THE

# PHYSIOLOGY, PATHOLOGY,

AND

TREATMENT OF

# ASPHYXIA:

INCLUDING SUSPENDED ANIMATION IN NEW-BORN CHILDREN—AND FROM DROWNING—HANGING—WOUNDS OF THE CHEST—MECHANICAL OBSTRUCTIONS OF THE AIR-PASSAGES—RESPIRATION OF GASES—DEATH FROM COLD, &c. &c.

BY

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TO THE

## ROYAL HUMANE SOCIETY.

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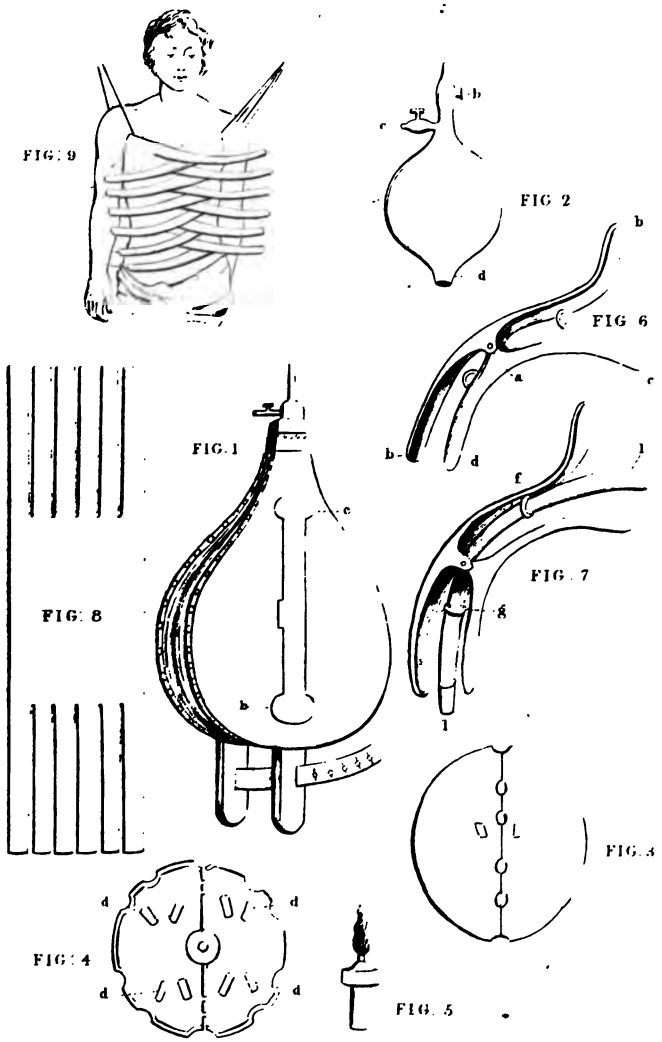
FIG: 9
FIG 2
FIG 6
FIG. 1
FIG. 7
FIG: 8
FIG. 3
FIG: 4
FIG. 5

# EXPLANATION OF THE FIGURES IN THE ENGRAVING.

The first figure represents the double-valved bellows, furnished with the graduated arc of a circle to adapt the quantity of air injected to the capacity of the chest in the person operated upon. The valve, moved in the directions *b* and *c*, permits the air expelled from the chest during expiration to escape from the bellows.

In some cases of Asphyxia, when external warmth cannot be applied from the want of a convenient apartment, and when the temperature of the atmosphere is extremely low, it may be desirable to have the means of warming the air injected into the lungs. I have therefore given a representation of an apparatus invented by Leroy for this purpose. The figures 2, 3, 4, and 5, represent the instruments necessary to this end. Figure 2 is the copper vessel in which the air is heated. There is a valve at *d*. The two stopcocks *b* and *c* permit the air in the reservoir to escape when it is too hot. This air-vessel is to be heated by a spirit-lamp—figure 5—placed in the centre of a reflector like that represented in figure 4. The reflector is formed of two half circles, articulated together, so as to envelope the reservoir, as is shewn in figure 3. Openings are made in the upper part to permit the smoke to escape. In figure 4, which exhibits the concavity of the reflector, are eight metallic prominences, intended to keep the reflector always at an equal distance from the reservoir.

Figures 6 and 7 represent Leroy's instrument for facilitating the introduction of the canula into the trachea. This instrument is composed of two parts articulated at *a* figure 6. The branch *b b* is fixed—the branch *c d* is moveable. When the extremity *c* is elevated towards *b*, the extremity *d* is depressed, and it is made to act on the base of the tongue so as to elevate the epiglottis.

Figure 7 represents the canula *l l* in its place in the instrument. It is attached to the fixed branch by a ring *f*, and at the other end it follows the motions of the other branch, to which it is attached by another ring *g*. The oscillatory motion of this branch, at the same time that it depresses the base of the tongue and elevates the epiglottis, directs the canula to the opening of the larynx, and, if it then be pushed forward, it enters the glottis.

Figures 8 and 9 represent the bandage used in producing artificial respiration, and the way in which it is applied to the chest. The breadth of the bandage should be 18 inches—its length 6 feet—and the length of each strip two feet. When it has been applied to the chest in the way exhibited in figure 9, the ends should be gathered together in a knot in the direction of the dotted lines, and the chest compressed by drawing the strips in opposite directions. For a further account of this bandage see pages 56 and 57.

TO HIS GRACE

# THE DUKE OF NORTHUMBERLAND,

K.G. K.P. F.R.S.

*PRESIDENT OF THE ROYAL HUMANE SOCIETY.*

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MY LORD DUKE,

I BEG to present to your Grace, as President of the Royal Humane Society, the Treatise which accompanies this Letter, and which contains some new views of the physiology and treatment of Asphyxia, founded on experimental inquiries. My attention has, for some time past, been directed to this subject. In 1826 I communicated to the Royal Medical Society of Edinburgh the results of some experimental inquiries, which I had then completed, concerning one portion of this most interesting question. An account of these researches was subsequently read before the Medico-Chirurgical Society of that city, by Dr. Alison, the able Professor of the Institutions of Medicine in the University of Edinburgh; and a paper, embodying the inquiry and its results, was afterwards published in the Edinburgh

Medical and Surgical Journal. In this essay an attempt was made to establish a new theory of suspended animation, which has since received the sanction of distinguished physiologists. In 1830 I read a paper before the Manchester Literary and Philosophical Society, containing a further development of the view which I had taken of the physiological changes occurring in Asphyxia, and extending the inquiry from an investigation of the causes occasioning the organic death of the lungs, heart, and muscles (the subject of the first paper), to an examination of the causes producing a cessation of the functions of the nervous system.

Whatever value may be attached to the opinions developed in these papers, their diffusion has been retarded by some very natural circumstances. These opinions related to one of the most difficult questions of physiology, and the essays in which they were announced, were cast in an abstract and unpopular form, because they were intended for the perusal of professional men alone. Moreover, the second of these papers was published in the North of England Medical and Surgical Journal, a work intended to promote scientific inquiry, and to encourage professional literature in the northern counties, but having chiefly a provincial circulation.

I have therefore, for some time past, intended to republish these essays; especially as I perceive, from the Reports of the Royal Humane Society, that they have never been so fortunate as to attract the attention of its distinguished members. Feeling that a just view of the physiology of Asphyxia must have a most important influence on the use of means for restoring suspended animation, and is also necessary to their further improvement, I have determined to combine, in this slight volume, an exposition of the physiology of Asphyxia, with a critical account of the most approved methods of treatment. The encouragement which the Royal Humane Society has ever afforded to all attempts to elucidate this most important subject, gives me sufficient assurance that in presenting this work to your Grace, its President, my humble efforts will receive the kindest consideration of the Society; and that I shall not be thought presumptuous nor intrusive, if I request the attention of its members to a popular statement of my views of the physiology of Asphyxia, and to an examination of the means at present employed to restore suspended animation.

The subject of this volume, unlike other physiological inquiries, is possessed of an interest not confined to the medical profession: and it is of the utmost importance that a right apprehension of the nature of suspended animation, and a critical knowledge of the method of treating it, should be disseminated as widely as possible. For this purpose, the Royal Humane Society has most properly published, in its annual reports, popular accounts of improvements in the means adopted to restore life in Asphyxia, and has, with great assiduity, distributed its directions for the treatment of persons apparently dead. It is however to be regretted that, especially in the provinces, the Reports of the Society have an exceedingly limited circulation, and that a knowledge of these improvements is very slowly diffused through this medium. Some very pernicious practices are still employed to restore suspended life, although they have been rejected by the Society; and there is a want of caution and discrimination in the use of others, which can only be removed by the diffusion of more accurate information. The hope of assisting in the promotion of this desirable result has induced me to address this letter to your Grace, as President of the Royal Humane Society, in which I shall develop, in as popular a form as possible, the physiology and treatment of suspended animation.

Many theories have been devised by physiologists to explain the phenomena of Asphyxia. It is, however, satisfactory to perceive that each successive explanation of these phenomena has been occasioned by those collateral improvements in medical science, which have successively illustrated this interesting but obscure subject. The Greeks and Arabians, prevented by superstitious scruples from acquiring an accurate anatomical knowledge of the human structure, supposed that Asphyxia was occasioned by the distension of the abdomen and chest by water, swallowed and inspired during immersion. Hence, their method of treatment consisted only of means for the expulsion of this fluid. The patient was suspended by the heels or rolled about on casks, in order that the water might be expelled by pressure, or suffered to drain by its own gravity from the organs which it was supposed to oppress. The vulgar dress themselves in the cast-off garments of philosophers, and this erroneous notion, attended by the pernicious practice founded upon it, though long rejected by science, still retains its grasp on the popular mind, with all the force and inveteracy of prejudice.

The study of anatomy dispelled this theory, but not until a comparatively recent period. Detharding, in 1774, demonstrated by dissection, that the lungs, after death by drowning, often contain no water. The discovery of the circulation of the blood had the most important influence on the opinions entertained concerning the nature and treatment of Asphyxia. Before proceeding further, it may therefore be desirable, as this letter may be read by some not well acquainted with anatomy, to give the unprofessional reader some account of the circulation. To this discovery of the immortal Harvey medicine is indebted for most of its subsequent improvements, and among these the advance made in the physiology of Asphyxia, immediately after its promulgation, is not a little remarkable.

The heart consists of four cavities, two on the right side and two on the left. The superior cavities are denominated auricles, and are much smaller and more slender than the inferior, or the ventricles, to which they may be considered, for the sake of simplicity, as antechambers—the right auricle opening directly into the right ventricle, on which it is superimposed; and the same arrangement being observed on the left side of the heart. The current of the circulation passes through the lungs, and the blood descends from them through the pulmonary veins, and the left auricle to the left ventricle. The blood here possesses a bright red colour, acquired in the lungs. By a contraction of the muscular walls of the ventricular cavity on its contents, the blood is propelled into the arteries, and distributed over the whole body by these channels, to nourish every part of the structure. While it thus ministers to nutrition, it acquires a dark hue, and flows out of the small vessels of which the body is every where composed, into the veins by which it returns to the right side of the heart, where it passes through the auricle into the ventricle. The blood in the right side of the heart, in the veins, and also, as we shall see, in the pulmonary artery, is dark, and is called venous blood. On the contrary, the blood descending through the pulmonary veins to the left side of the heart, and thence propelled into the arteries, has a bright red hue. Two changes of colour therefore take place in the current of the circulation—one in the small vessels of the body which receive red blood from the arteries, and return dark blood to the veins—the other in the minute vessels of the lungs, which receive dark blood from the pulmonary artery, and return red blood to the pulmonary veins. The unprofessional reader will derive advantage from a minute account of this part of the circulation, and I shall therefore describe it with the greater care.

The dark blood returns from the tissues by veins which gradually unite until they form two great trunks, one ascending from the abdomen, the other descending through the upper part of the chest, and which unite in the right auricle. Thence, the dark blood passes into the right ventricle, and is transmitted from its cavity—being impelled by a contraction—through the pulmonary artery, into minute vessels which form or surround the air cells of the lungs. When air is inspired, it descends through the windpipe into smaller channels called bronchi, which subdivide like the branches or roots of a tree, until this arborescence terminates in minute vascular cells, surrounded by the dark blood, which is here exposed to the influence of the air. Before the blood leaves these minute vessels, it undergoes a change of colour, indicating an alteration in its qualities, and it is thus fitted for circulation in the vessels which convey red blood, and to nourish and stimulate every organ of the body. The air inspired is deteriorated, having lost certain qualities abstracted by the blood, and acquired others emitted from this fluid. Respiration, or the constant inspiration and expiration of air, is therefore necessary to this change in the colour of the blood, and hence, as we shall see, to its further progress through the minute vessels of the lungs, and its consequent descent by the pulmonary veins to the left side of the heart.

Harvey and Haller, rightly supposing that when respiration is suspended the circulation ceases, in consequence of some impediment in the lungs, and ignorant of the chemical changes produced in the blood by respiration, conceived that the obstacle encountered by the circulation in the pulmonary tissue was purely mechanical. They attributed death, therefore, to the collapse or corrugation of the pulmonary structure, by which its minute vessels were compressed, and the circulation in them arrested. As near an approach was thus made to the true theory of Asphyxia as the state of science would admit; and it is wonderful that, on the discovery of the chemical changes occurring in the blood during respiration, physiologists did not at once adopt the proper explanation of the phenomena of Asphyxia, so directly indicated by these celebrated men.

Subsequently, Kite, correctly rejecting the evidence of mechanical obstruction, supposed the alternate expansion and contraction (or "the motion" of these organs, as he denominated it) to be necessary to the progress of the blood through their tissue, thus making a still nearer approach to the truth. More recently, and after an advance had been made by Goodwyn to a more accurate appreciation of the importance of the chemical changes produced in the blood by respiration, when considered in relation only to the *mechanism* of the circulation, Coleman revived the theory of Haller, and maintained that death occurs in Asphyxia because the circulation is arrested in the lungs, by their collapse, when respiration ceases. To these theories it is unnecessary to reply, and they are introduced to your Grace's attention, and to that of the general reader, only for the purpose of showing how dependent science is in all its parts, by exposing the errors committed by the greatest physiologists, because they were not acquainted with the chemical changes occurring in the blood during its transit through the lungs, and could not therefore discover their connection with the mechanism of the circulation.

Not long after the discovery of the chemical constitution of the atmosphere, in 1774, by Dr. Priestley, juster views of the physiology of respiration prevailed. Lavoisier, in 1787, explained the nature, and developed the importance of the chemical changes produced in the blood by respiration, and Goodwyn, in 1788, published his treatise "On the connexion of Life with Respiration," in which, the first attempt was made to connect the chemical changes in the blood with the mechanism of the circulation. Goodwyn clearly proved that no mechanical obstruction exists to the passage of the blood through the lungs, even after the fullest expiration—the air then remaining in the air cells being amply sufficient to distend them, so that the blood may circulate freely through them. Perceiving, however that a change in the blood from the dark venous hue to an arterial redness, is necessary to the maintenance of the circulation, and therefore to life, he supposed that the circulation ceases when respiration is suspended, because the blood being no longer exposed to the influence of the air, retains its venous character, and passing through the pulmonary structure is unable to stimulate the left auricle and ventricle to contraction. He imagined that the motion of the left side of the heart thus ceases from the want of its natural stimulus, and that the circulation is consequently arrested.

The celebrated French physiologist Bichat, guided by more expanded views of the human structure, and aided by the progress of science, overthrew, by a well devised and beautifully executed series of experiments, every preceding hypothesis, and proposed a theory which has remained unquestioned until a very recent period. Bichat proved that the heart continues to act for some minutes after respiration ceases—that during this period blood of a dark colour permeates the lungs, and proves a sufficient stimulus to the left ventricle, being vigorously propelled by that organ into the arteries, and thence into all the structures of the body. This was shewn by an experiment of the most conclusive nature. He inserted a stop-cock into the windpipe of a dog, and having laid bare an artery and divided it, he then closed the stop-cock. Having thus prevented inspiration, he permitted blood to flow from a divided artery. At first, it issued in a full stream, and of a bright arterial hue:—as the oxygen contained in the air cells was exhausted, it gradually lost its arterial character, and acquired a darker colour, until it resembled venous blood. The stream then soon became weak and slender—and at length ceased. At the expiration of three minutes, even when great loss from hæmorrhage is avoided, little blood flows from the extremity of a divided artery, and in five minutes, even the slightest oozing of this fluid is generally at an end. After respiration has therefore ceased, the circulation continues little more than three minutes, and life is generally quite extinct in five minutes. Bichat perceiving the change which occurs in the colour of the fluid circulating through the system, attributed death to the noxious qualities of the dark blood, thus propelled into all the organs of the body. He thought the presence of this fluid in the organs incompatible with the exercise of their functions, and that especially the irritability of the heart and muscles, and the powers of the brain and nervous system perished, under its deleterious influence. He supposed the organic life of all the tissues to be thus extinguished by a poisonous tide which penetrated them, and which exerted a fatal influence on the most minute portions of their structure. Had this theory of Asphyxia been correct, vainly might we have expected any auspicious results from attempting resuscitation. No means, short of removing from the minute vessels of the body that fluid, the qualities of which were thus considered incompatible with life, could have been sufficient to accomplish resuscitation, which would therefore have been impossible. That the mass of the blood pervading the whole system, and every where employed in sustaining vitality, should be converted from a fluid abounding in vital energy into one destructive of life, was so hopeless a view of Asphyxia, that it is wonderful that the fact of resuscitation from apparent death having not unfrequently occurred did not excite a suspicion, that a hypothesis so gloomy, was incorrect. The theory of Bichat, however, still retains its place in some of the most recent writings of physiologists, and it is of no small consequence to the interests of humanity that its fallacy should be exposed.

Those Chapters of the following Treatise, which relate to the physiology of Asphyxia in warm blooded animals, contain an account of the experimental enquiries, by which I have endeavoured to prove that the theory of Bichat is incorrect. For an account of the experiments by which this is accomplished, and by which also another view of the phenomena of suspended animation is evolved, I must beg to refer your Grace to those chapters, should curiosity prompt you to further inquiry into this subject, because it is impossible in the popular account of these researches, which I now offer through your Grace to the Royal Humane Society, that I should give more than a general statement of the argument.

By these experiments, it is shewn that venous blood has no noxious influence on the heart and muscles when injected into their tissue, or when allowed to circulate through them, but that it is capable of supporting their organic life for a considerable time, though with less energy than the arterial blood. The circulation of dark blood during suspended animation tends to sustain the vitality of the heart and muscles in an inferior degree, while sense and voluntary motion become gradually weaker: but even this supply soon ceases, and the circulation is arrested in three or four minutes. Moreover, though the venous blood possesses little power of ministering to the functions of the nervous system, it is not positively deleterious; for it may be freely injected into the brain without occasioning death, and, notwithstanding the unnatural pressure exerted on this delicate organ during the injection of this fluid with a syringe—a rude operation at the best—the only effect observed is some slight diminution of the powers of the nervous system. We are obliged, therefore, to reject the hypothesis that the venous blood is utterly incompatible with life, though it evidently possesses inferior stimulating and nutritious powers, when compared with arterial blood. This hypothesis rejected, the phenomena of Asphyxia remain unexplained. The experiments which overthrow the theory of Bichat also supply a solution of the question at issue.

