearances have advanced further than in the cases already mentioned, before succour has been afforded ‡; thus

* Percival relates a case which he quotes from the Epistiles of Donatus, of two boys, where the pulsation continued after they had been exposed to the fumes of charcoal; they died.

† Troja thinks otherwise, hence the dangerous tendency of his hypothesis.

‡ This is evinced in the case of M. L'Abbé Briquet, whose vital functions were completely suspended by the fumes of charcoal, and still he recovered. Vid. Ros. Journ. 1774. vol. 2. p. 464.

thus no exertions should be spared to secure the most trifling advantages to the patient, howsoever desperate the case may appear, whilst at the same time, we should be ever upon the guard, not to be too much flattered by appearances, lest we give rise to hopes which the true state of the matter will not admit of.

THE remedies which our view of the subject, and the experience of many will allow us to make use of are but few.

OUR first endeavours, however, should be directed to remove the patient from the noxious cause. Here too many cautions cannot be inculcated, against entering places in which animals have perished, lest by rashly obeying the dictates of a blind, though laudable humanity we are hastily precipitated into the same deplorable situation, from which it was our ardent desire to rescue a fellow mortal.

IT has latterly been generally deemed safe to trust our lives in places which are confined, provided there was a sufficient quantity of oxygene gas to support flame.

IF the extinction of flame, and of animal life, depended upon the same principles, this idea would be just, but as flame can subsist as long as there is vital air to support it *, and it has been proven already that this is not the case with animal life, the hypothesis cannot be just, and some more effectual tests should be resorted to before we decide on the event. Lime water is the best test to ascertain the presence of fixed air, but to be certain that no evil consequences will ensue, it will be necessary to try its effects first upon some animal less valuable than man.

IN cases when we are not certain of the length of time taken to produce the morbid effects, it may be proper to use the above precautions, before we attempt to afford relief; but when we know that the effects have been sudden and violent, the fact itself evinces the dangerous consequences of exposing ourselves to its influence, and then the patient must

* I prepared a facitious atmosphere as before, and found that a candle burned in it with great lustre and rapidity until almost all the vital air was consumed. MOROZZO found that a candle burned very vigorously in the oxygenous gas, in which many animals had perished.

must be withdrawn with hooks and other convenient implements best calculated to be successful, at the same time offering as little into the body as possible.

WHEN the patient is perfectly under our command the following method ought to be pursued as it has ofteneft been crowned with success.

HAVING obtained a thorough command over the body, we are as quickly as possible to expose it to a full current of air. In these cases very little assistance is wanted, and we must not permit unoccupied persons to remain, as they would only contaminate the slender portion of oxygenous gas, which ought to be carefully husbanded, for the use of the unfortunate patient.

IF circumstances will not admit of moving the patient to an airy situation, we must by artificial means, endeavour to render the place of necessity, as eligible as possible by agitating the surrounding air and blowing upon the body with large fans, &c. In the mean time,
 however,

however, we should be preparing to inflate the lungs with oxygenous gas, if it can be procured, without delay; but, if not, with the common atmospheric air, not neglecting repeatedly to dash cold water over the face and body of the patient; ice may be applied with advantage when very cold water is not at hand.

IN many cases assistance is afforded so soon as to preclude the necessity of resorting to inflations, as when the respiration is not quite arrested, here we may only employ the cold bathing and ventilations with advantage.

BLOOD LETTING, which was instituted in former days under a false idea of the cause of the evil (that it arose from apoplexy) is not adviseable, as the quality of the remaining blood, as respects the noxious cause, cannot be changed by this means.

THE promiscuous use of stimulating remedies of all kinds, operate in a direct line with those which precipitated the catastrophe, and are therefore hurtful*.

THE

* Troja, Journ. Ros. an. 1778. vol. 1. p. 485.

THE use of inflating the lungs cannot be doubted by the most sceptical, for it is only by restoring the proper quantity of oxygenous gas to the blood and muscular system that life can again evolve its various functions.

THE indication of repeated ablutions with cold water, is not quite so obvious. The frequent services * it has rendered to animals suffering from the effects of fixed air, have established it as a remedy of the utmost importance, but the ratio operandi, however, as yet, has been involved in a degree of obscurity.

IT

* “ Un cuisinier de Nancy, suffoqué par la vapeur
 “ du charbon, et resuscité par l’asperion de l’eau fraîche.
 “ Journ. de Rosier, 1775, Vol. I. p. 31.

The case of M. L’abbé Briquet de Lavaux—Ros: Journal, wherein it is related by M. Banau, M. D. “ M.
 “ L’Abbé de Lavaux étoit absolument sans pouls et sans
 “ respiration, son visage très-rouge et bouffi, ses yeux
 “ saillans. Il ne donnoit aucune marque de vie, et si l’on
 “ en excepte la putrefaction, il avoit tout les signes de
 “ la mort.”

He was recovered principally by the use of cold water, and a great current of cold air. The only animals which I succeeded in recovering, were such as were treated by inflations and cold bathing.

IT may, however, be remembered that an increase of heat was observable in animals who were deprived for a time of vital action by this destructive gas. The cold water here steps in to reduce that, and to bring the whole system to such a state (I may call it a state of temporary hybernation) in which by the suspension of all stimuli, the irritability of the body will have time to accumulate, and then the gradual application of natural stimuli will regulate the motions of the system, and finally restore order and tranquility.

THE remedies after the body has emerged from imminent danger, must be applied according to the state of the system and the varying nature of the present circumstances.

As the *necessity* of writing, alone could have prompted me thus early to have appeared in the literary world, I must beg the indulgence of the critic, the man of candour and generosity will offer it spontaneously.

T H E E N D.

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