All the organs of the body consist of a congeries of small blood-vessels, denominated from their minuteness capillaries. These vessels are possessed of peculiar powers, by which, in a healthy state, they only admit fluids of a certain quality, and exclude those which are incompatible with the functions of the part. They even resist the forcible introduction of foreign fluids, when injected with a syringe; by which means a force much greater than that exerted by the heart is usually applied. Membranes, so thin as to be quite transparent, and not only lying contiguously to each other, but closely united by cellular tissue, circulate in their minute vessels fluids of a totally different character; and sometimes different vessels, occurring in the same line of succession in an organ, contain different fluids. In the lungs, minute blood-vessels exist in an exquisitely delicate net-work, forming the lining membrane of the air-cells. In these vessels the venous blood is exposed to the influence of the atmospheric air. Here, its qualities are changed, it loses its dark colour and acquires a bright red hue, and hence, it is probable that the vessels in which the arterial blood circulates must differ in their peculiar sensibilities from those which propel the venous blood. The laws generally observed to regulate the action of the small vessels in other structures would be violated, if the vessels which usually convey arterial blood were also able to convey, with equal facility, venous blood in every stage of its changes, until it acquires its darkest colour. When air is no longer inspired, a considerable quantity of this fluid remains in the pulmonary cells, and as long as this air contains a certain proportion of oxygen, the blood still undergoes its proper change in the pulmonary vessels from the dark venous hue to an arterial redness, and consequently, the circulation proceeds with its ordinary activity; but as the proportion of oxygen is diminished, the blood ceases to acquire the bright vermilion colour, and becomes gradually darker. As this change proceeds, the circulation becomes more feeble and slower at each successive step of the change, until when venous blood enters those vessels which formerly conveyed arterial blood only, this degenerated fluid is no longer able to excite their action, and the circulation stagnates in the structure of the lungs. The pulmonary veins then discharge their last meagre supply through the left auricle into the left ventricle, which propels its last and feeblest tide into the arteries, in which the circulation has, every moment, become more scanty, until the pulsation has gradually been extinguished.

The theory of Bichat supposes that the heart, the muscles, the nervous system, and the other organs are poisoned by the circulation of the venous blood in their structure. Direct experiments, already adverted to, prove that though the venous blood is less capable of maintaining the vitality of these organs than the arterial blood, yet, that it exerts no positively noxious influence on their functions. Edwards also discovered that those reptiles, in which the circulation of venous blood is permitted to proceed when they are deprived of air, live much longer than others, in which it is under similar circumstances prevented. Moreover, I found that when respiration and the circulation of blood are arrested, the irritability of muscles may be maintained for a considerable period longer, than it would otherwise survive, by producing congestion in their tissue by putting a ligature on the vein receiving blood from them. The heart, so far from being rendered less irritable by the presence of venous blood in its structure, retains its irritability longer when this fluid fills its cavities, and when a certain congestion of its fibres is produced by retarding the exit of the venous blood from the small veins of its tissue. If the irritability of the heart could not survive the circulation of this blood through its fibres, the circulation ought to be arrested in the left auricle and ventricle; and their cavities and the pulmonary veins should be found congested with this fluid. On the contrary, the left ventricle is invariably found contracted, and containing no more blood than that which moistens its parietes. In the left auricle accumulate the last drainings from the pulmonary veins; but this supply is so inconsiderable as to be unworthy of notice, and the pulmonary veins themselves are always empty. The obstacle to the circulation does not therefore exist in the heart, but in the lungs.

The venous system, the right side of the heart, and the pulmonary artery (conveying the venous blood from the right ventricle for exposure to the air in the lungs) are extremely congested with this fluid; but it does not permeate the lungs, and on the other side of the impediment which prevents its progress through the pulmonary tissue, the veins which generally convey arterial blood from the lungs, and also the left cavities of the heart and the arteries are empty.

The view of the phenomena of Asphyxia, inevitably suggested by these facts is of the utmost importance, as otherwise we should be obliged to regard with the utmost suspicion every account of resuscitation, by means of an artificial supply of air to the lungs. Were the theory of Bichat correct, no such hope could be entertained, because the introduction of oxygen into the air cells could not change the character of the blood existing in the pulmonary veins, in the left cavities of the heart, and in the internal structure of every organ. The heart, paralysed by the deleterious influence of this fluid, would be unable to assist in propelling red blood into its own structure, by which alone its irritability could be restored, even could the red blood, generated in the lungs, pass the pulmonary veins without losing its properties by admixture with the venous blood, which, according to

Bichat's theory, must fill these veins. The nervous system, poisoned by the same pernicious influence, would be unable to assist in promoting the changes which usually occur in the lungs during respiration—which changes could not proceed without its aid. Were this theory of Asphyxia correct, we should be obliged to abandon the most efficient method of restoring suspended animation, first practised by the celebrated Hooke—that of applying the most appropriate remedy (a supply of oxygen) immediately to the seat of the disorder, the capillary vessels of the lungs. Yet Bichat himself gives us a most beautiful illustration of the effects of this remedy, in the experiment already alluded to. "If a stop-cock," says this celebrated man, "be adapted to the trachea exposed and divided; and afterwards be shut, the blood becomes darker, and springs for some time with its usual force" from a divided artery; "but at length the jet becomes gradually feebler; *re-admit the air*, the blood becomes almost immediately red, and its saltus rapidly increases." In this experiment, the exclusion of air is not continued so long as to produce a perfect abstraction of the oxygen remaining in the air cells, when the stop-cock is closed; nor to extinguish the respiratory powers, the manifestation of which is resumed as soon as the stop-cock is re-opened. The blood changed in colour, but not yet so much impaired in its qualities as to be unable to traverse the lungs, still circulates, and air is admitted at a moment when the danger of the occurrence of Asphyxia is imminent, but when the respiratory powers and the organic functions are still supported, by a blood partially oxygenated.

Death occurs in Asphyxia, because, the air not being admitted into the lungs, the changes which are necessary to the transmission of the blood though their structure no longer ensue, and the circulation gradually becomes feebler, and is at length arrested in the capillaries of the pulmonary tissue. Before this result takes place, the blood by degrees assumes more and more of the venous character, until its qualities become incompatible with the activity of the minute vessels of the lungs. A certain quantity of dark blood, not so changed as to be inconsistent with vital action, is transmitted by the heart and arteries to all the organs of the body, and circulated through the nervous system and muscles; but it is found that this fluid, far from destroying the vitality of these parts, maintains the life of the muscles for a certain time, though comparatively in a feebler manner; and it is also discovered that though it is deficient in stimulus to the nervous system, and is not capable of supporting the greatest activity of the nervous power, it has no positively noxious influence on it. The cause of death in Asphyxia is the arrest of the circulation, but during the supply of the darker blood to the organs (as it is deficient in stimulating and nutritious qualities,) and the rapid diminution of the supply of even this fluid, the functions of every part are enfeebled, and sense and voluntary motion extinguished, before the circulation has actually ceased.

We must therefore regard the chief indication, in treating Asphyxia, to be the restoration of activity in the capillaries of the lungs, by supplying the blood contained in them with oxygen. As this may sometimes be accomplished by exciting natural respiration, without the artificial injection of air; but by means calculated to restore the activity of the respiratory system of nerves and muscles, it is desirable, before we dismiss from our attention a consideration of this state of the circulation, that we should inquire how the organs are affected by it. Every tissue is dependent on the nervous system for a supply of the nervous influence necessary to its nutrition, and to the peculiar function exercised by the part. Thus the power of contraction possessed by muscles is inseparable from the influence of the nerves on their fibres. Besides this relation, the healthy condition of the organs cannot be supported without a constant supply of blood. The powers of the nervous system are, in Asphyxia, primarily affected by the deficient supply of this fluid, and by the diminution of its nutritious and stimulating qualities; and every organ suffers secondarily from the loss of energy in the nervous influence which it enjoys in a healthy state, as well as from the want of its own natural supply of blood. Every organ ought therefore, in this enfeebled state, to be placed under the influence of those agents which are most conducive to the support of its enfeebled powers, and every thing likely to occasion their exhaustion should be avoided.

A consideration of the causes which affect the duration of life in young animals, and in the cold-blooded, will afford us some data on which to proceed in speaking of adult warm-blooded animals.

The circulation of the fœtus, or embryo, differs from that of the adult, inasmuch as the current of the circulation, proceeding from the right side of the heart to the left, does not pass through the lungs, which are yet unexpanded by the respiratory process, but is conducted by two short channels; one being a communication between the pulmonary artery and the aorta—the great artery which rises from the left ventricle; and the other, consisting in an opening permitting the blood to pass freely from the right into the left auricle. Thus, the torrent of the circulation passes directly from the right to the left side of the heart, without going through the lungs. As the fœtus in *utero* cannot respire, its blood is supplied with nutritious and stimulating qualities by an organ attached to the uterus of the mother, and consisting of a spongy mass of vessels, denominated the placenta. In this organ, the blood of the fœtus undergoes changes which supply the want of those ordinarily effected by respiration. At birth this connection ceases, and it is then necessary to the life of the child, that respiration should commence.

But certain peculiarities in young animals render them capable of enduring the want of air, immediately after birth, for a longer time than adults. This depends on two circumstances; the peculiarity of their fœtal circulation, which continues active for some time, even when respiration is not established, because it is not interrupted by any obstacle in the lungs. And secondly, young animals are endowed with a faculty of producing heat inferior to that of adults; and the constant supply of a highly oxygenated blood is therefore less necessary to them. The venous blood which continues to circulate in their organs supports life for a considerable period.

When the connection of the fœtus with the mother is dissolved immediately after birth, the blood of the infant ceases to derive nutritious qualities from that source, and unless respiration commence, its circulation continues to be carried on for some time by the fœtal channels, which conduct it from the right to the left side of the heart. It does not encounter the impediment which occurs in the lungs of adults when respiration is prevented, because the lungs not having yet been expanded, and the fœtal channels remaining pervious, the circulation is conducted through these openings. Hence, though the vital qualities of the blood are diminished, it continues to be propelled into all the organs, and supports life for a longer period than it would continue, if the access of this blood to them were prevented. The faculty of producing heat is more feeble in young animals than in adults, and Edwards found that this peculiarity is always connected with the power of retaining life for a longer period when respiration is suspended, than when the animal heat is greater. The organs of an adult warm-blooded animal speedily become enfeebled, and cease to act from want of stimulus, when supplied with such blood as would support life long in an animal producing less heat.

This peculiarity also bears a direct relation to the natural temperature of young animals, and in this respect they are divided into two classes. The first class consists of those which produce so little heat that they may be said to have no proper temperature, but are influenced by that of external agents, and therefore generally assume the temperature of the surrounding atmosphere. The second class consists of those which generate sufficient heat to preserve an elevated temperature, when the air is not too cold. The first of these classes, in the mammiferous animals, is born with the eyes closed; with obtuse senses and feeble powers of motion; and is dependent on the care of the mother for the preservation of the heat necessary to life. In birds, a class resembling this has little down and no feathers when hatched, and is unable to move from the nest and seek food. Birds of this class preserve their warmth by mutual contact, the protection of the nest, and the heat imparted by the parent birds, who brood over them. In young animals, having feeble powers of producing heat, the circulation proceeds and life is maintained for a considerable period without respiration. Buffon even thought, that by repeatedly immersing young dogs in water immediately after birth, the channels through which the fœtal circulation proceeds might be kept open, and the power of existing beneath the surface without air preserved to adult age. He did not, however, observe, that, though life continues, sense and voluntary motion are soon extinct, when these young animals are deprived of air; and he did not know, that, as they soon acquire a power of generating heat equal to that of the adult, they speedily cease to exhibit the surprising faculty of existing so long without respiring. In the experiments of Buffon, puppies lived half an hour under water, immediately after birth; in those of Legallois, the mean duration of life in young rabbits, under similar circumstances, was twenty-eight minutes; and Edwards has sometimes, though rarely, seen new born puppies live fifty-four minutes under water. The second class of young animals, born with more mature senses and powers of motion, and a superior faculty of producing heat, die much sooner when deprived of air. The infant is in this class, and with so precarious a tenure of vitality at birth, it is of the utmost importance that the influence of external agents on the duration of its life, when respiration does not commence, should be determined.

Of these agencies, one of the most powerful is external temperature. Kittens a day or two old died in four minutes and thirty-three seconds when immersed in water at 32° Fahr.: at 50°

Fahr. their life extended to ten minutes and twenty-three seconds: at 68° Fahr. its duration increased to thirty-eight minutes and forty-five seconds; and at 86° Fahr. a retrograde course commenced, they lived twenty-nine minutes; and at 104° Fahr. life continued only ten minutes and twenty-seven seconds.

A temperature which would produce the sensation of cold in warm-blooded animals—since it is 36° Fahr. below the mean of their temperature—is therefore most conducive to the preservation of life in the young of this class, when they are deprived of air. A warmer or a colder external medium has a deleterious influence. Edwards, to whose ingenious experiments we are indebted for these very important practical results, concludes that the remarkable influence, thus shewn to be exerted by external temperature on the duration of vitality in Asphyxia in young warm-blooded animals, extends to every period of life.

Without descending, in this popular summary, to those more minute particulars, which are narrated in the body of the work, and which might embarrass the general reader, it may be sufficient here to state, that, from the effects produced by the exposure of the hybernating animals when in a state of torpor to a long continued external cold, and subsequently immersing them in cold water, it is evident that temperature exerts a similar influence on the duration of life in Asphyxia in the superior classes of animals. But the means of observing the influence of these agencies is necessarily more limited in the warm-blooded than in the inferior classes; because they are generally unable to bear so great a reduction of temperature, or to endure so long an exposure to a more moderate cold, as hybernating, or cold-blooded, animals. The experiments of Edwards, however, indicate that the duration of life in Asphyxia in warm-blooded animals, is greatest, when the power of producing animal heat is most feeble, and when the body is exposed to a mean temperature; but that very great cold, and more than moderate warmth, are prejudicial.

The most intimate relation subsists between animal heat and respiration. An elevated temperature cannot be maintained in any race of animals, unless their respiratory organs enable them to expose the blood freely to the influence of the atmosphere. Those animals which consume the greatest quantity of air, and have therefore the greatest natural heat, are least able to bear a deprivation of the supply of oxygen. Young animals and the cold-blooded consume less oxygen than the warm-blooded, and in hybernating animals the state of torpor is distinguished by the slowness and infrequency of their respiratory movements. The state of the organization, therefore, which produces the greatest quantity of animal heat, requires the largest supply of air, and is least able to endure the deprivation of this supply. The batrachian reptiles are able to live under water with no more air than that which is contained in the water itself, and which acts solely on their skin. By this cutaneous respiration alone, and with the smallest quantity of air, these animals live, provided the temperature do not sink lower than 32° Fahr. nor rise higher than 50° Fahr.; but if the external temperature be greater, they require a greater supply of air, and if not then permitted to come to the surface to respire, they die. During the winter, and at other seasons, when the thermometer is below 50° Fahr., these animals live at the bottom of ponds and marshes; but when the mercury rises above this degree of heat, they are obliged to come to the surface, and the more frequently as the temperature is greater; until, at a certain heat they can endure the want of pulmonary respiration for so short a space of time, that they generally leave the water, and bring both the lungs and the skin in contact with the atmosphere, without which double exposure, they would die in great numbers. At this temperature they are not able to support life, without air, much longer than the warm-blooded animals.

The increase of heat establishes the same relation with the external air in them, as a naturally high temperature in the warm-blooded animals, and renders their need of a due supply of oxygen nearly as urgent.

The same phenomena are observed in fish, they can live below the water only in winter; but as the heat increases, they are obliged, in proportion as their sensibility to the influence of heat is greater, to rise the more frequently to the surface to respire.

Similar effects ensue in attempts to limit the supply of oxygen. Thus, frogs can live a considerable time enclosed in plaster during winter, supplied by the small quantity of air which penetrates this envelope; but, in summer, they perish in this situation, almost as soon as when plunged in water. In young warm-blooded animals also, the same relation between external heat and respiration is observed.

In the application of these remarkable facts, I solicit attention to the following comments of Edwards. "We shall now," he says, "apply this principle to adult age, and particularly to man. A person is asphyxiated by an excessive quantity of carbonic acid in the air which he breathes;

the beating of the pulse is no longer sensible, the respiratory movements are not seen, his temperature is still elevated. How should we act to recal life? Although the action of the respiratory organs is no longer visible, all connection with the air is not cut off. The air is in contact with the skin, upon which it exerts a vivifying influence; it is also in contact with the lungs, in which it is renewed by the agitation which is constantly taking place in the atmosphere, and by the heat of the body which rarifies it. The heart continues to beat, and maintains a certain degree of circulation, although not perceptible by the pulse. The temperature of the body is too high to allow the feeble respiration to produce upon the system all the effect of which it is susceptible. The temperature must then be reduced; the patient must be withdrawn from the deleterious atmosphere, stripped of his clothes, that the air may have a more extended action upon his skin, exposed to the cold, although it be winter, and cold water thrown upon his face until the respiratory movements reappear. This is precisely the treatment adopted in practice to revive an individual in a state of Asphyxia. If instead of cold, continued warmth were to be applied, it would be one of the most effectual means of extinguishing life. This consequence, like the former, is confirmed by experience."

"In sudden faintings, when the pulse is weak or imperceptible, the action of the respiratory organs is diminished, and sensation and voluntary motion suspended, persons the most ignorant of medicine are aware that means of refrigeration must be employed, such as exposure to air, ventilation, sprinkling with cold water. The efficacy of this plan of treatment is explained on the principle before laid down."*

I have endeavoured to trace the steps by which this position is obtained with as much brevity as possible, though I have been more minute in my account of the researches which have led to this result than I should have been, had not the conclusion to be derived from them possessed such great practical importance. I am inclined, not to confine the principle deduced from these experiments to Asphyxia produced by the influence of carbonic acid gas, or to syncope; but to extend it under certain modifications to the treatment of suspended animation from drowning. These researches would induce me to reject the employment of a temperature so elevated as that recommended in the Royal Humane Society's directions

* P. 149 of Dr. Hodgkin's "Edwards Sur l' Action des Agens."

for the recovery of persons apparently dead. The directions given in the Society's last printed report, concerning the application of heat, are inserted at the foot of the page.* They appear to me to be liable to two objections, which, with the hope that my observations may not be considered presumptuous, I venture to offer through your Grace to the attention of the Society.

The temperature to be employed is sufficiently indicated in the recommendation, that the body

* "HEAT.—While some assistants are engaged with artificial respiration, others, we have already hinted, should be employed in communicating continued heat to the body. Dry warm blankets, bags of warm grains, or sand bladders, or bottles of hot water, or hot bricks, or hot blankets wrung out of hot water, are amongst the means most easily obtained. The body may be placed before a fire, or in the sunshine, if strong at the time. Whatever may be the means employed, the restoration of warmth should always be assiduously pursued. Should the accident happen in the neighbourhood of a steam-engine, brew-house, bake-house, or any fabric where warm water may be easily procured, it would be of great importance to place the body in a warm bath, moderated to a degree of heat not exceeding one hundred degrees. The warmth most promising of success is that of a heated bed or blankets. Bottles of hot water should be laid at the bottoms of the feet, to the joints of the knees, and under the arm pits; and a warming-pan, moderately heated, or hot bricks wrapped in cloths, should be passed over the body, and particularly in the direction of the spine. A large bladder should be applied, filled with hot water, and inclosed in flannel, to the region of the stomach and heart. The natural and kindly warmth of a healthy person, lying by the side of the body has been found, in some cases of adults, and particularly of children, very efficacious; but the warm bath, where it can be procured, is preferable to all other means of communicating heat."

*Royal Humane Society's Report*, 1833, *p.* 100.

should be placed "in a warm bath moderated to a degree of heat not exceeding one hundred degrees;" and in the directions given concerning the application of "continued heat" to the body, by means of "bottles of hot water, hot bricks, or hot blankets wrung out of hot water."

The temperature thus recommended would be too high if the directions were implicitly obeyed, and, when the treatment of such cases is entrusted, as it often necessarily is, to the ignorant, the enfeebled vital action of some important organ is in danger of extinction from the rash application of such remedies as hot bricks, and bladders full of hot water to the stomach, or from immersion in too hot a bath.

The Society also directs that the body, when taken from the water, stripped, and dried, should be *re-clothed;* and in the section concerning the application of heat, the importance of exposing the whole surface to the influence of the air is again neglected, since immersion in a bath at 100 degrees, and wrapping the body in hot blankets wrung out of hot water, are recommended. The free access of air to the skin is of such importance, that it can only be superseded by those more efficient means which cannot be applied without preventing cutaneous respiration. The requisite warmth may, however, be employed without depriving the body of the influence of this powerful agency. A proper temperature may be applied to the spine and back, by the tin mattresses, filled with warm water, recently used in the Cholera hospitals. In addition to this means, the warmth of an apartment in which the temperature ranges from seventy to eighty degrees, or, exposure to the influence of a warm fire, are sufficient sources of heat; especially, as this mode of applying warmth to the body does not interfere with friction of the surface, nor with cautious but persevering attempts to restore life by artificial respiration, and leaves the skin exposed to the vivifying influence of the external air. Heat has a direct action on the nervous system, and a due regulation of the external temperature, is chiefly of importance as a means of preserving and invigorating the nervous energy in the various organs. When exposed to a low temperature, the powers of the nervous system are depressed, and too great heat exhausts them. The temperature of the external medium, however, chiefly exerts a conservative influence, and the action of the air on the skin in rousing the action of the capillaries and imparting oxygen to the blood—friction, and other remedies—and above all, artificial respiration, are the efficient means of restoring suspended animation.

The effects of external temperature on the duration of life in new born animals deprived of air are shewn by the experiments of Edwards. The infant ought, therefore, never to be exposed to a high degree of heat. Young dogs are found to live longest when immersed in water at 68° Fahr., and it would be improper, without other facts, to subject the still-born infant to a much greater warmth than this. As this temperature may be easily obtained without immersion in water—which has a deleterious influence on the nervous and muscular systems, and prevents the free exposure of the skin to the external air, and the employment of other means to excite respiration—the bath ought never to be used in attempting to revive infants which have not breathed. Resuscitation in such cases will be best accomplished by inflation of the lungs, alternated with pressure on the abdomen and chest—by moderate friction of the body with the hand—by the application of stimulants to the nostrils, temples, and pit of the stomach;—and by gentle agitations, as described in the Royal Humane Society's directions.

The theory announced in this work, to explain the changes which occur in the organs when the body is deprived of air, emphatically proves the paramount importance of introducing fresh air into the air cells of the lungs as early as possible. In Asphyxia from submersion, the air contained in the lungs is deprived of almost all its oxygen —an element necessary to the production of those changes in the blood, which must occur before it can circulate through the lungs. Other changes also occur in the last agony which are worthy of notice. Owing to the extreme congestion of the pulmonary artery, and of the capillary vessels of the lungs in which it terminates, and the *vis a tergo* communicated to the mass of blood by the contractions of the right ventricle, and by the irregular motions of the chest itself, a considerable quantity of mucus sometimes suffuses the lining membrane of the bronchi and air-cells; and occasionally this effusion occurs in such quantities as to form a serious impediment to the restoration of the respiratory process. On the insufflation of air, it mingles with this mucus in the small or great bronchi, and forms a frothy fluid, which prevents the proper access of air to the capillaries of the lungs. At other times, the throat and larynx are choked with a spumous matter ejected from the windpipe, during the last efforts to respire, and which may be more easily removed. Goodwyn and Meyer have also satisfactorily proved, that, during the last moments of life, the spasmodic action of the glottis is sometimes overcome, and that water then enters the bronchi; and Orfila has rendered it extremely probable that when the body remains long immersed, this accident generally occurs. But the quantity of fluid which enters the lungs is usually small, and it is very seldom found in the bronchi in quantities sufficient to occasion death, and then chiefly in cases in which submersion has continued so long as to prevent any hope of resuscitation being entertained. Before proceeding to attempt artificial respiration, it is, however, desirable to remove the mucus which may have accumulated in the mouth and throat; and then, by inserting a curved tube into the glottis (the opening from the throat into the windpipe) and by sucking the air through it, either with the mouth or with a syringe, to examine whether an accumulation of fluid may not have occurred in the bronchi, and to attempt to remove it by suction.

In all the directions given by the earlier, and even by more recent physiologists, who have written concerning Asphyxia, none of the dangers attending insufflation are anticipated. By reference to the chapter on Insufflation, in the body of this work, it may be seen, that in the inflation of the lungs, the latest authors recommend the employment of a force sufficient to distend the chest considerably. Until the recent researches of Leroy, no apprehension was entertained that the lungs might thus be injured, but the experiments which he has performed, so clearly exhibit the dangers encountered in this operation, that it is of the utmost importance to disseminate a knowledge of them as widely as possible, This may, I think, be accomplished, without weakening the confidence which ought to be reposed in the operation, and without preventing a prudent trial of it at the earliest moment after animation has been suspended. The Royal Humane Society have therefore, most properly, given some account of Leroy's experiments in their last two reports, but it is to be regretted that no sufficient caution has been embodied in their code of directions for resuscitating persons apparently dead. The Reports of the Society are neither widely diffused nor generally read, and the code of directions issued separately from the reports is implicitly obeyed by all who are not well acquainted with the most recent discoveries in physiology, and who have not an opportunity of perusing the Society's Reports. It is therefore of the utmost consequence that these directions should contain every thing that it is of importance to know—an object which may be accomplished without diminishing their simplicity or materially increasing their length. I hope, therefore, that I shall not be considered presumptuous, if, with the hope of assisting the diffusion of this information, I embody in this letter, a short account of the results of Leroy's experiments, referring to the body of this volume for more minute particulars.

Brisk insufflation of the lungs, which from the resistance of the parietes of the chest, implies the use of considerable force, is often fatal by rupturing the air-cells, and occasioning an effusion of air either into the substance of the lungs itself, or into the cavity of the pleura.

In either case the air-cells are compressed by the air effused, and the quantity which escapes into the cavity of the pleura is often so great, as to occasion the collapse of the lungs and the cessation of the respiratory movements. This result may be best comprehended by the general reader, if he suppose each lung to be a bag contained in the cavity of the chest; naturally distended with air and filling that cavity; and that by the escape of the air into the chest, on the rupture of this bag, its collapse occurs.

The natural respiratory movements are very gentle, and only a very moderate quantity of air is drawn into the lungs and expelled, at each successive inspiration and expiration. The inspired air descends, without any increased pressure, into the chest when it is expanded, and very little force is employed to expel the air. But inflation of the lungs is resisted by the weight of the contents of the abdomen pressing against the diaphragm, and by the pressure and rigidity of the parietes of the chest; and, if force be employed to overcome the resistance, the air-cells of the lungs are generally ruptured. This fatal result is produced in animals, even when the chest is expanded only by the force of an expiration from the human lungs.

It is, therefore, very important that insufflation should be performed by experienced persons only, and by them in the most cautious manner. M. Leroy was naturally so much impressed by the result of his experiments, that he invented a bellows, provided with the graduated arc of a circle, on which he marked the quantity of air proper to be injected into the lungs of patients at different ages. This quantity he determined by previous experiments on the natural respiration of children and adults. He also invented curbed tubes to be inserted into the glottis, through which to inflate the lungs. These tubes have a different caliber, according to the age for which they are intended, rendering it impossible to introduce the proper quantity of air (as indicated on the arc of the bellows) more rapidly than it would be inspired.

By means of these two instruments, insufflation may be performed with perfect safety, if care be taken to produce an expiration after each inflation of the lungs, by pressing on the abdomen and chest. But if the process of artificial respiration be entrusted, without them, to inexperienced persons, it is an operation of the utmost danger. Even in the hands of skilful surgeons, during the hurry necessarily attendant on the use of means to restore life suspended by a frightful accident, the bellows may often be resorted to with too great eagerness, and used with too little caution, unless Leroy's graduated arc and tubes be employed. Insufflation by the bellows ought, therefore, to be interdicted to every unprofessional person, and the use of these new instruments ought to be recommended to every surgeon.

Another pernicious practice ought to be extinguished, since the results of these researches have been published. From the difficulty sometimes experienced in attempting to introduce a curved tube into the glottis (the natural opening from the throat into the windpipe), many experienced surgeons have recommended that an incision should be made in the throat, and the windpipe having been divided, that the nozle of the bellows should be inserted into it, and artificial respiration thus maintained. This is a coarse operation, offering such temptation to the employment of improper force in inflating the lungs, and actually requiring the use of so much power that it must be discarded. Mischief may also be done by an accumulation of air in the lungs, consequent on successive injections of air not followed by an expiration. This mode of inflating the lungs is peculiarly liable to this danger, because the nozle of the bellows must be somewhat tightly fixed in the windpipe, in order that injection of air may succeed; and this circumstance will prevent the egress of the air, unless the bellows be removed after each injection. Rupture of the lungs is often thus produced. This operation has the less excuse, since Leroy has invented an instrument to facilitate the introduction of the curved cannula into the glottis; but even when this cannot be accomplished, the dangers attending tracheotomy, and the force afterwards required to inflate the lungs through the divided trachea, render the adoption of some other method of supporting artificial respiration desirable.

The Royal Humane Society published in their report for the year 1832 some account of the result of Leroy's experiments, and very properly recommended a new method of imitating respiration, invented by this physiologist, which is free from all danger, and may be employed by the most inexperienced persons. The parietes of the chest consist of the ribs and certain cartilages which are elastic, and which therefore yield to a certain degree of compression. Leroy's method of producing an inspiration and expiration of air consists in reducing the size of the cavity of the chest, by a moderate but general pressure on the ribs and their cartilages and on the abdomen, and then permitting the air to re-descend into the lungs on the removal of this pressure. The elastic parietes yield, when drawn together by means of a bandage or when pressed upon by a superincumbent weight, but they immediately resume their former shape when this force is removed. Thus the cavity of the chest may be alternately diminished and again permitted to re-expand, and air alternately expelled and reinspired.

To facilitate the application of pressure to the parietes, for this purpose, Leroy has invented a simple bandage, which is described in the Society's report for 1832, and a second time also, in the directions given to the report for 1833—in which last report these directions are also accompanied by a wood-cut of the bandage as applied to the body of the patient. We shall shortly give a minute description of this bandage and of the method of using it.

These remarks premised, I hope I shall escape the suspicion of presumption, if I offer to the consideration of the Society, through your Grace, a series of directions for the treatment of suspended animation, in which I shall endeavour to interweave the results of recent researches with the treatment already recommended by the Society.

*General Directions for the Treatment of the Drowned.*—After the body is found, particular care should be taken to employ the means recommended by the Society, in the order in which they are described, and as quickly as possible; but, at the same time with a most careful abstinence from all violence and rough usage—an error into which the inexperienced may be led by laudable eagerness, especially in the hurry and confusion which too commonly occur on such occasions.

When the body is dragged from the water, the mouth and nostrils should immediately be cleansed. Sometimes, much frothy mucus will be found in the throat,—this should be carefully removed with a handkerchief tied round the finger. The wet clothes should be immediately stripped from the body, which should be wiped dry and clean, and then, without exposing it to a cold atmosphere one moment longer than it is necessary, it should be wrapped in a dry blanket. Cold depresses the vital energies, and should be avoided; and evaporation equally so, as it occasions great cold. The first object is therefore to make the body dry, and to avoid its exposure to the influence of a low temperature. These directions therefore, important at all times, are especially so in cold weather, and unless the body can be instantly carried into a convenient shelter, the wet clothes should be removed, and the body wiped and wrapped in blankets or dry clothes on the bank of the water from which it has been dragged. Generally, however, a house will be near the spot, and thither, without a moment's delay, the body should be conveyed.

In conveying the body the assistant should forbid its being lifted or carried by the shoulders and legs, because in this position the head is unsupported and its weight will hang forwards on the chest, or drag the neck backwards—both which postures are pernicious. The body may be best carried on a blanket; or on a board; (a door) or in a cart. A room containing a good fire should, if possible, be selected for the subsequent exertions of the attendants.

When the body has been conveyed to such a room, it should be immediately stripped, and laid upon a sofa—or on a board supported on chairs—or on a table of convenient height before the fire, but at such a distance as not to be scorched, whilst it is exposed to a warmth of seventy-five or eighty degrees. A greater degree of heat is injurious, because it exhausts the vital energies. Great care should therefore be taken that a higher temperature should not be even locally applied, excepting to the extremities, lest the vital power of some neighbouring important organ should be thereby enfeebled. During all the subsequent operations, *the head and chest should be raised, and the nostrils and mouth kept thoroughly cleansed and open.*

The chief means of restoring suspended animation are to take care that the body is exposed to that temperature, which is found, by inquiry and experience, to be most conducive to the support of the vital powers—and especially to attempt to re-excite respiration. Temperature has, however, little or no direct effect in *stimulating* the vital energies, and must be regarded as chiefly exercising a *conservative* influence. Too high a temperature exhausts, and cold depresses the nervous power of the body, when sense and motion are suspended; but a moderate warmth is most favourable to the continuance of those powers, on which we must depend for the restoration of life.

The influence of the air on the blood is the most effectual means of reanimating the apparently dead, and though this influence is most efficiently exerted, when the blood is exposed to fresh air introduced into the lungs; yet the skin itself is a medium through which the vivifying effects of the external air are so freely communicated to the blood circulating in it, that the body should be exposed, as much as possible, to a warm atmosphere, during the whole process of attempting its resuscitation. The desirableness of this exposure need not interfere with some of those processes from which great benefit is derived, such as friction, and which may be applied successively to different portions of the body. But when the convenient temperature can otherwise be obtained, the benefit resulting from free exposure to the air is so great, that it forms an objection to immersing the patient in a bath, especially as water exerts an injurious influence on the nervous and muscular systems.

The *preparatory measures* therefore are to cleanse the mouth and nostrils—to strip and dry the body with all possible dispatch—to put it in blankets, in order to prevent the effects of exposure to cold—all which may be accomplished on the spot, unless a convenient place be near; but, in this case, it is desirable to convey the body before it is stripped, without any delay, to a warm room, in which these directions should be immediately attended to.

The body should then be placed on a table, exposed to a genial warmth before a fire, but not scorched—nor heated beyond seventy-five or eighty degrees. The head, shoulders, and chest should be somewhat elevated, and the skin freely exposed to an atmosphere moderately warm.

In conducting the *Resuscitative Process*, it is of importance to remember, that though life cannot ordinarily be restored, when a man has been deprived of air four or five minutes, yet that, under some peculiar circumstances, this may be accomplished after a much longer period. Under the horror which affects the mind of any one exposed to a frightful accident threatening existence, *fainting* often occurs, at the moment when the individual is plunged into the water; or, whilst struggling with his terrible fate beneath the surface, terror deprives him of consciousness, before the air in his lungs is exhausted. The state of the nervous power in fainting differs from that in Asphyxia, and when it is thus suddenly extinguished a considerable volume of air remains in the lungs, which supplies small quantities of oxygen to a feeble tide of blood, still circulated through them from time to time from the heart. Life may thus be maintained much longer in this state than in Asphyxia—in which last condition, the circulation is arrested in three minutes in the lungs, and when the powers of the nervous system are suspended, not from a frightful moral impression, but from the stoppage of a supply of blood by an impediment in the lungs. When therefore a person has fainted immediately before, or immediately after immersion in water, he may be restored after a much longer interval has elapsed, than he could be, if he were deprived of consciousness, simply from the interruption of respiration.

These cases cannot be distinguished by any known signs, it is therefore of importance that every case should have the benefit of the doubt which must exist concerning its character, and that the most unremitting and persevering efforts should be made to restore life, even after a considerable period has elapsed, and when all hope might otherwise appear to be extinguished. Instances of recovery after periods incredible, unless supported by the most unimpeachable testimony, are recorded for the encouragement of the benevolent in their laudable endeavours to restore life; and to warn the negligent, lest they incur the fearful responsibility of having abandoned a fellow-creature to his fate, from the want of sufficient perseverance.

In treating of the *Resuscitative Process*, the most important means demands our earliest attention. *Artificial Respiration*, as it introduces fresh air into the cells of the lungs, and thus imparts oxygen to the blood, and restores the circulation, is the chief method on which reliance must be placed in restoring suspended animation. In inexperienced hands, and when performed without due caution, this operation as formerly applied, by means of the bellows, is exceedingly dangerous. We therefore first direct the attention of persons, not possessed of the anatomical knowledge and surgical tact requisite for the proper performance of this operation, to a new method which may be safely, and often efficiently applied by the most inexperienced persons. The chest is elastic, and respiration may be imitated by alternately compressing the chest and abdomen, and then allowing them to re-expand. In order to obviate every difficulty which might be felt by inexperienced persons the Society has described in its last two reports, a bandage which may be conveniently used for this purpose, and of which an engraving is given.

A piece of strong flannel, an old blanket, sheet, or other cloth—most easily to be obtained at the moment—is to be cut of the following size, and in the following manner. It should be six feet in length, and in breadth eighteen inches. Six strips are then to be cut or torn lengthwise on each side. Each strip is to be three inches broad, and two feet long. The untorn portion (two feet in length and eighteen inches broad) is to be placed under the back of the patient, from the armpits to the upper part of the thigh bones. The strips are then to be brought together over the chest and belly, interlacing each other from the opposite sides, as the fingers are interlaced in clasping the hands. The strips thus arranged are to be gathered into a bundle on each side, and if they are then drawn in opposite directions by two assistants, the edges of the bandage will made to approach, and firm and equal pressure be produced on the chest and belly of the patient.

The assistants should thus compress the body of the patient by drawing the bandage in opposite directions, and should then relax it, permitting the chest to re-expand, and performing this process at the rate of twenty-five times in the minute. If the head and shoulders be elevated the contents of the abdomen will, on the relaxation of the pressure, cause the diaphragm to descend by their gravity, and will thus enlarge the chest. By applying the flame of a candle or the fine down of a feather to the mouth and nostrils, it will be readily seen, that, on each firm pressure of the body, air is expelled from the lungs; and upon the relaxation of this pressure, the chest regains its original size, and air rushes in.

In the absence of such a bandage, two or three silk handkerchiefs may supply its place, and, if applied in the same manner, will answer a similar purpose, though not so efficiently.

The other methods of producing artificial respiration can only be entrusted to persons possessed of a sufficient degree of anatomical knowledge, and aware of the danger which attends them when incautiously employed. The surgeon should be provided with a set of the curved cannulas invented by Leroy, and adapted to different ages, by means of which the too rapid introduction of air into the chest may be prevented. The bellows should also be provided with the graduated arc of a circle fixed in one handle, and passing through the other, on which should be marked the quantity of air which it is proper to impel into the lungs at different ages. Otherwise, without great caution, the operator is liable to the error of introducing too great a quantity of air into the chest at each impulse of the bellows, and even of introducing the proper quantity with too great rapidity and force.

The patient being placed in as convenient a position as circumstances will permit, the curved cannula should be introduced through the glottis into the windpipe. This may be more easily accomplished, by using an instrument invented by Leroy, which depresses the tongue and elevates the epiglottis. When this instrument is not at hand, the finger must be placed upon the root of the tongue, and the epiglottis having been raised by pressure on the tongue, the cannula may easily be introduced into the windpipe; for by passing it along the finger, it naturally slides into the glottis. The cannula having thus been introduced, the bellows, provided with a graduated arc, indicating the quantity of air proper to be introduced at different ages, should be attached to the tube. Previously to commencing inflation, if there be any suspicion that water has entered the windpipe, an effort should be made on the introduction of the cannula, to remove it by suction at this tube, with the mouth or with a syringe. Then the prominence in the neck (the larynx) being held backwards, and also compressed laterally between the fingers and the thumb of the second assistant, so as to grasp the cannula contained in it, air should be cautiously impelled into the lungs.

The lungs having been thus expanded by a moderate quantity of air, and the left hand of the second assistant having been previously placed lightly on the pit of the stomach, he should now compress the chest and belly, and expel the air which has been introduced. The operation thus described should be repeated regularly and steadily, until natural respiration begins, or until this and other measures have been persevered in for a long time. Dr. Curry recommends that these means should be continued "at least six hours without any appearance of returning life."

This is the most approved, and, unless in the most judicious and skilful hands, the only safe method of practising inflation. To men of great professional skill, and especially, when they are deeply embued with a consciousness of the dangers encountered in this operation, the common double-valved bellows and common curved tubes may be entrusted, when other instruments are not at hand. Such men alone can ever be permitted to inflate the lung from the nostril with common kitchen bellows, as has been formerly recommended and practised; but which operation should never be performed excepting in an extreme emergency, and then, with a caution and skill which few can be expected to possess. To the danger of rupturing the air-cells by violence, or by an accumulation of air in the chest, is, under these circumstances, added the risk of inflating the stomach and bowels with air, and thus compressing the lungs. The dangers accompanying this method are, therefore, so great that it is not described lest it should be rashly practised by improper persons.

An unnecessary and pernicious practice of opening the windpipe by making an incision in the throat, has been so frequently recommended by surgeons of eminence, that we feel compelled formally to oppose the authority of the Society to this method. It is unnecessary, as any surgeon competent to perform such an operation can introduce the curved cannula into the glottis. It is pernicious—because of the delay which it occasions; of the hæmorrhage which often occurs; and of the difficulty of preventing the blood from entering the windpipe; and particularly, because of the temptation thus offered to the use of greater force than is proper in the introduction of air into the chest, and the great risk that an accumulation of air in the lungs may be produced; and because the wound produced is extremely dangerous, even if life be for a time restored.

*Temperature.*—While artificial respiration is thus supported, the body should be exposed to the external air, provided a certain temperature can be maintained. This may usually be accomplished by an ordinary fire in a room of moderate size. If the room be larger, a screen may be placed round the table on which the body lies, to prevent the too rapid dissipation of the heat. Bottles containing warm water, heated bags of sand, or warm bricks, or a bladder filled with warm water, may be placed along the legs and arms, if the surrounding air be too cold, but great care should be taken not to apply anything heated above eighty degrees to the body itself, as a higher degree of temperature exhausts the vital energies. The natural and kindly warmth of a healthy person lying by the side of the body has been found, in some cases of adults, and particularly in children, very efficacious; but if this means interfere with the more important process of supporting artificial respiration, it should not be attempted. When, however, the bandage is employed for this latter purpose, the best way of applying warmth would be that a warm and healthy man should lie down at the side of the patient, as closely as possible to the body, or even that one should lie on each side.

The warm bath interferes with the exposure of the body to the air; and water exerts, in a certain degree, an injurious influence on the body. Therefore this means of preserving a proper temperature should not be employed, provided other methods can be adopted for this purpose without preventing exposure to the atmosphere.

*Friction.*—Friction with the warm hand, or with the hand clothed with warm woollen gloves, or flannel, should be applied chiefly to the extremities, and is useful in communicating a proper degree of warmth to the body, and in reviving the circulation in the small vessels.

*Stimulants.*—These means are employed on the supposition that the vital powers exist, and are in a state to be called into action. Irritation applied to the nose has considerable influence in exciting the action of the muscles concerned in respiration; for this purpose, the nostrils may be occasionally touched with a feather dipped in spirits of hartshorn, aromatic spirit of vinegar, &c. During the state of torpor which pervades the whole system when respiration has been suspended, all stimulating applications are useless, and, when they interfere with other means, prejudicial. When, from exposure to a proper warmth, and the use of means to excite respiration, sensibility has in some degree returned to the body, spirit of hartshorn, or equal parts of this spirit and salad oil, may be rubbed on the wrists, ancles, temples, and parts opposite the stomach and heart. When the signs of returning life are somewhat more evident, a moderately warm and stimulating liquor may be introduced into the stomach by means of a syringe, and flexible tube; such as *half a pint* of warm negus, or water with spirits of hartshorn, or essence of peppermint. Until the power of swallowing is pretty well restored, it will be dangerous to attempt getting fluids down the throat in any other way. A clyster of two or three pints of water moderately warmed, with the addition of the materials beforementioned, or of rum, brandy, or gin, may be administered as early as possible after the body is removed from the water.

*Bleeding* can be permitted in suspended animation only when it is performed with the utmost caution. The right side of the heart and the venous system conducting the blood to it are, from the stoppage of the circulation through the lungs, so gorged with blood, that the abstraction of a certain quantity from the jugular vein may often be useful. The extreme congestion of the heart interferes with its action, and though, when more moderate it supports the contractile power of this organ, yet, when excessive, it has a tendency to exhaust that power. But in ex-sanguine and thin persons, in whom the mass of blood is less, and the accumulation consequently not so great, a smaller abstraction of blood may suffice, even if it be necessary at all. These circumstances can only be rightly decided upon by a professional man, and this operation should, therefore, never be performed by an inexperienced person.

When Asphyxia is produced by *suspension*, it is especially useful to abstract blood. When reanimation has taken place, a slight degree of excitement not unfrequently occurs, and symptoms of inflammation appear, which require the use of the lancet. In such cases, the quantity of blood taken away must be regulated by that discrimination concerning the symptoms and the constitutional powers of the patient, which can only be exercised by the medical attendant.

Concerning other parts of the directions issued by the Royal Humane Society, I have fewer suggestions to offer, and I beg, therefore, to defer the consideration of them to the chapters most appropriate to them in the body of this work. Galvanism has frequently been recommended in the treatment of Asphyxia, but without any precise notion of the benefits to be derived from it. It has been vaguely imagined that the nervous energy might thus be excited, the action of the heart roused, or the respiratory motions stimulated; and for these different purposes it has been directed to be as variously applied. Leroy has, however, devised a simple method of employing this powerful agency, which deserves the serious consideration of the Society, and a description of which will be found in one of the ensuing chapters.

Should the Society decide to recommend this plan, it would be desirable to furnish stations with galvanic apparatus, and a very few plates would be necessary for each station.

Having thus completed this popular sketch of the physiology of Asphyxia, and its application to the treatment of the most common form of suspended animation, I must content myself with referring the reader to the succeeding chapters for more minute information on this subject. I shall endeavour to confine myself, as much as possible, to a consideration of the simplest forms of Asphyxia, because my design is chiefly to shew the connection which subsists between some recent discoveries in physiology and the treatment of this state; and because their application to these simpler forms of suspended animation having been exhibited, it will be very easy to apply the same rules to more complicated states. It is the less necessary for me to advert to the effects of the poisonous gases, because Dr. Christison, in his recent admirable work on Poisons, has treated that subject in a manner which, in the present state of our information, leaves little or nothing to be added.

Trusting that I shall obtain from your Grace, and from the other distinguished members of the Royal Humane Society, the most favourable construction for the motives which have induced me to present this letter to the Society,

I beg to subscribe myself,

Humbly and respectfully,

Your Grace's faithful Servt.

J. P. KAY.

*Manchester,*
*March,* 1834.

THE

# PHYSIOLOGY AND TREATMENT

OF

# ASPHYXIA.

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## CHAP. I.

Asphyxia, a term derived from σφύξη, *the pulse,* with the privative *a,* and whose literal signification is therefore simply the loss of pulsation indicating a cessation of the heart's action, has, by modern usage, been employed to distinguish that form of pulselessness which is produced by any cause preventing the decarbonization of the blood accomplished by respiration. Syncope differs, as we shall afterwards show, in some important respects from Asphyxia, though few external signs exist by which these states can be discriminated, when the circumstances occasioning them are similar, or when they are not known.

Respiration can be suspended for a very short space of time, ere alarming symptoms supervene. The first effect of the deprivation of air is a sensation of embarrassment in the lungs accompanied by a desire to breathe, and by convulsive efforts to expand the chest. This internal agony rapidly increases, until, in cases in which the experiment is voluntarily made, it subdues the most resolute. But if air be excluded, a short interval only elapses ere vertigo and cerebral oppression ensue, followed by a torpor which benumbs every sense. The face and lips become livid, and the surface generally more dusky than the natural hue. The pulse is rapidly enfeebled, and is soon extinct; first, in the extremities, and afterwards in parts nearer the center of the circulation. As pulsation fails, consciousness and the faculties of sensation and motion are impaired; until, at the expiration of three or four minutes, voluntary motion and feeling are extinguished. About the same time, the last feeble tide of blood flows from the heart into the larger arteries, and the motions of that organ afterwards consist only of irregular contractions of the right ventricle on its contents, and of the expiring efforts of the left ventricle and auricle emptied of blood, and whose cavities are gradually diminishing.

The body is then at rest—the limbs relaxed and motionless—the organic heat gradually fails, and the face wears the last expression of the agony of the mortal struggle. To a superficial observer, all the functions seem to have expired, from the moment in which the faculties of sensation and motion and intellectual consciousness are abolished; but the organic life of the tissues still continues some time, and physiologists observe that the bodies of persons asphyxiated preserve their temperature long. From this fact alone, it may be presumed that the minute vascular motions on which nutrition and secretion depend continue active for some time, though they soon become weaker and occasion a less perfect elimination of caloric. Moreover, the functions of the various organs may often be restored, after this state has been for some time established. Though voluntary motion and the action of the heart have ceased, the contractility of this organ and of the voluntary muscles continues, and may be excited by appropriate stimuli; and, in other structures, the apparent death is not real. Though the action of many organs has been changed, so as to be incapable of giving evidence of life by its natural phenomena, an action continues which supports a mode of life peculiar in its phenomena, and sometimes so long, that, by the use of means to restore the function of the lungs and circulating system, the natural actions may be revived. In a similar way, a depression of the skull may suspend voluntary motion and sensation. The motive power, however, still continues in the muscles, but is not exercised from the want of a volition; and consequently no evidence of the surviving contractility transpires, unless the powers of the motor nerves and of the muscles are excited by artificial stimuli.

We may also conceive that, during suspended animation, motions may be excited in the nerves of sensation by external stimuli; which would have so affected the cerebral organs as to have produced sensation, had not the action produced in the brain by these agents been so morbidly changed, or so feeble, as not to have acted on the mind in such a manner as to cause sensation.

The changes necessary to support the functions of different organs cannot occur without corresponding motions. Whether these motions take place in simple fibres, or in secreting vessels, or in organic molecules, it would be perhaps impossible to determine, and for the purpose of our present argument it is unnecessary to inquire. That motion which supports the most healthy condition of any organ must be considered natural. All other motions must be less capable of supporting the function, and in proportion as they differ from the normal movement they will tend to suspend the proper result of the organic action. They thus become morbid, and we may conceive them to become so much so, as altogether to change the proper results of the organization, and to pervert the function of the part. This may occur in any tissue in the body. The phenomena of all may be thus changed, and though it is improbable that organs, the accordance of whose action supported a life of certain phenomena, would be capable of assuming different actions, and still preserve the balance of their activity, so as to act together for any great length of time in the support of a life of different phenomena; yet we may conceive this to happen for a considerable period.

In the following pages, the minute detail of the phenomena will be exhibited. Actions, it will be discovered, continue in Asphyxia for a considerable period in many of the organs—in some, longer than the time in which any instance of the resuscitation of natural phenomena has occurred—and the capability of action on the application of stimuli survives the moment when actual motion ceases. Asphyxia is a mode of life possessing few of the usual phenomena of animation, but in which vital actions proceed during a certain period in all the organs; which actions are susceptible of being changed, by peculiar methods of treatment, into those which exhibit the usual phenomena of life.

The death of the body, as distinguished from the organic death of the tissues, consists in the disunion of the intellectual principle from the corporeal organization.

This connection is maintained by various peculiar intestine motions in the various organs, but many facts indicate that the brain is the intimate residence of this mysterious tenant. The intestine actions of the brainular mass may be primarily or secondarily affected, that is, by the previous lesion of other organs, or without their lesion; but, until these organic motions become such as to disunite the immaterial intelligence, life continues, though none of the usual evidence of its existence be given by phenomena of which the senses can be cognisant. But, as we cannot conceive, that when once the union between mind and matter has ceased, the intellectual principle can be recalled to the corporeal organization—all states in which resuscitation is said to take place must be only apparent death, and the revival consists in a change from those morbid actions which suspended the usual phenomena of life, to those natural organic motions by which its usual functions are supported.

Asphyxia differs from death, therefore, as in it the minute actions of all tissues continue such as to support the connection with the intellectual principle. Although in death, as after decapitation, (when we cannot conceive the intellectual principle to be connected with the corporeal organization) contractility and nervimotion long survive, and minute organic movements are continued, yet, they have lost that portion of the organization which maintains the union with the intellectual principle. Whilst life yet remains, the minute actions may be so morbid, that no means can revive those by which life can be supported for any period, and then death is certain. But the separation of the intellectual principle from the corporeal organization may take place, long before all motion has ceased, and then death has ensued; yet as life may be restored in the early stages of Asphyxia, it follows that death has not happened, and that this state must be regarded as life peculiar in its phenomena.

Asphyxia is produced by causes which prevent the entrance of air into the lungs, or which make the air so impure as to render it unfit to sustain life, or which interfere with its elaboration in the air-cells.

Animals placed in the exhausted receiver of an air-pump die, after a certain interval, the length of which is determined, partly by the power of the instrument and the consequent degree of atmospheric rarity produced; and especially, by the comparative need of a supply of oxygen experienced by the animal, as a consequence of the greater or less elaboration of heat, and of the degree of rapidity with which its organic changes proceed. Cold-blooded animals, as will be shewn in another part of this treatise, can exist under favourable circumstances, with a very scanty supply of oxygen, and can even live for a long time in a state of torpor, when the access of atmospheric air to their respiratory organs is altogether precluded. But warm-blooded animals, especially the vertebrated, and of this class, those which eliminate most caloric, die very soon in a very rare atmosphere like that produced in the receiver of a pneumatic apparatus. As the air is exhausted, the animal gives evidence of great suffering,—gasps frequently,—its respiration becomes very rapid, and ere long it staggers and at length falls; and, after some quivering of the limbs, becomes motionless. Some travellers who have ascended very high mountains have suffered much from the rarity of the atmosphere near their summits. They have been unable to walk more than a few yards without stopping to take breath, and feeling extreme fatigue. This breathlessness has sometimes been accompanied by hæmorrhage from the lungs, sudden exhaustion of the muscular power, and fainting.

These alarming symptoms are produced by the want of a sufficient supply of oxygen to the lungs, whilst, at the same time, the pressure of the atmosphere on the capillary vessels is diminished, and a condition of the circulation produced, such as will be described when we treat of the physiological consequences of suspended respiration. Asphyxia from void has this peculiarity, that the capillary vessels of the whole surface of the body are congested from the removal of the atmospheric pressure on them, and particularly, that in the delicate and very vascular structure of the lungs, this congestion becomes so great as frequently to occasion hæmorrhage, and always to interfere with the effect of the air on the blood circulating in that organ. We may dismiss this form of Asphyxia by observing, that no remedy can relieve it but a proper supply of air. When the danger of its accession is imminent, the best method of preventing its occurrence is to avoid everything which can accelerate the circulation, impede the motion of the chest, or prevent a supply of oxygen to the lungs and skin. Perfect rest—a recumbent posture—and free exposure to the air, together with the application of stimulants to the olfactory and respiratory nerves, are the remedies from which the greatest benefit may be expected.

If the air be prevented from penetrating into the lungs, Asphyxia ensues. Inspiration is effected by the ascent of the ribs, which enlarges the antero-posterior and lateral diameters of the chest; and by the descent of the diaphragm, which increases its capacity from above downwards. When these motions of the parietes are made, the air descends by its own gravity into the expanded air-cells, unless prevented from entering by some obstacle in the pharynx, larynx, or trachea; such as a tumour or a foreign body, which may close these passages. The remarkable researches of Sir Charles Bell, whose views have received ample confirmation from the experiments of Majendie, and other French physiologists, shew, that the muscles of the glottis are connected by a beautiful sympathetic system of nerves with the muscles of respiration. When the respiratory muscles expand the chest, the glottis is opened to permit the entrance of the air. I had once a remarkable opportunity of observing this singular connection between the respiratory muscles illustrated in a female, whose pharynx and tongue had been destroyed by syphilis, and whose glottis was thus exposed to the eye. During inspiration the glottis was opened; it was partially closed during expiration, and completely so when each expiration was finished. If the muscles expanding the glottis be paralysed, their sympathy with the respiratory system is destroyed—the muscles which contract this aperture act spasmodically, and air is prevented from entering the lungs. This occurs in a singular disease to which infants are especially liable, but which I have seen in one adult, and which was first described by Clarke, but the nature of which has been more fully illustrated by recent writers. Spasm of the glottis is always an alarming, and not unfrequently a fatal disease. It generally occurs in infants of very excitable temperament, and is commonly excited by fits of laughter and screaming, which call the respiratory system of muscles into violent action. The laugh or the scream is suddenly suspended, and respiration at the same moment ceases, and the spasm is frequently not subdued, until consciousness, or even life, is extinct. This dangerous malady requires much sagacity to devise a method of treatment for its removal. It will not seldom be found connected with some tenderness in the cervical portion of the spinal column, and sometimes with such general delicacy and mobility of temperament, as will derive great advantage from a residence on the sea-coast, and a cautious use of tonics.

Œdema glottidis occurring in pharyngitis and laryngitis—the effusion of lymph, and the formation of false membranes on the glottis in croup, or chronic laryngitis—abcess in the glottis—chronic growths—fungi—and tumours—as also ulcers penetrating among the muscles of this part; a foreign body filling the cavity of the trachea—these, and other similar circumstances, may occasion an obliteration of the canal through which air enters the lungs.

Recently, atrocities unheard of before have been disclosed. Miscreants employed in the exhumation of bodies, having, in the course of their connection with the schools of anatomy, acquired a somewhat more precise knowledge of the human structure, than is common to persons of their class, employed a new method to extinguish the life of victims, whom they afterwards sold in the schools as exhumed bodies. They knelt upon the chest and abdomen; preventing the action of the diaphragm and of the muscles of the chest and abdomen, and closing the nostrils and mouth with their hands, prevented the entrance of air into the chest, and thus extinguished life, in a manner which left fewer traces of violence than any other means which they could have employed.

Whatever destroys the motive powers of the chest and of the diaphragm, will occasion Asphyxia. Amongst these causes are extensive wounds of the diaphragm, by which its innervation is affected—a section of the phrenic nerves—or of the spinal marrow above the first dorsal vertebra. In decapitation, the immediate cause of death is the paralysis of the respiratory apparatus; for the experiments of Legallois prove, that the animal can survive the loss of the influence of the brainular mass, and the effects of hæmorrhage, for a much longer period than the cessation of the respiratory process. Legallois first sustained life in animals for a considerable time after decapitation, by insufflation of the lungs.

Some causes preventing the entrance of air into the lungs yet remain to be considered. One of these is the effect of large wounds in the parietes of the chest, and another is submersion. To the former of these subjects I shall devote a chapter towards the close of this work; and the latter is so intimately connected with the special object of this treatise, that it will receive ample consideration in those portions of this volume, in which a description of the peculiar effects of submersion may be necessary, to explain the treatment necessary for the recovery of the drowned.

Asphyxia in new born children has some peculiarities, and though the description of them will lead us to anticipate, in some degree, the results of inquiries which will be described in a subsequent part of this volume, that anticipation of future results will not be so great as to render the description of this form of Asphyxia inconvenient in this chapter. In children born in this state the surface is extremely pale, the muscles are soft and flaccid, respiration does not commence, and the limbs are motionless, though the pulsations in the chord may still continue for some time. The animal heat rapidly declines, and this state will rapidly terminate in death, if respiration be not established. Gardien* disputes the propriety of applying the term Asphyxia to this state, and proposes to call it the Syncope of the new born Infant, He seems however to be of opinion that in these cases the pulsation of the chord has always ceased—an opinion, in which he is not confirmed by Desormeau†; nor by Burns,‡ who says, "pulsation may continue for

* Traité complet d'accouchemens. Tome III. p. 135.

† Diction. de Medicine. Article Nouveau-Né. Tome xv. p. 135.

‡ Principles of Midwifery. Seventh Edition, p. 556.

some time without respiration, and, when it stops, may for a time be renewed by inflating the lungs." Gardien considers pulselessness to be the chief sign of this state, and contrasting a condition which he supposes to be produced by hæmorrhage or by an arrest of the supply of blood—with the circulation of dark blood, which was supposed by Bichat to produce all the phenomena of Asphyxia, he concludes that Asphyxia differs essentially in its character from this state. He agrees with Leroux, of Dijon, in calling it syncope, because he affirms that it commences with the heart, which is deprived of blood, and which can no longer exert its influence on the other organs of the economy, by that supply with which it formerly nourished them. "On* doit regardé que cette maladie affecte primitivement, et pour ainsi dire d'une manière exclusive le cœur, s'il est certain que toutes les circonstances que l'expérience apprend donner lieu à cet état appelé Asphyxie, ne le produisent que parce qu'il y a defaut de sang vers le cœur."

Yet, notwithstanding this declaration, Gardien agrees with Ladmirault,† that there is no deficiency of blood in the vessels of children born in this state after compression of the chord.

* Gardien. Traité complet d'accouchemens, Tome III. p. 137.

† Recherches sur l'Asphyxie de l'enfant.

On opening the bodies of children still-born after uterine hæmorrhage, or after compression of the chord, large quantities of dark blood escape from their vessels. He disagrees with Fretau, who conceives that pressure on the chord may interrupt the flow of blood in the umbilical vein, without producing the same effect on the arteries, and thinks that the quantity of blood in the fœtus is never diminished by these means.

After uterine hæmorrhage, when the infant is frequently born in states of extreme feebleness, or even without any sign of life, he thinks that there can be no doubt that the quantity of blood circulating in the infant is seriously diminished, because a due proportion is no longer maintained between that which it receives from the mother, and that which it returns to the placental circulation.

The most frequent causes of Asphyxia in new born children are the presentation of the chord at the same moment with the head, and a foot presentation, when the child is delivered without turning—in all which cases, the chord is liable to pressure before the head is born, and the child can breathe. Gardien supposes that death occurs in these accidents from the want of a supply of blood to the heart. Hence, he concludes* that

* Gardien. Ibid. p. 141.

the state of pallor, feebleness, and absence of motion, exhibited by many new born children, must be considered a syncope which results "d' une faiblesse réelle," occasioned by the want of a supply of blood to the heart, or rather, he adds, of such blood as contains the qualities necessary to stimulate the nervous system.

After uterine hæmorrhage, the quantity of blood circulating in the infant may be in some degree diminished, but it is most probable, that the pallor and unconsciousness of the child at its birth are rather produced by the partial or complete separation of the placenta, and the consequent interruption of the placental circulation before the child is born. These cases therefore more nearly resemble those produced by compression of the chord, than Gardien appears to suppose; the effects in both being rather produced by the suspension of the influence of the placenta on the blood of the child, than from any want of that fluid.

The placenta supplies to the fœtus *in utero* the the want of respiration and aliment. In this organ the blood acquires the stimulating and nutritious qualities necessary to the growth of the embryo. At the moment of birth, the placenta is detached from the mother—the child ceases to derive nourishment from this source—and its blood requires to be exposed in the lungs to the action of the atmospheric air, thence to derive qualities necessary to support the functions of its tissues, and especially of the brain and nervous system. If, by pressure on the umbilical chord, or by the separation of the placenta, the fœtus is deprived of its natural supply of this blood before respiration commences, it is placed in a condition resembling in no slight degree that of an adult deprived of atmospheric air; for there is no evidence to prove that the quantity of blood circulating in the fœtus is diminished, but this state results rather from the want of the placental influence on the blood. This condition of the fœtus therefore resembles Asphyxia. Truly, the lungs have not been expanded. The foramen ovale and ductus arteriosus are still open, and though the blood is gradually deprived of its stimulating qualities, the circulation is continued for a considerable period through these channels. On the contrary, in the adult, the blood—rapidly deprived of its arterial qualities when respiration ceases, and assuming a venous hue—soon becomes so degenerate in its nature, that, after three or four minutes, it can no longer permeate the pulmonary capillaries, which seem paralysed by contact with it. But though, in Asphyxia, in adults, the circulation is arrested at a much earlier period than in infants, these states resemble each other in this respect, that in both, from the first moment in which the influence of the organ which bestows stimulating and nutritious qualities on the blood is removed, a fluid, becoming every moment less nutritious, circulates through the body, and occasions a deficiency of vital power in all the organs, but especially in those which require the largest and most constant supply. The brain, the spinal chord, and the organic system of nerves especially suffer from these defects in the qualities of the circulating fluid, and hence the respiratory actions, which ordinarily take place on exposing the infant to the air, are not excited by their natural stimuli, but require some artificial process for their development.

In a future part of this volume, it will be seen that life is prolonged, in this state of the circulation, for a greater period in the infant than in the adult, because its powers of producing heat are yet but imperfectly developed, and it has therefore less need of a highly oxygenated blood for its support. This has been already shewn in the preliminary letter appended to this treatise, and any further reference to the subject may therefore be the less necessary here.

Much controversy has taken place concerning the propriety of dividing the chord, before proceeding to apply the means appropriate to the restoration of children from this state of Asphyxia. Smellie, Levret, Chaussier, Freteau, and others advise that the connection of the child with the mother and the placental mass should be maintained; and think an early section of the chord dangerous. The directions of Burns* appear very judicious. "If the pulsation have stopped," he says, "no good can accrue from allowing the child to remain connected with the mother. The chord is directly to be divided, and means used, as shall be directly mentioned, for the production of respiration. If pulsation continue regularly and steadily, the child is not in danger from want of respiration, for the fœtal mode of living is continuing." "†When the chord pulsates at the time of birth, we are never to be rash in dividing it. It is of importance to keep up the fœtal circulation till the new mode of acting can be established, and we ought not completely to divide the chord, in such cases, till pulsation stop; because if respiration stop, we have the placenta as an auxiliary, and if the connexion still exist, and the pulmonary action being suspended, the fœtal mode will continue, and support life till

* Principles of Midwifery, p. 550. † Burns. Ibid, p. 551.

respiration become vigorous; for the two modes of changing the blood are not incompatible." If breathing do not soon commence, and the placental circulation become weaker, other remedies must be resorted to, and it may be reasonably doubted, whether, if the connection with the mother interfere with the application of these means, it should be permitted to continue, when, the placental circulation having become weaker, it is evident that their application cannot be longer, with propriety, delayed.

The body of the child thus separated from the mother should be kept moderately warm, but exposure to too great heat should be carefully avoided. The young* of some species of warm blooded animals live longest, when deprived of air, in a temperature of 68° Fahr. and the infant should not be exposed to a much greater degree of warmth. Immersion in a bath, deprives the surface of the vivifying power of the surrounding atmosphere, whence, the blood circulating in the skin abstracts oxygen, and which stimulates the cutaneous nerves, whose sentient extremities are exposed to its influence. As the bath is not necessary to the application of a proper degree of warmth to the body of the child, as it prevents the

* Edwards' "Sur l'action des Agens."

beneficial effects of the atmosphere on the skin —and, moreover, as it is found* that it has a depressing influence on the nervous and muscular systems, it should not be used. The child should be received in warm cloths, and exposed in some degree, but not too closely, to the influence of the fire. Gardien† and Desormeau‡ recommend the friction of the body with various stimulating applications, and especially in the regions of the chest and stomach, in order to excite the motive powers of the respiratory apparatus. Spirits are recommended for this purpose by Burns,§ and a liniment of ammonia and oil by Gardien. The application of spirits to the nostrils, to rouse the respiratory nerves to action, is also strongly advocated.

Sometimes, the mouth and pharynx are obstructed by mucus, which should be carefully removed with a piece of linen dipped in a solution of chloride of sodium—a more efficient method, and one less likely to abrade the parts, than the use of the finger, which is a common practice. Héroldt of Copenhagen discovered in 1798 that, in animals and in the infant, the liquor amnii

* Edwards' Sur l'action des Agens sur la vie.

† Traité complet d'accouchemens. T. iii. p. 141.

‡ Dictionnaire de Medicine. Article, Nouveau-Né.

§ Principles of Midwifery. p. 551.

frequently penetrates the trachea, and fills it. Subsequently Schéele* of Copenhagen made observations confirming those of Héroldt. They advise, for the removal of this fluid, that the head of the child should be placed somewhat lower than the feet, and that moderate pressure should be made on the chest and trachea. Héroldt, by these means, saved twelve out of thirteen children apparently dead from this cause. Schéele also recommends that a cannula should be introduced into the trachea, and that a syringe, adapted to it, should be employed to remove the fluid from the respiratory passages.

The experiments of Leroy d'Etioles shew that insufflation may be performed with much less danger in the infant than in the adult, because the structure of the lungs is firmer in the child, and there is therefore less danger of a rupture or dilatation of the air-cells. Whilst, therefore, the child is exposed to a proper temperature, and means are employed to excite the capillary circulation and the action of the muscles of the chest—after any mucus which may obstruct the fauces has been removed—a curved cannula should be introduced into the trachea, and the lungs should be inflated through this

* Commentatio de liquoris amnii asperæ-arteriæ fœtuum humanorum naturâ et usu, &c. 1798.

with the bellows recommended by Leroy, and which will be hereafter described. The tube used by Chaussier, at the "Maison d' Accouchement" at Paris, is recommended for this purpose by Desormeau. If no bellows be at hand, breath from the lungs of the assistant may be employed, provided he take care to renew the air in his lungs, before each successive inflation of the lungs of the infant. When the lungs have been, with due caution, sufficiently expanded, the air should be expelled by gentle pressure on the abdomen and chest; and these processes should be alternately repeated for some time. Air expelled from the human lungs has the advantage of being warm and moist, and if care be taken to renew it before each inflation, it will contain very little less oxygen than the atmospheric air. Héroldt found, that air inspired and immediately afterwards expired had only one hundredth part less of oxygen than the common atmospheric air —a quantity too small, seriously to affect its qualities. Insufflation from the lungs of the operator can always be more easily performed, and it is therefore, when employed with proper caution, preferable, perhaps, to the use of the bellows in children.

A small galvanic apparatus might be used with advantage, in the manner recommended by

Leroy, to excite the respiratory motions. The acupuncture needles might be introduced into the diaphragm one or two lines on each side of the chest, and two wires, each leading to an opposite pole of the galvanic circle, might be connected with these needles. On completing the galvanic circle, a contraction of the diaphragm would be produced, which might be suspended by removing one wire, for a moment, from its connection with the battery. The relaxation of the muscle might then be effected by gentle pressure on the abdomen, and this process might be alternately repeated until respiration was established.

The physiological condition of young warm-blooded animals when they do not respire after birth, can be more conveniently considered, after the phenomena of Asphyxia in cold-blooded animals have been explained in the ensuing chapter. To this place, therefore, is referred any account of the laws affecting the duration of life in young warm-blooded animals.

## CHAP. II.

The effects of age, of the power of producing animal heat, and of temperature, on the duration of life in Asphyxia in warm-blooded animals, are illustrated by the interesting researches of Edwards concerning Asphyxia in reptiles, in cold-blooded, and hybernating animals, and in the new born mammalia. Before considering the phenomena of Asphyxia in adult warm-blooded animals, it is therefore desirable that the results of Edwards' experiments on the inferior tribes should be related, as they contain some important principles, necessary to the elucidation of the special subject of this volume.

Reptiles can live some time when the heart is removed. By this operation, respiration and the circulation of the blood are annihilated. Some blood escapes, and that portion which remains may be regarded as a constituent part of the organs. The nervous and muscular systems alone are left, and they are inseparably connected.

The excision of the heart of reptiles, therefore, afforded Edwards an opportunity of determining the relative influence of air and water on the nervous and muscular systems—a question of grave importance, when considered as affecting the treatment of Asphyxia. For the purpose of determining this question, he removed the heart and the bulb of the aorta in salamanders, frogs, and toads; and placed one half of the animals thus prepared in air, and one half in water deprived of air. The salamanders placed in the water became motionless in four or five hours. Those exposed to the air, however, survived twenty-four or twenty-six hours. If frogs were similarly treated, those placed under water lived two hours, and those in the air three, and their activity decreased far more rapidly in water than in air. If a frog whose heart has thus been removed be immersed in water, and taken from it, and again exposed to the air, at the moment when its life seems extinct, it will immediately begin to recover. If again plunged into the water, it will again lose sense and motion, and will recover on re-exposure to the air; and this process may be repeated several times with the same results. These experiments prove the deleterious influence of water on the nervous and muscular systems, and the vivifying effects of air.

In order to determine the influence of the circulation of venous blood on the nervous system, frogs, whose hearts had been removed, and an equal number of these animals left entire, were immersed in water deprived of air by boiling. The frogs, in which the action of the heart and the circulation continued, always survived the others a considerable period, and sometimes twenty hours. The same results were observed when toads and salamanders were used in the experiment. Hence, Edwards concludes that the circulation of venous blood is favourable to the maintenance of the powers of the nervous and muscular systems, though it cannot prolong life beyond a very limited period.

It might be presumed, that the water in which the animals were immersed in these latter experiments—exerting a deleterious influence on their nervous and muscular systems—prevented the venous blood from maintaining life, so long as it would have done in a less noxious medium. Edwards, therefore, strangled some frogs by covering their heads tightly with a piece of bladder, so as completely to exclude the air; and though the ligature with which the bladder was tied was so tight as to occasion paralysis, frogs, treated in this manner, lived in air from one to five days, whilst, in water, they died in ten or twelve hours. A salamander lived twelve days, when its head became gangrenous from the effects of the ligature.

It also appeared, that air exerts some influence on the blood of reptiles through the medium of the skin, for carbonic acid gas was found in the receiver of an air pump, in which some frogs were confined. The difference in the duration of life in the animals strangled, and in those immersed in water, as compared with those left in the air, likewise shews, that, in the latter class, life is supported many days without any other action of the air, than that which may perhaps be exerted on their nervous systems, and its evident effects on the blood through the medium of the skin. It further appeared, that when the animals were neither mutilated nor immersed in water, but incased in a solid material which had no deleterious influence on their nervous systems, that they lived a much longer period than in either of the former states, though life was supported by the circulation of venous blood only. Toads are found in the centre of great blocks of stone, where they must have existed without air an incalculable length of time. Herissant also proved in 1779 that toads could live eighteen months in boxes, enclosed in plaster, but the animals in his experiments were surrounded by the air in the boxes, from which they could derive some nourishment.

Edwards, therefore, embedded some toads in plaster. One was found alive on the nineteeth day, the others were opened at intervals of six weeks or two months, and were found dead, and completely desiccated. He thinks that their death was hastened by the loss of the fluids perspired from the skin, and that life was supported by the small quantity of air which penetrated the plaster: as animals embedded in plaster, and then immersed in water, died almost as soon as if the water had been in contact with their bodies. Toads live longer in plaster or sand than they would in air, because the loss by perspiration is less in these situations than it is in the air. Under an exhausted receiver, the combination of the effects of a want of air and of rapid evaporation occasions death in a very short period.

The duration of life in reptiles deprived of air is, therefore, in strict relation with the comparative need experienced by their organization for a supply of this fluid. Under certain circumstances of season and temperature, diminishing their need of oxygen, their life is prolonged for a much greater period; but we may with greater advantage advert to these circumstances, in treating of Asphyxia in the young of warm-blooded animals, and in those of this class which hybernate.

In young warm-blooded animals, Edwards found that though the temperature of some species, when in contact with their mother, is equal to hers, yet, that when separated and exposed to the influence of the atmosphere, it falls considerably, even when they are regularly supplied with food, and that it continues falling, until, in the course of a few hours, its descent is arrested only a very few degrees above the temperature of the surrounding medium. This phenomenon cannot be attributed to the want of an artificial covering, which could only retard and not prevent the depression of their temperature; and in some animals, well covered with hair at birth, exposure produces the same effects. Less heat is therefore produced in a given time in the young animal than in the adult. Shortly after birth, the young mammalia gradually acquire the power of producing greater quantities of heat, and, at the end of a fortnight, they enjoy this faculty equally with the adult animal.

The young of the mammalia are however to be divided into two classes, as regards the production of animal heat. Some are born with their eyes closed—these enjoy at birth a limited power of evolving heat; others are born with their eyes open—and these possess from the first their natural capacity. The former may be regarded as cold-blooded at birth; the latter as warm-blooded; and at the end of a fortnight, when the eyes of the former class open, their faculty of producing heat is equal to that of adults of the same species.

Young birds are also to be divided into two classes. Some, when hatched, can eat and run, and are covered with a tolerably thick down, and this class can maintain a moderately elevated temperature, if exposed to the air in a favourable season. Another class is born without down or feathers, is incapable of providing for itself, and is in a similar condition in relation to the production of heat, with cold-blooded animals. Young birds, however, require a degree of heat equal to that of adults of the same species. The temperature of this class is preserved by close contact in the nest; and by the care of their parents who shelter them, and impart the warmth of their own bodies to them; but when separated from each other, and exposed to the atmosphere, they rapidly cool down to within one or two degrees of the temperature of the air. An adult stripped of its feathers does not however suffer any depression of its natural heat. Before young birds are able to take care of themselves, or have acquired their plumage, their power of producing heat is gradually increased, until in spring and summer, their temperature, unassisted by subsidiary aids, is equal to that of adults.

From these and similar facts, it appears that the power of producing heat in warm-blooded animals is at its minimum at birth, and increases uniformly until adult age.

These facts naturally led Edwards to inquire the cause of the loss of temperature, and of the torpor experienced by certain warm-blooded animals during the winter months. These hybernating animals belong to various genera, and are not distinguished, by any peculiarity of structure, from other animals of the same class which do not hybernate. In the winter months, however, their temperature sinks, almost to that of the surrounding medium—they become torpid—their respiration is feeble and irregular—occurs only after considerable intervals—and they continue in this condition several months without taking nourishment.

M. de Saissy examined the temperature of these animals at different seasons. On the 6th of August, when the temperature of the atmosphere was 73° Fahr. that of a marmot was 98° Fahr. On the 23rd of September, when the air was 64° 5 Fahr. the heat of the marmot had sunk to 88° Fahr. and on the 10th of November, when the air was 44° 6 Fahr. that of the animal was only 81° Fahr. or it had lost 16° Fahr. since the month of August. A garden dormouse had a warmth of 88° Fahr. on the 3rd of August; of 87° Fahr. on the 23rd of September; and only 69° 8 Fahr. on the 10th of November, having lost almost 28° Fahr. since the first examination.

A hedgehog, whose temperature was 99° Fahr. on the 3rd of August, and 96° Fahr. in September, indicated only 57° Fahr. in November, having lost 40° Fahr.

These facts shew that in Autumn hybernating animals produce less heat than other warm-blooded mammalia, and that, as the cold of the season increases, their temperature sinks, when they are exposed to the influence of the air. M. de Saissy does not say whether the animals on which his experiments were performed took food regularly, whilst undergoing this loss of temperature, and as it might be supposed that the difficulty of procuring food in cold weather alone occasioned the torpor of hybernating animals, it became important to determine whether this state could be produced when the animals were well-fed.

M. de Saissy produced torpor in a marmot in the months of May and June, by enclosing it in a box with a small aperture, and exposing it in an ice-house to an artificial cold of 18° Fahr. below the freezing point. In eleven hours, its temperature sank 41° Fahr. and it was in a state of complete torpor, yet its health did not suffer more than from ordinary hybernation, for on exposure to the atmosphere, it resumed its wonted activity. In the experiment of M. de Saissy, he had been unable to produce absolute torpor, without closing the small aperture of the box in which the marmot was enclosed, so that the result was occasioned by the combined influence of diminished respiration and external cold. In order to separate the influence of this last agent from that of the former, Edwards exposed an adult bat, of the long eared species, in good condition, in April (when the temperature of the air was 61° Fahr. and that of the animal was 93° Fahr.) to an artificial cold of 33° 8 Fahr. Free communication with the air being permitted, the temperature of the animal was reduced 36° Fahr. whilst guinea pigs and adult birds lost, under similar circumstances, not more than two or three degrees, though the cold air was applied for a longer time, to compensate for the difference of size. Edwards does not say that torpor was produced in this animal. The experiment demonstrates that the power of producing heat is less in the bat than in other warm-blooded animals, and a striking analogy is shewn to exist between it and the young of most warm-blooded animals, with this difference, that a condition, transitory in them, becomes permanent in the bat.

Edwards extends the analogy to the whole group of the hybernating animals, and concludes, that whatever other causes affect their temperature during hybernation, this state is chiefly to be attributed to a deficiency in the power of producing heat.

The preceding researches concerning the action of air and water on reptiles, and the circumstances affecting the torpor of hybernating animals have a most important relation to the comparative duration of life in young warm-blooded animals, when deprived of air after birth. In adult warm-blooded animals, the privation of air is generally fatal in three or four minutes, whilst, the young of some of these species live after birth various periods, according to the circumstances in which the experiment is performed. Buffon and Legallois first discovered this extraordinary difference between the young and adult animal. Perceiving that habit has some influence in increasing the length of time during which the diver can remain under water, Buffon was led to inquire whether by the submersion of animals immediately after birth, the foramen ovale and ductus arteriosus might not be kept pervious to the current of blood, and whether, by frequent subsequent immersions in water, the faculty of remaining long beneath this fluid without respiring might not be cultivated. Habit has, however, very little influence in increasing this faculty. A moorhen plunged in water by Edwards survived only three minutes. Led by the hope of producing a different result, Buffon placed a large greyhound bitch in a tub of warm water, when in the act of parturition, and secured her so, that she was obliged to expel her offspring beneath the water. The young animals were afterwards, without giving them time to breathe, transferred to a tub of warm milk, in order that they might have an opportunity of taking nourishment. In this latter vessel they remained half an hour, when, on being removed, they were all found alive. Having been permitted to breathe half an hour, they were again immersed in warm milk, and on removal, at the expiration of another half hour, two were found not to have suffered at all, but the third appeared weak, though it soon recovered on being carried to its mother. The other two were permitted to respire for about half an hour, and afterwards, were again immersed in the same warm milk, for half an hour, when they appeared on removal as strong as before. One of them, however, died that day, but whether from accident, or in consequence of the experiment, could not be discovered. The two others lived and were as healthy as other puppies produced by the same bitch, after she had been removed from the water, and which had not been subjected to the experiment. Legallois was led to make similar experiments, in order to discover how long a fœtus could live without respiration when separated from its mother. He found, that when he immersed new born rabbits in water, the mean duration of their life was twenty-eight minutes. This power of enduring the want of air rapidly diminishes with the increased age of the animal. Young rabbits five days old live only sixteen minutes when plunged in water: in five days more, this time is reduced to five minutes and a half, and when they are fifteen days old, Legallois discovered that they do not differ from adult warm-blooded animals in their faculty of enduring the privation of air.

These facts appeared to indicate that the mean duration of life in the young of warm-blooded animals was, under these circumstances, half an hour; but Edwards discovered, on immersing a guinea pig in water immediately after birth, that it lived only three or four minutes longer than the adult animal, and, on further inquiry, he found that the difference between the young and the adult animal was not greater in other species.

The previous inquiries of Edwards, concerning the relation of young animals to the faculty of producing heat, furnished him with the means of reconciling these apparent incongruities. In some young animals, the faculty of producing heat is very feeble—they have a close analogy with reptiles and fishes in this respect, and resemble them in their power of enduring the privation of air. These young animals are born with their eyes closed. In other young animals born with their eyes open, the faculty of evolving heat is considerable at birth, and they cannot live long without air. The former class also rapidly acquire a power of producing heat equal to that of the adult, and as this faculty increases, they are less able to sustain the deprivation of air, until, in a few days, they, in both respects resemble the adult animal. Edwards extended these observations from the mammalia to birds, and obtained similar results.

The temperature of the external medium has also a remarkable influence on the duration of life in young animals, when deprived of air. In some kittens a day or two old, all signs of sensibility and motion were extinguished in four minutes and thirty-four seconds, when they were immersed in water at 32° Fahr., taking the mean of nine experiments. At 50° Fahr. they lived ten minutes and twenty-three seconds, and at 68° Fahr. the duration of life increased to thirty-eight minutes and forty-five seconds. At 86° Fahr. they lived but twenty-nine minutes, and at 104° Fahr. only ten minutes and forty seconds.

This influence of external temperature on the duration of life when the animals are deprived of air, extends to every age in the opinion of Edwards, and should serve as a strong reason for not rashly applying a high external temperature, for the restoration of persons from a state of suspended animation.

The duration of life, when animals are deprived of air, is therefore chiefly affected by two circumstances, viz. their power of producing animal heat, and the external temperature to which they are exposed.

This influence of temperature extends through the whole series of animals. The batrachian reptiles, in the experiments of Edwards, lived two or three days in water deprived of air, but this extraordinary duration of their life depends on two external circumstances; the first of which is that the water in which they are immersed shall be at 32° Fahr. and the second, that the air shall have been for a long time previously to the experiment at nearly the same temperature, in order that the constitutions of these animals may have undergone a change consequent on the continuance of this cold. If they be immersed in summer, in water at 68° Fahr. they live about an hour; slight variations from this period being determined by the preceding temperature of the air. At this season, and under these circumstances, therefore, little difference exists between them and new-born warm-blooded animals, which will sometimes live fifty-four minutes under water. But if the batrachiæ, at the same season, be placed in water at 104° Fahr. the mean temperature of warm-blooded animals, they live no longer than the adult mammalia. The same result occurs with fishes, especially the small species. The lizards lived only six minutes under these circumstances. "Hence," says Edwards, "we see that heat, whether externally or internally produced, has the same influence on the duration of life in Asphyxia."

The influence of cold on the vital actions of warm-blooded animals in Asphyxia is involved in greater obscurity. Experiments like those performed on reptiles and fishes cannot be extended to the warm-blooded animals, because they cannot endure so great a reduction of temperature, nor can they remain so long a time exposed at an equally low temperature. But the hybernating animals differ from the rest of this class, in being able to bear a more considerable depression of temperature, and to live longer when subjected to the influence of a cold air. The duration of life in them, when deprived of air, was found by Edwards to be regulated by laws similar to those which affect it in reptiles and fishes.

Bats immersed in water at 68° Fahr. when they are not torpid, live only four or five minutes. On the other hand, when long subjected, in a torpid state, to the influence of a cold air, and when they have undergone the greatest reduction in temperature of which they are susceptible, the same phenomena are observed in them as in the batrachiæ. Spallanzani exposed a torpid marmot to 53° 6 Fahr. in a receiver containing carbonic acid gas for four hours, and, when removed, it did not appear to have suffered from the experiment, though it was subjected, not to a simple deprivation of air, but also to the pernicious influence of a gas possessed of properties tending to extinguish the powers of the nervous system.

Besides those causes which prevent the entrance of air into the lungs, such as mechanical impediments, void, or rarefaction of the atmosphere and submersion, Asphyxia may be produced by the admixture of certain gases with the air, or by an increase in the relative proportion of one of its constituent elements. That mixture of gaseous elements found in the atmosphere, is most conducive to the support of life; but the quantity of oxygen may be considerably increased, without very injurious consequences immediately ensuing. When, however, the disproportion of the quantity of oxygen is very great, as in the experiments of Broughton, or when an animal is immersed in the pure gas, though no inconvenience is at first perceived, in an hour or little more, the circulation and respiration are much accelerated, and the whole body excited. This excitement is soon followed by debility, which gradually increases until the animal becomes insensible, and death ensues in a few hours. After death, the blood is every where found extremely florid, and the motions of the heart continue, long after respiration has ceased. On the other hand, an animal cannot live long in an atmosphere in which the oxygen consumed in respiration is not renewed by a fresh supply. The necessity for a due supply of oxygen, has a very intimate relation to the animal's powers of evolving heat.

The air expired from the lungs is warmer than that inspired, and is charged with vapour; but it also contains a quantity of carbonic acid gas, equivalent to a quantity of oxygen which it has lost. When, therefore, an animal is confined in a limited quantity of air, a process ensues—consisting in the constant abstraction of a certain quantity of oxygen, and the substitution of a certain quantity of carbonic acid gas—and proceeds until so much oxygen is removed, that the remaining air is incapable of supporting the life of the animal, which, unless removed into a purer atmosphere, expires. This mode of depriving the air of those qualities which enable it to support life is, ultimately, as fatal as the abstraction of air, or immersion in water; and the phenomena of Asphyxia, thus produced, are chiefly distinguished by the gradual manner in which they ensue. A method is thus obtained of determining the comparative necessity for a supply of oxygen which is experienced by different animals, and which, it has been discovered by Edwards, has an intimate relation with the constitution of the animals. Edwards placed some sparrows, in every respect as much alike as possible, in vessels of the same form, and each containing about a pint and three quarters of air inverted over mercury. The experiments were also simultaneously performed, in order that they might not be affected by differences in the temperature, pressure, aud humidity of the air. He discovered, from a great number of experiments of this kind, that a considerable difference in the duration of life occurred in different animals, with the same quantity of air, and that the greatest of these differences was about one-third. The air was changed to the same degree of impurity by all, and the duration of life was, therefore, chiefly affected by the comparative rapidity with which oxygen was consumed.

Edwards then proceeded to examine animals at different ages, relatively to their consumption of oxygen. Previous researches had shewn him that the power of producing heat is much less in young than in adult animals; but a priori reasoning might otherwise have led him to suppose, that, at a period of life, when the whole efforts of the organization are combined to promote the growth of the body—and when the activity of the functions of digestion and respiration is therefore greatest—that the consumption of air would necessarily be larger, than at adult age, when the development of the organs ceases. Comparative experiments performed on species in which there is a great difference in the size of the young and of the adult animal, would yield no exact results, because the quantity of air consumed, which must be attributed to the greater size, and the consequently greater extent of the lungs of the adult, could not be determined, and therefore, no calculation could be made of differences, occasioned by the state of the constitution in the young and in the full-grown animal. It was therefore necessary to employ, in these experiments, animals in which no great increase of size occurs.

*"The experiment," says Edwards, "was made with vessels containing a pint and three quarters, or sixty one cubic inches of air, inverted over a solution of caustic potash. The animal was placed on a partition of gauze. The young sparrows which I employed were apparently from eight to ten days old: their bulk was about two cubic inches and a fifth, and that of adults rather more than twice as much. The difference in size alone would occasion a more rapid consumption of air by the older birds, and it ought not to appear extraordinary that they died sooner. The mean duration of their life was one hour, thirty minutes, and thirty-two seconds; but the younger sparrows prolonged their existence to so disproportionate an extent, as to astonish me; their mean term was fourteen hours, forty-nine minutes, and forty seconds.

"Towards the close of the experiment, when they have altered the air, until it is no longer

* Dr. Hodgkin's Translation, p. 94.

capable of supporting life, we may suppose that they still live as long as they can, when deprived of air. We have seen in the former chapter upon Asphyxia, that this period is longer in young, than in adult animals. But the maximum in sparrows is seven minutes. It is evident, therefore, that in allowing for all these differences, the young sparrows lived much the longest, in the same quantity of air, and that, consequently, their consumption of it is comparatively less." The consumption of air is therefore, in the different periods of life, strictly in relation with the development of animal heat.

This was still more satisfactorily proved, by trying the same experiments on animals of the same species, at less distant ages, and when, in the young animal, the faculty of producing heat had increased. Young sparrows, as soon as they begin to feed themselves, are able to support their natural temperature, when unprotected, in the open air, and they are about equal in size to adults. "Five of these young animals placed in sixty-one cubic inches of air, and supported by a gauze partition, over a strong solution of caustic potash, lived, on an average, two hours thirty-nine minutes; but adults, in the same circumstances, lived only one hour thirty-two minutes. Here we have no correction to make for volume, or for difference in the duration of life, after air has become unfit for respiration. These are alike in both these respects, or differ too slightly to deserve attention; but, they differ essentially in the production of heat, and we see that young birds, which produce less heat, also consume air more slowly than adults." These researches were extended to the mammalia, and similar results were obtained.

Warm-blooded animals also possess a greater faculty of producing heat, in winter, than in summer; and from a series of comparative experiments, performed at different times in the year, Edwards discovered, that they consume more oxygen in the cold than in the warm seasons. This difference depends on a change in the constitution of the animals, effected by the influence of the seasons.

These researches naturally introduce us to the consideration of some most important questions connected with Asphyxia in the warm-blooded animals, and which will form the subject of the ensuing chapters.

## CHAP. III.

THE organs of the body consist of almost infinitely numerous capillary vessels. Cuvier* considers vascularity to be essential to organization, and the circulation or imbibition of a nutritious fluid necessary to the maintenance of life. In the higher orders of animals, the tissues are generally nourished by arterial blood of a florid red hue. In those animals which produce less heat, less perfectly arterialized blood is often circulated, and they are capable of existing (at periods when their faculty of generating heat is least, and in low temperatures†) for a considerable time in a state of torpidity, whilst the respiratory function and the circulation are almost suspended. From arterial blood, however, in the higher classes of the animal series, the different secretions are, by various vascular actions, eliminated, the organs nourished, and the functions supported.

The last chapter was devoted to an account of the relation of the respiratory function to those

* Leçons d' Anatomie Comparée.

† Edwards' Sur l' Action des Agens sur la vie.

classes, which possess a faculty of producing heat, inferior to that of adult warm-blooded animals. The effects of the deprivation of air in cold-blooded, in hybernating, and in young warm-blooded animals, in various circumstances of temperature and season, were described; and it is now necessary to examine the connection subsisting between respiration and the organic life of the various organs in warm-blooded animals. In pursuing this investigation, it will be discovered, that the researches which were the subject of the last chapter greatly illustrate this question.

After the arterial blood has contributed to the nutrition of the structures of the body, and to the support of the functions of the various organs, it is poured into the veins, where it is found to have undergone great changes, of which the chief evidence exists in the remarkable alteration of its colour. The vivid scarlet hue of the arterial blood is succeeded by the dark chocolate colour of the venous fluid. Physiologists have always conceived, that, in this state, it is no longer capable of supporting the functions of the human organization. Goodwyn*—as has been stated, in the short history of previous opinions, given in the letter preliminary to this treatise—

* On the Connexion of Life with Respiration.

supposed that it paralysed the heart, by mere contact with the internal surface of its parietes; and Bichat* imagined that he had demonstrated, that it possessed positively noxious qualities, and that it extinguished the organic motions and life, as soon as it was propelled into the structures of the body. Sufficient evidence has, however, been given, in the preceding chapter, that, in the inferior classes and in the young of warm-blooded animals, the circulation of venous blood supports life, for a considerable period after respiration has been suspended. The results of these researches, therefore, naturally lead us to inquire what relation this fluid has with the structures of adult warm-blooded animals, and what effect the suspension of the respiratory function produces on the different organs. This chapter will, therefore, be devoted to an inquiry into the circumstances which cause a cessation of the contractility of the heart and muscles, when respiration is suspended in warm-blooded animals.

When the access of atmospheric air to the lung is in any way suddenly prevented, about a minute elapses, during which the animal exhibits no external evidence of distress; it then makes an effort to inspire, resembling a deep sigh,

* Sur la Vie et la Mort.

which is necessarily ineffectual. This is followed by rapid gasping, by which the whole body is agitated, and every muscle which has power in respiration is most violently contracted to overcome the obstacle to the admission of air. The limbs quiver, writhe, or are fixed in tetanic spasm. The surface and mucous membranes become livid, the sensorial faculties are abolished, and the action of the voluntary muscles ceases. The circulation and the action of the heart continue for a short period only. On more minute examination, the whole capillary system is found to contain only dark fluid blood; the left auricle a considerable quantity; the left ventricle scarcely more than is sufficient to moisten its parietes; the arteries are empty, but the venous system, especially where it empties itself into the right heart, is gorged. The right ventricle and auricle and the pulmonary artery are distended to the utmost, with a dark fluid blood. If Asphyxia have been produced gradually, the colour of the blood is darker, and the engorgement of the lung more perfect, and this always differs, in proportion to the length of time which elapses ere death occurs; but the left ventricle and arteries are empty.

On this subject, the opinion of Haller,*

* Elementa Physiologiæ, Vol. III. p. 249.

Kite,* Coleman,† Bichat,‡ Orfila,§ agree in the general fact, though they differ slightly in describing some of its features.

The analysis and explanation of the phenomena of this mode of death have occasioned the most vehement controversy, from very early periods in the history of medical science, and the most distinguished of its professors have illustrated the subject with their names. A rapid sketch of the progress of science in elucidating this subject, has been given in the beginning of this volume, but, for the purpose of illustrating some important principles connected with this inquiry, it will be necessary to recur to some of the opinions which have been formerly entertained, and to demonstrate their fallacy.

The first effect of interrupting respiration, is to retard the progress of the blood through the minute vessels of the pulmonary tissue. In the rapidity of the circulation, there is a marked difference during inspiration and expiration. Harvey‖ and Haller,¶ in whose day the con-

* On Suspended Animation, p. 56.

† On Suspended Respiration, p. 6 and 7.

‡ Sur la Vie et la Mort, p. 229.

§ Dictionnaire de Medicine. Asphyxie, Tome III., p. 60.

‖ Exercit. Anat. de motu Cordis et Sang: circul. 18mo. p. 157.

¶ Elementa Physiologiæ. Vol. III. p. 250.

nexion of chemical laws with animal physiology was little understood, conceived that Asphyxia was produced by an interruption in the circulation, owing to a mechanical impediment, occurring in the lungs during expiration, from the compression of their vessels.*

Many of the older physiologists attempted to ascertain the quantity of air which enters the lungs at each inspiration, and which is afterwards expelled. The names of Willis, Bernouilli, Bartholin, Borelli, Boerhaave, Jurin, Senac, Hales, &c. attest the importance which has been attached to this investigation. They have, however, all obtained different results, and modern inquirers have been scarcely less unfortunate. It is, how-

* "Vasa ergo sanguinea omnis generis, cum adtensis bronchiis necessario extenduntur, et flexiones alternæ in quas ea vasa in seipsa retracta, in statu pulmonis minimo se reciperant, eæ nunc in rectitudinem exporriguntur:—Porro quæ sibi incumbebant proxima, ea a mutuo contactu discedunt, et anguli inter divisiones vasorum majores fiunt, spatiaque adeo vicinis vasis interponuntur.——Hinc in inspiratione summa facilitas nascitur sanguini de corde dextro exeunti.——In expiratione vero pulmo undique urgetur, et in multo minorem molem comprimitur: vasa ergo sanguinea breviora quidem fiunt cum retractis bronchiis, eademque augustiora nunc sunt, siquidem pectus secundum tres suas dimensiones arctatur.——Sanguis ergo quidem in pulmones undique comprimitur; et venosus æquâ vi pressus, partim versus arteriosum quidem reprimitur, eumque moratur aliquantum, partim versus cor sinistrum promovetur.——Quare in expiratione quam ponimus stabilem superesse, pulmonis pro sanguine immeabilitas oritur, quam neque absque palpitatione, et vitioso conatu, demum, omnino ullis suis viribus cor vincere queat."—*Elementa Phys.* Lib. VIII. sect. 4.

ever, determined with sufficient precision, that the greatest quantity of air which can enter the lungs of a man of ordinary size by a forced inspiration is about seventy cubic inches. It is much more difficult to determine the result of an ordinary inspiration. Menzies and Goodwyn estimate it at twelve cubic inches; Jurin at twenty; Cuvier at sixteen or seventeen; Gregory at only two; Davy at about fifteen; and Thompson at thirty-three. An ordinary expiration would, therefore, have little or no effect on the transmission of the blood through the lungs, and fluid frequently exists in the cavity of the pleura, in quantities much greater than the largest volume of air ever expired, but without arresting the circulation through the lungs, and often without occasioning much embarrassment to the breathing. Goodwyn* satisfactorily shews, that after the fullest expiration, the air remaining in the air-cells distends them sufficiently to permit the blood to circulate freely through them.

Besides the mechanical effects of air upon the lung, it has well known chemical relations with the blood, which must powerfully influence its progress in the pulmonary tissue. The minute vessels of all structures have peculiar sensibilities of

* The Connexion of Life with Respiration, p. 46 and 47.

organization, probably from the difference of their innervation, by which, in a healthy state, they circulate fluids of certain qualities only, and resist the introduction, by mechanical violence, of any fluid foreign to their tissue, so long as its peculiar sensibilities continue active. Thus, contiguous tissues circulate in their minute vessels fluids of very different qualities without commixture, and some, in different degrees of the same succession of vessels, always contain different fluids. In the lungs minute vessels exist, which convey the venous blood to the ultimate membrane of the pulmonary cells, where it is exposed to the atmospheric air. Changes ensue in its transition through this space which alter its qualities. The dark venous character is lost; it assumes the arterial red. It has more oxygen, and less carbon proportionally; and therefore, a priori, we should be induced to conclude, that the innervation or organic sensibilities of the minute vessels which circulate the arterial blood must be different from those which convey the venous. Reasoning from the general laws of the economy, it must have been regarded singular, had the vessels of arterial blood in the pulmonary tissue been capable of conveying blood, with equal velocity, in all stages of the venous degeneration. In suspended respiration we should expect, that, so long as the oxygen contained in the pulmonary cells should remain unexhausted, the ordinary changes of the blood would ensue, and the circulation for a period would continue with its usual vigour; and in proportion afterwards, as the oxygen diminished, the blood not undergoing that change which would be necessary, in order that it might permeate the vessels of arterial blood in the pulmonary tissue, that its circulation would be impeded. As the change, however, is only gradual, and the susceptibilities of action in all tissues are great, the venous blood would doubtless penetrate with diminished velocity the pulmonary organization, until its character was so greatly altered, as no longer to be capable of exciting the action of the vessels of arterial blood. If, then, air were admitted it would re-oxygenate the blood exposed to its action in the pulmonary cells, and bestow on it those qualities which are necessary to its circulation.

An experiment of Bichat is beautifully consonant with these conceptions.* "If a stopcock be adapted to the trachea, exposed and divided, and afterwards it be shut, the blood becomes darker, and springs for some time with its usual force" from a divided artery, "but at length the

* Sur la Vie, &c. p. 222.

jet becomes gradually feebler. Readmit the air, the blood becomes almost immediately red, its saltus also rapidly increases." The blood, it will be remarked in this experiment, was observed to flow from an artery dark, and must therefore have permeated the lung without undergoing the usual changes. This, however, continues for a very short period.

Exp. 1.—The trachea of a large rabbit was tied, the abdomen and chest opened, and at the end of the second minute from the commencement of the experiment the external iliac artery was divided, a considerable quantity of dark blood flowed, but at the third minute it had almost ceased to escape. The heart continued contracting vigourously; very small quantities of dark blood collected slowly every twenty seconds at the extremity of the artery. In five minutes all flow of blood had entirely ceased. The left heart contracted spontaneously for a very considerable period longer.

I repeated this experiment with similar results. In experiments of this nature I felt aware that the cessation of the arterial action might be attributed to the quantity of blood, which escaped when the artery was divided, so very soon after Asphyxia has been produced.

Exp. 2.—I therefore tied the trachea of a small hare. The chest was opened. During three minutes the blood issued *per saltum* with a gradually diminished force from the mammary arteries, and then ceased. On putting my finger on the aorta I could discover no pulse. The aorta was divided, and a very small quantity of blood flowed, and immediately ceased. After three minutes and a half had expired no blood flowed from the aorta; little blood had been lost. The heart continued vigorous the usual period, and all the other circumstances of Asphyxia were observed as usual.

This experiment was confirmed by subsequent observations. I however varied it thus.

Exp. 3.—A rabbit was asphyxiated by tying the trachea. The chest was opened. At the end of three minutes and a half no pulse could be discovered in the aorta. The left venous sinus was then opened, the blood contained escaped, and blood for a period of from one to two or three minutes occasionally collected in very minute quantities, as though it gradually drained from the larger vessels of the lungs, but never, as often as the experiment was repeated, collected in quantity. The heart continued vigorous the usual period, and all other circumstances of Asphyxia were observed.

The supply of blood from the lungs to the heart is arrested, therefore, a very short period after Asphyxia has been produced. But in the experiment of Bichat, when the flow of blood from a divided artery in Asphyxia had ceased, by permitting the usual supply of air to the lung, the circulation was immediately re-established with its usual vigour. Without the supply of oxygen the blood undergoes the asphyxial degeneration; and the circulation being arrested, we must conceive that the vessels destined for the reception of arterial blood are incapable of conveying blood which has undergone this morbid change. But when oxygen is again supplied to the pulmonary cells, the blood becomes alterialized, and at the same moment the circulation is re-established, the minute vessels acting as usual, when stimulated by arterial blood. The celebrated experiment of Hooke is of a similar nature with that of Bichat. It consists in reviving animals apparently dead from Asphyxia, by insufflating air into the lungs, until the circulation and natural respiratory motions are restored.* Haller, attempted to explain these phenomena, simply by the mechanical effect of the air upon the lung. "Sed pulmo per suas causas immeabilis, sanguinem ad ventriculum cordis sinistrum nullum transmit-

El. Phys. Vol. III. p. 250.

tebat. Is idem pulmo, per aerem vi impulsum, extensis vasis, diductis vesiculis, sanguine pervius redditur, ut ex dextro corde, ad sinistrum venire possit."

I endeavoured to ascertain the relation of the arterial and asphyxiated blood to the lung in the following manner.

Exp. 4.—Two rabbits being secured, the trachea of the first was tied, and the chest immediately opened. About the third minute in general no pulse could be discovered in the aorta. The left venous sinus was divided, and the blood contained escaped. Small quantities collected to the fifth minute, or even the seventh. The lungs never collapsed. The pulmonary artery being tied close to the root, the beak of the syringe was introduced into its trunk. The vena cava of the same rabbit was divided, and asphyxial blood received into the syringe and injected into the pulmonary artery. I was once or twice deceived in the result. When not injected in quantity and with force, it did not permeate the lung, though immediately afterwards arterial blood obtained from the aorta of the second rabbit penetrated it easily, and was discharged in quantity. But on repeating the experiment, using large quantities of blood, and injecting with greater force, the asphyxial blood permeated, and was discharged at the opening made in the venous sinus. Though this experiment cannot therefore be adduced in favour of the opinion which has been entertained, concerning the chemical relations of the blood to the healthy action of the minute vessels of the pulmonary tissue and its circulation, yet it cannot be adduced against it; the power of operating being so very different, the strength of the human arm, with the mechanical aid of a syringe, containing a much greater quantity of blood, being contrasted with the power of the right heart of a rabbit, acting with little energy in comparison, and on an extremely small quantity of blood.

This part of the subject is much illustrated by the experiments of Nysten. Bichat had supposed that air injected into the veins of animals was fatal by its noxious influence on the brain; and, carried onward by the impetuosity of his sanguine mind, he fancied that he had seen spumous blood filling the carotids and arterial system.

His experiments were carefully repeated by Nysten* with a totally opposite result. No air was ever found in the left heart or arterial system; but the right heart was always distended with a spumous bloody fluid, or with air. Nysten concludes from this appearance, that the injection of

* Recherches de Physiologie et de Chimie Pathologiques.

air into the veins is fatal, by producing distention of the heart, and mechanically resisting its contraction. He supports this opinion by experiments, showing, that when the spumous fluid is evacuated from the heart, by large openings made in the veins of the neck, the circulation is restored. I think, however, his own experiments contain the evidence, upon which a different explanation must be founded. When air is injected in small quantities death does not ensue; and, allowing some interval of time to elapse between each injection, he found it possible to convey into the circulating system of animals, without immediate death, much larger quantities than would produce that catastrophe, were the whole administered at one time. Two circumstances of great importance, however, succeeded those experiments. After repeated injections of air into the veins the arterial blood assumed a darker hue. This effect in some measure depends on the absorption of a greater quantity of azote than oxygen in the dissolution of the air; but much must also be attributed to the embarrassment of the respiratory function, from the air present in the pulmonary blood vessels.

When, however, repeated injections of air were performed at intervals, death did not ensue immediately. The injections were attended by some rapid and short respiratory motions indicating the pulmonary obstruction. These symptoms seemed in a great measure to vanish when the animal coughed, shortly after, which was the first symptom of fatal pneumonia, which in every instance rapidly terminated its life. These circumstances all tend to prove that repeated moderate injections of air into the venous system are always fatal, by occasioning great obstruction to the pulmonary circulation and consequent inflammation. When exceedingly small quantities are injected, and the animal is left without a repetition of the experiment to the resources of its system, a temporary embarrassment ensues, and the animal gradually recovers. Nysten supposes that the gases have then been dissolved in the blood, and either been exhaled from the lungs, or passed into the general circulation. But when repeated injections are attended with a fatal pneumonia, he supposes, that, all the gases not being dissolved, the spumous fluid obstructs some of the pulmonary vessels, and excites inflammation. It seems, therefore, strange that he should not have regarded the lungs as that part of the system in which the obstacle to the circulation arose, when large quantities of air were injected. This mode of death therefore resembles Asphyxia, where the circulation, being arrested in the lungs, exactly similar phenomena ensue, from the interruption of the supply of blood to the various tissues. Manifestly, if small quantities of air have such fatal effects upon the pulmonary organs, we cannot conceive that much larger quantities would be able to traverse them.

The organic sensibilities of the pulmonary vessels appear also to be illustrated by the fœtal circulation.

If respiration were not necessary to the transition of blood through the pulmonary tissue, it would be difficult to conceive why the foramen ovale and ductus arteriosus should form separate, less perfect, and unnatural channels for the circulation. Why must all the contingencies attending the dilatation of the lungs be hazarded? Why, if there be no obstruction during the absence of the air from the pulmonary cells, if the blood might circulate as freely in the fœtal as in the adult lungs, is it not transmitted through that medium, which, since it is longest employed, must be the best? In the adult, however, the deprivation of air is followed by a sudden arrest of the circulation. When oxygen is again supplied to the pulmonary cells the pulse and life return. These phenomena indicate surely that the circulation is arrested in the lungs.

Goodwyn supposed that the action of the lung continued a longer period than the contractile power of the left heart; and that in Asphyxia the circulation was interrupted, because the blood, permeating the capillary system and the lungs, became at length so far disoxygenated that it was incapable of stimulating the left auricle, and stagnated in its cavity. We have however seen, that the action of the left heart continues long after blood has ceased to flow from a puncture made in the pulmonary veins. The experiments of Bichat also prove that the heart circulates dark blood for a short period. He injected dark blood into the left cavities of the heart without destroying their contractility, whilst respiration proceeded with the right lung, and the heart contracted vigorously.* "I† have also re-established," he says, "the contractions of the heart, weakened in different violent deaths, by the contact of the dark blood injected into the left ventricle and auricle from a syringe adapted to one of the pulmonary veins." It cannot, therefore, destroy the contractility. The phenomena of the cessation of motion in the left heart in common Asphyxia are these. A smaller quantity of blood is received into its

* Op. Cit. p. 215. † Ib. p. 216.

cavities, and expelled for a time vigorously into the arteries, the ventricle meanwhile diminishes in size, as the quantity of blood supplied becomes less, until at length, though spontaneous contractions still occur in its fibres, no blood issues from a divided artery, and the ventricle, by contraction, has obliterated its cavity. After this, blood slowly accumulates in the auricle from the large vessels of the lungs, and its contractility continues for a very considerable period. The obliteration of the cavity of the ventricle is especially evident in frogs and cold-blooded animals, where it becomes transparent. The contractility of the auricle, it must be remarked, continues, though it contains the blood which the hypothesis of Goodwyn supposes to be fatal to it. By reference to experiments in a more advanced part of this inquiry, it will be found, that the spontaneous contractions and motive power of the different parts of the heart continue, always in proportion longer as they contain more of the asphyxial blood. Thus, in the experiment of Haller, the left heart may be made to contract longer than the right, by retaining the dark blood in its cavity, and by discharging it by an incision made in the venæ cavæ from the right. The action of the auricle may even be restored to its former vigour, by re-establishing the circulation through the lungs, as in the experiment of Hooke, though evidently the insufflation of air into the lungs could not reoxygenate the dark blood contained in the auricle.

Bichat, however, observing that the circulation of dark blood continues for a period, and reasoning from thence that it must pervade all the tissues of the body, conceived that the functions of the various organs were destroyed, by the positively noxious qualities of the blood which circulated in their vessels. This theory, however, as far as it concerns the heart, is supported by no direct evidence. He relates no experiment by which the noxious influence of the dark blood on the heart is demonstrated. The theory principally rests on general arguments drawn from his experiments on other organs of the body. No analogy can, however, be drawn between the heart and other organs, excepting the muscles. The brain, upon which Bichat's most remarkable experiments were performed, has so little analogy with muscle, that, even were it allowed that his experiments conclusively prove the noxious influence of the dark blood upon the tissue of the brain, it would be impossible to infer that its influence on the muscles must be similar. The only direct evidence which Bichat adduces in support of his opinion is the supposed influence of the dark blood on the muscles of voluntary motion.* "Inject into the crural artery of an animal this species of blood obtained from one of its veins, you will perceive the muscles soon becoming very sensibly feebler, and that sometimes immediate paralysis ensues." He then adds, that the ligature of the artery paralyses the limbs, especially if it be placed upon the aorta; but does not attempt to show that the paralysis occurs earlier when dark blood is injected than when the artery is simply tied. The following experiment, however, proves that the effect is entirely owing to the ligature of the artery.

Exp. 5.—Three rabbits were secured. The abdomen of each was opened. The aorta of one was tied above the renal arteries, and also the left common iliac close to the aorta. In eight minutes the vena cava of the second was opened; the blood which immediately flowed was injected into the aorta of the first. The contractility of both extremities was found to be equally vigorous. At the fourteenth minute, the degree of contractility having been ascertained by the insertion of needles attached to the wires of a battery, another quantity of blood was injected.

* Op. Cit. p. 278.

No difference could, by careful examination, be discovered in the contractility of the muscles in the two extremities. The injection of venous blood obtained from the cava of the third rabbit was twice more repeated in the course of thirty minutes. At each interval between the injections, the wires were equally applied to the muscles of both extremities, their contractility gradually and equally declined in each, as in experiments in which the artery is simply tied. Some feeble contractile power survived one hour. Wishing, however, to compare the effect in the muscles, and with the blood of the same animal, *cœteris paribus*, the following experiment was performed. Present Dr. N.

Exp. 6.—If the blood of Asphyxia have a more hurtful influence on the functions of muscle than the defect of the arterial blood, if we totally cut off the supply of blood to any muscle in Asphyxia, its contractility ought to continue longer than all the others which are subjected to the influence of this fluid. The trachea of a rabbit was laid bare, a ligature was passed beneath it, and one also beneath the abdominal aorta, above the superior mesenteric artery. The aorta and trachea were tied nearly at the same moment. The muscles continued equally vigorous for some time on the application of the wires of the battery. They then equally and gradually declined in strength, and in one hour ceased, contracting to the stimulus at the same time, the muscle of the upper extremity appearing towards the close of the experiment to be somewhat stronger. This experiment was repeated. I afterwards varied it thus.

Exp. 7.—The trachea of one rabbit was tied. In another the chest was opened, and in one minute the heart tied at its base. The muscles continued contractile an equal time in both.

The supply of dark blood from the left heart in Asphyxia has, therefore, no positive noxious influence on the muscles; but they are affected in exactly the same degree as when the supply of blood to their tissue is interrupted.

The connection between the blood and the contractility of muscular fibre is most intimately involved in this inquiry. Blood is necessary to muscular contraction. The most superficial observer is at once impressed with the extreme vascularity and the deep red colour of its tissue when contrasted with that of the rest of the body. Its power is in the direct ratio of its vascularity. All diseases which diminish the quantity of blood impair its power, and most of the causes which augment it are accompanied with a very evident increase of vascular energy. The colour in the young is scarlet, in manhood of a deeper red, and in old age it becomes a yellow and duller red.* It is influenced by sex, temperament, and diseases; is diminished in dropsy, consumption, hæmorrhagy; and in paralysis, the muscles often become pale and discoloured like cellular tissue. Bichat notices† that in many diseases of great prostration of strength the muscles become pallid; motion increases vascularity and power. "Some birds, as the black game,‡ thus have the external pectoral muscles of a deep colour, whilst the interior are pale." This appearance is observed in the most actively employed muscles of men of various trades. Fowler remarked§ that the contractions of a frog's leg were rendered much more vivid by exciting the vascular action.

Boerhaave, Stenon, Cowper, and many other of the older authors knew that a ligature of the artery destroyed the contractile power of muscle. Legallois, whose experiments in pursuit of other objects often led him to observe the same fact, conceived it merely to prove how necessary the circulation was to the nervous power. Etchepare‖ has lately more minutely observed its conse-

* Dic. des Sciences Medicales. Tome xxxiv. p. 562.

† Anat. Gen. Tome iii. p. 333.

‡ Phil. Trans. Carlisle, C. L. 1805.

§ Animal Electricity, p. 128.

‖ Magendie's Journal de Phys.

quences. It must, however, be premised, that it is impossible to isolate any portion of the body by the ligature of large trunks, since the circulation in the capillary system continues, and with such vigour as to be able to supply nutrition to the part, until, by the increased size and activity of its vessels, it has again connected itself directly with the heart's influence. On ligature of the abdominal aorta in a dog, excessive weakness of the lower extremities ensued, and in eight or ten minutes the motions became almost imperceptible. I have witnessed these phenomena. The contractility is however perceptible by the stimulus of a powerful battery, from forty minutes to a somewhat longer period than one hour, though of course it continues but a very short time vigorous, and towards the close of the experiment the contractions are almost imperceptible.

It is remarkable, however, that though the presence of venous blood in the tissue of muscle has been considered by Bichat and others to be fatal to its contractility, when the vein only is tied, or the artery and vein together, preventing the egress of this blood, the phenomenon does not so soon cease as in the simple ligature of the artery. The power of muscle does not become instantly extinct on the ligature of an arterial trunk, I imagine, because its capillary system still contains a great quantity of blood, and the ligature only prevents a fresh supply from the arterial trunks which irrigate this system, whilst the communication with the whole capillary system, which contains a much greater quantity of blood than the arterial, remains unobstructed. In purpura and scurvy the blood does not coagulate after death, and these diseases are marked by great prostration of strength. In animals which have not the power of quick motion,* the arteries supplying muscles are subdivided into a net-work of extremely numerous small branches, which again unite, retarding the progress of the blood by this mechanical arrangement. From these facts Sir A. Carlisle concludes, that, for the rapid and frequent motions of any muscle, it is necessary that it should enjoy an ample and unobstructed supply of blood. Frequently also in diseases of the arteries muscular debility, or from their obstruction, paralysis ensue. The subject is so extensive, however, that it is impossible to give a detailed view of it in this place, and I shall refer to the sources of information.†

* Home's Comp. Anat. Carlisle, Croonian Lecture, 1800, 1805.

† Trans. of a Society for the Improvement of Medical and Surgical Knowledge, Vol. iii. p. 448. The Medical and Surgical Journal, Vol. xv. p. 14 to 16. Phil. Trans. Vol. xxiii. p. 1194. Grainger's Medical and Surgical Remarks, p. 182.

I have also in my possession the aorta and obliterated femoral artery of a case of this nature, in which the paralysis was perfect.* The power of contraction is therefore in the direct ratio of the quantity of blood circulating in its tissue, and its capacity is determined by the facility and velocity of that supply. When it is abstracted contractility ceases. Blood is therefore necessary to contraction.

Having from the preceding reasoning formed this conclusion, I inquired whether, after the contractility of muscle had expired from the ligature of an artery, it could be revived by the transfusion of blood, and whether of arterial only or of venous also.

Exp. 8.—A large rabbit and two small ones were confined. The chest of the first was opened on the left side, the aorta divided, and the beak of the syringe introduced into the lower portion. After waiting some time, it was found by repeated application of the wires, that the contractility was extremely feeble in the lower extremities. The chests of the small rabbits were opened, and ere this could be performed the contractility of the inferior limbs was found to have expired. The aortæ of the small rabbits

* Edinburgh Medical and Surgical Journal, Vol. xvi. p. 308. North of England Medical and Surgical Journal, Vol. i. p. 278.

were successively divided; the blood received into the syringe and injected into the aorta of the large rabbits. On applying the needles of the different poles of the battery to the muscles of the lower extremities, their contractility was found to have revived to the degree in which it existed after dividing the aorta of the animal.—Present Dr. N.

Exp. 9.—In this experiment a large dog was secured. The arterial blood was obtained from his carotid, and the abdominal aorta tied. After the contractility had expired a considerable longer period than in the last experiment, the arterial blood was received into a warm syringe, and injected into the abdominal aorta whilst the animal was still breathing. The contractility of the muscles of the lower extremities revived. They contracted vividly a few times, and then became motionless. The blood of the dog coagulates so soon, that from this reason probably the power of motion expired earlier than in the other cases.—Present Dr. N.

Exp. 10.—This experiment was performed on rabbits. The blood being taken from the abdominal aorta of one, and injected into that of the other, when the motive power was no longer perceptible even on repeated application of the wires of a galvanic battery in vivid excitation, the contractile power immediately revived, and continued vivid for some time. Similar experiments having been afterwards performed with blood of a different character confirming this result, I did not repeat these experiments oftener, especially as to the most eager adventurer in physiology, there is much that is deeply repugnant to the feelings in its pursuits.

Arterial blood is more favourable to contraction than venous. Some physiologists have even asserted that it is essential. It is necessary, in order to refresh the memory of the reader, that reference should again be made to the researches of Edwards, of which a summary was given in the last chapter. I shall therefore briefly advert to a few of those facts, which are necessary for the complete elucidation of this subject. Buffon found that newly born animals have the faculty of living a longer time immersed in water than adults. Edwards discovered that this is intimately connected with the faculty of generating heat,* young animals producing less than adults; and that the period during which life continues in Asphyxia is intimately connected with this law, in animals of the same and different species, and in animals of the same and different

* Sur l' Action des Agens sur la Vie.

ages. Thus hybernating and cold-blooded animals, at certain seasons of the year, may be said to have no proper heat, but assume the temperature of the atmosphere. Their faculty of generating heat is *less* than that of animals of warm blood; and at the period when least heat is produced, in winter, they live immersed in water much longer than animals of warm blood. In young mammiferous animals the faculty of living without respiration is intimately connected with this law, and they may be divided into two classes:—1. Those which produce so little heat that they may be said to have no proper temperature, but are influenced by that of external agents. 2. Those which generate sufficient heat to preserve an elevated temperature when the air is not too cold.

The first live long in Asphyxia, the others a shorter space of time. In the submersion of these young animals, however, the circulation proceeds; and as the lungs have not been dilated by respiration, it must resemble that of the fœtus, the foramen ovale and ductus arteriosus remaining open. Buffon even thought, that by repeated submersion these channels might be caused to remain pervious, and that thus the animals would preserve the faculty of living a long period without respiration. The phenomena, however, (were the result of the experiment, as it respects the channel of fœtal circulation, successful,) could not ensue, as the faculty of generating heat increases with the age of the animal, and it requires a greater supply of oxygen. One just conclusion, however, Edwards has, I think, neglected to draw from his experiments. Inquiring whether the blood in this state tends to support life in mammiferous animals, he asphyxiated them by submersion, but arrested the circulation by an excision of the heart in some. Those, in which the circulation was arrested, lived only half the period during which the others survived.

The same laws apply to the cold-blooded animals. In summer, and when exposed to high temperatures, they produce generally a greater quantity of heat, and lose the faculty of living long without respiration. But when their temperature declines under the influence of continued cold, their faculty of generating heat is diminished. I have repeated the experiments in which Edwards discovered that cold-blooded animals can live respiring only the air contained in water. When they have been long exposed to a very low temperature, and water is at zero, they live immersed in water without oxygen two or three days. Their lungs being only an appendage of the general system, the circulation is not obstructed in them when they do not breathe, but continues as before. But if, cæteris paribus, they be thus contrasted; if the circulation be suppressed in some by the excision of the heart and bulb of the aorta, and others be exposed to similar circumstances with no supply of oxygen, but without excision; those, in which the circulation continues, live thrice the period that those, in which it is suppressed, survive. He concludes justly, that the asphyxial blood in these animals tends to support life.

But in the young animals, were the foramen ovale and ductus arteriosus closed, the circulation could not proceed, since the lungs, when they have not been dilated by atmospheric air, are not permeated by the blood of the general system, and after respiratory motions have been established, the circulation is arrested immediately after the loss of the usual supply of oxygen. The life of these animals is prolonged, therefore, because the lungs in Asphyxia do not form in them an obstacle to the circulation of the blood, though the period to which this life extends is increased by their low faculty of generating heat.

We have remarked, that in these instances asphyxial blood certainly tends to support life, Its relation to muscle must now be minutely examined.

In former experiments, we have observed that the ligature of the aorta produces paralysis in various periods of time, seldom or never exceeding forty minutes or one hour; but the ligature of a vein occasions paralysis after some hours only. I have often performed experiments, of which the following is an example.

Exp. 11.—In a full grown rabbit, the common iliac artery of one side, and the common iliac vein of the other, were tied.

A galvanic battery of forty plates was used to stimulate the muscles of the extremities, the integuments of which were removed from an equal space. The wires of the battery were applied every quarter of a minute to each extremity, for seven minutes, when the contractions became weak. In about a quarter of an hour they were imperceptible in the limb in which the artery was tied, and ceased shortly afterwards, probably because the battery was very powerful, and they were constantly stimulated, though both limbs were equally galvanized. The contractions in the other appeared to be under the influence of the will. Its contractility continued, though somewhat feebler, but in three hours the change had not proceeded rapidly; the contractions were still energetic. The cessation of contractile power ensues earlier when both the artery and vein are tied, but not so soon as when the artery alone is secured.

Dark blood is therefore less favourable than arterial to the contractility of muscle, but its presence in the tissue supports this power a considerable period after the ligature of the artery. That venous blood is favourable to muscular contraction is confirmed by the following experiments.

Exp. 12.—The abdomens of two rabbits were opened, and the abdominal aorta having been tied above the renal arteries, the beak of the syringe was introduced into its lower portion. The common iliac artery of the left side was then secured. The motive power continued strong to the stimulus of the battery half an hour. I then observed that the vena cava was extremely distended, and remembering M'Fadyen's experiments on the motion of the blood in the veins, I aided its ascent by constantly drawing my finger along the vessel towards the heart, and then preventing its return by pressure, and performing the same action with the other hand. After having continued this about three minutes, during which time a very considerable quantity of blood had been propelled towards the heart, I was surprised to find that the muscles, which had before been very energetic, had almost lost their contractility—the feeblest and most tremulous motions only being performed. Immediately afterwards, no contraction could be obtained from repeated applications of the wires. The vena cava of the second rabbit was divided, the blood received into the syringe, and injected into the aorta of the first. The contractile power of the right leg, in which the artery was pervious, immediately became strong; that of the left limb, in which the iliac artery was tied, remained extinct. In a few minutes more, a second quantity of blood, which had collected from the divided cava, was injected, and in a few minutes a third. Vivid contractions ensued, on the application of the stimulus in the right limb, and continued, though with decreasing force, a quarter of an hour.—Present Drs. N. and B.

Exp. 13.—The experiment was repeated on two smaller rabbits. The aorta and left iliac of the first were tied. In half an hour the contractility of its inferior extremities became weak, and then suddenly expired. Care was taken by repeated applications of the needles attached to the wires, to prevent any motion remaining unobserved. A small quantity of blood only, from the size of the animal, could be obtained by the syringe from the cava of the other. It was injected, and the contractility of the right leg, in which the artery was pervious, immediately and remarkably revived on applying the stimulus ; the other leg remaining perfectly immotile. The injection was repeated with increased effect. The experiment could not, however, be prosecuted any further from the want of blood, and the motive powers soon expired.—Present, Drs. N. and B.

I had observed, that after the ligature of an artery, the congestion of blood in the veins of the muscle maintains its contractility a longer period than when the artery is simply tied. I then inquired whether the asphyxial blood had the same power. In experiments, I had found that the asphyxial blood, when freely supplied by the natural contractions of the heart to the muscles of voluntary motion, had no positively hurtful influence. The contractile powers of such muscles continued as long as in those to which the supply of this blood was prevented. But the congestion of venous blood appears to have the power of maintaining contractility a certain period. Does the blood of Asphyxia maintain this phenomenon of muscles in a similar way ? I observed that the muscles of the superior and inferior extremities were equally congested, (from the accumulation of blood from the general system of minute vessels in all the structures of the organization) the inferior with venous, in the sixth experiment, and the superior with asphyxial blood, and the contractility remained during the same period in each. Was not, I inquired, the contractile power of the superior extremities maintained by the congestion of asphyxial blood in their veins?

Exp. 14.—The abdominal aorta and vena cava, and the trachea of a rabbit, were tied at the same time. The chest being opened, the lungs were found well dilated. After a few minutes had expired the superior cava was divided. The needles attached to the wires of the battery were then applied to the muscles of the upper and lower extremities; they were equally and vigorously contractile. From the superior cava flowed a great quantity of blood, which had the asphyxial characters. The muscles of the upper extremities became gradually feebler, and their contractility expired in thirty-five minutes. Those of the lower extremities were very vigorous, when the contractility of the superior was extinct, and continued so during twenty minutes afterwards; and contractions could be obtained by the application of the wires, at the expiration of an hour and a quarter.

These experiments appear to prove, that neither asphyxial nor venous blood have any noxious influence upon the contractility of the voluntary muscles, but that their presence supports the contractile power for a considerable period. The analogy, therefore, which Bichat has drawn from influence of venous blood upon the voluntary muscles is without foundation.

The heart, it may be objected, has a peculiar sensibility; it differs from the voluntary muscles in having a peculiar innervation—in its constant action—somewhat in the distribution of its vessels—and the right auricle is regarded by physiologists as the *ultimum moriens.* These circumstances are sufficient to throw on any analogy drawn from the muscles of voluntary motion a doubt, which, in the investigation of truth, it is necessary to remove. The fact, that the right auricle continues longer motile than any other muscle, has been regarded since the days of Galen as evidence of some peculiarity in the contractile power of the fibres of the heart. It has been generally esteemed to prove that the heart has, in the language of the day, a greater proportion of vital energy, or in that of Haller, a greater irritability.* For instance, Orfila,† commenting on the opinions of Bichat, says, "the heart, which is not so soon paralyzed as the other muscles, continues still some time to propel the venous blood

* El. Phys. p. 481, Vol. i. † Dict. de Med. p. 75. Asphyxie.

to all the structures." The continuance of the contractility of the right auricle, after all other muscles have ceased to act, appears to favour this opinion. Nysten and Haller‡ agree in their observations on this subject. The right ventricle and auricle in common death always contracting longer than their corresponding systemic cavities, and the venous sinus and auricle longer than the ventricle. In the experiments of Nysten the action of the ventricles expired before that of the voluntary muscles. The dependence of the muscular contractility on the proper supply of blood has been previously shown, and it is probable that the continuance of contractility, after the obstruction of the great vessels, depends on the general anastomoses of small branches, and the uninterrupted communication of the capillary system, which maintain a supply sufficient to support a feeble contraction. Now it is evident, that, from the imperfect connections of the heart, with the general capillary system, by means of continuous tissue, this communication must be more imperfect in this than in any other organ; and that, consequently, its contractility, unless supported by some other means, ought first to expire. But the right auricle ceases last to contract. The

* El. Phys. Vol. i. p. 423, 24, 25, 26.

contractility of different parts of the heart expires at different periods.

Have these phenomena any connection with the state of its vascular system, or by what other means is the contractility of the right side of the heart supported longer than that of the left? The continuance of the contractility of each auricle beyond that of its ventricle may perhaps be attributed to the difference of the tissue of an auricle and a ventricle; either to the actual difference of the muscular or of the nervous system in an auricle, which, if exposed to the same causes, continues to act longer than a ventricle. But we find that the right auricle continues its contractions longer than the left, and the right ventricle than the left, and the reason of this difference is the object of the inquiry. Haller supposed that the motion of the heart was maintained for a longer period, because the natural stimulus which excites the motion of its cavities was present in them to prevent their quiescence. The heart, however, being a muscle, must be subjected to the general laws of muscular fibre. The muscle in life is fatigued by exertion, and after the ligature of an artery, or when the circulation of the blood has ceased, stimuli weaken the remaining force of the contractile power, which expires earlier in proportion as the iteration of the stimulus is more rapid, and as its power is greater. When the supply of blood to the coronary arteries has ceased, each successive application of stimuli must on this account weaken the power of the heart's contraction. The deduction therefore from the following celebrated experiment of Haller must be different from that which he maintained. "I* divided the venæ cavæ, and emptied the right auricle and ventricle, afterwards tying the veins. I opened also the pulmonary artery by an ample wound, that the right ventricle might more easily discharge its blood, so that the right auricle and ventricle evacuated their contents; on the other hand I left the pulmonary veins free, but placed a ligature on the aorta, so that the left auricle and ventricle received blood, but could not expel it. The left auricle and ventricle always continued acting longer than their corresponding cavities, even to the fourth hour. The right auricle was in perpetual quiescence. The right ventricle contracted either imperfectly, languidly, or a shorter time, when it was not altogether immotile; or its quiescence was perfect, as often as the experiment had so succeeded, that the cavities were entirely evacuated."

From this experiment Haller infers, that the

* El. Phys. Vol. i. p. 492.

presence of the blood in the cavities of the heart maintains by its constant stimulus the contractility of the fibre. But the left auricle always contains a quantity of blood in common death, sufficient, in the language of this hypothesis, to act as a stimulus in maintaining its contractility; yet it always expires earlier than that of the right auricle.

The congestion of the venous blood in the muscular fibre maintains, during a certain period after the supply of blood has ceased, the contractile power of muscle. The heart, in the death of the brain and lungs, is similarly situated with a muscle whose artery is tied. Blood for a certain time is supplied from the pulmonary veins, and during a certain time its contractions continue as strong as they usually are. As this blood diminishes in quantity, the supply to the coronary arteries becomes less, and the contractions of the heart are impaired. After, however, all supply to the arteries has ceased, the heart continues to contract; but it rapidly becomes feebler, as it now depends for the maintenance of its contractility solely on the blood contained in its fibre. So far the heart obeys the law of muscular fibre in the intimate connection of this phenomenon with the supply of blood. If then, by any means, the egress of blood from its veins were obstructed, this must tend to support its contractility in this state.

Vieussens first, and afterwards Thebesius, Lancisi, Lieutaud, and many other later authors, have described veins of moderate size which enter into the cavities of the right venous sinus and auricle, especially. Haller,* confirms their testimony, and describes one small vein whose mouth is generally discovered near the fossa ovalis, which returns blood from the right auricle and its sinus. Other similar terminations of conspicuous veins are found in the right sinus and auricle, and, according to Vieussens, even in the vena cava. Afterwards in a similar way he describes the venous terminations in the left auricle, its sinus, and even in the pulmonary vein. Supported by the same authorities, Vieussens, Thebesius, Rochet, Verheyen, Lancisi, Kawe, Boerhaave, &c., other smaller veins have been described opening into all the cavities of the heart, and into the sinuses of the venæ cavæ and pulmonary veins, with oblique mouths which are protected by valves. Haller informs us that if the tube of an injecting syringe be introduced into the vein of the heart, and all the mouths of the smaller veins that can be discovered opening into the cavities be tied, any coloured liquid or mer-

* El. Phys. Vol. i. p. 380.

cury may be injected easily, and will be observed to exude through the oblique terminations of the veins, in the auricles, sinuses, and ventricles, but chiefly in the septum cordis, and in the right cavities. The arteria profunda of the septum cordis has no vena socia, and it is probable that some other way has been prepared by nature by which the blood of this artery may return to the general circulation; and Haller insists upon the necessity of its return to the cavities, by veins similar to those described. The deep-seated veins of the muscular fibres of the heart must, it is evident, have more direct communication with its cavities than the superficial, since in passing through an interlaced tissue alternately contracted and relaxed, their circulation would be nearly obstructed, and the functions of that part of the tissue would suffer in proportion. In the experiment of Haller, quoted above, the permanence of contractility was transferred from the right to the left cavities, by emptying the former and producing a congestion of blood in the latter. This congestion, which maintained the contractile power of the left cavities of the heart, must have impeded the return of blood by the small veins which enter them, and produced in the fibre that venous turgescence which, when the supply of blood is obstructed, supports contractility. In the cessation of the heart's action consequent on that of the brain or lung, the left ventricle is found almost empty, and its contractility first expires: the right ventricle, which must be contrasted with it, is gorged, and its contractions continue a much longer period. When, however, their state is changed, and the left is gorged and the right empty, the phenomena are reversed. The left auricle, also in this state, contains a considerable quantity of blood, but the right sustains the whole pressure of the venous and capillary system, and its contractility is most permanent; when the circumstances are reversed, by emptying the right auricle, and maintaining a congestion of the left, the contractile power of the right expires first. Nysten also observed, that the irritability of the pulmonary cavities was greatly impaired by injections of air into the veins; if the injections were excessive the contractility very rapidly ceased. A distention with air, or a spumous fluid, must operate not merely by preventing any congestion of the internal veins, and allowing a free escape of blood contained in the fibre, but, as in paralysis of the bladder from a similar cause, by preventing a supply of blood to its fibre. Smaller injections of air, which are not so soon fatal to the contractility of the pulmonary heart, must act simply in the former way.

The preceding arguments led to the following experiments.

The left auricle generally contracts longer than the right ventricle, according to Nysten. Has this any connection with the blood contained in its cavity? To determine this point the following experiment was performed.

Exp. 15.—The chest of a rabbit was opened, and in a minute and a half from the commencement, the lungs had been tied at their base—the heart was contracting rapidly and vigorously. At the fifth minute its contractions occurred irregularly and slowly. In the eighth they were eighty-eight. Tenth—left ventricle much diminished; right gorged; contractions feeble. Twelfth—left auricle had ceased; contractions twenty-four. Fifteenth—contractions twenty; extremely feeble. Eighteenth—left ventricle immotile. Twenty-fifth—fourteen contractions of the right side. In thirty-five minutes the ventricle and auricle were also immotile to common stimuli. The right side was gorged, the left empty.

Exp. 16.—In a full grown rabbit the trachea was tied, and in two minutes the chest had been opened, the lungs tied at their base, and the venæ cavæ divided at the distance of one-fourth of an inch from the right auricle. The auricle was evacuated; but as no pressure was made on the ventricle, and the pulmonary circulation was arrested, it remained distended. At the sixth minute the auricles were flaccid—their cavities appeared empty—their contraction had gradually become feebler, and less frequent; at the end of eight minutes they were immotile: the sinus venosus of the right auricle contracted, however, a somewhat longer period. The left ventricle gradually diminished in size; its contractions became feebler and less frequent; and at the end of eighteen minutes, when it appeared to have expelled all its blood, it become immotile to common stimuli. The right ventricle contracted vigorously at the end of half an hour, and continued irritable longer. On examination, all the cavities, except the right ventricle, contained no more blood than was sufficient to moisten their parietes, but the right ventricle was distended.

Exp. 17.—The left side of the chest of a rabbit was opened, the pericardium cut, and a ligature having been passed round the aorta, and pulmonary artery at their origin, an interval was allowed to elapse, during which the animal breathed well, though rapidly, with the right lung. The ligature was then tied close to the root of the arteries. Respiration proceeded well with the right lung, and continued about a minute and a half, when struggles and violent convulsive gasping ensued, and the animal died exactly as in Asphyxia. The struggles had ceased in three minutes and a half. The trachea was tied when all motion had ceased several minutes. The right cavity of the pleura was then opened. The mediastinum was discovered perfect; but in the interval which elapsed ere the trachea was tied, some air had permeated through it into the right pleura, and the lung had in some degree collapsed. At the close of the experiment the pulmonary artery was found gorged with blood, which flowed from an incision in very great quantity. The aorta was nearly empty. The circulation had therefore been arrested in its full career, and the cavities of the heart must have been distended with blood. The contractions of the ventricles continued synchronous, and they both contracted the last time at the thirty-fifth minute. The auricles contracted one hour and thirty-five minutes synchronously. The right then contracted most frequently. In one hour and forty-two minutes the left ceased to contract spontaneously, though doubtless, it was contractile to stimuli. The right auricle contracted spontaneously two hours and ten minutes, and was then contractile. The ventricles were equally distended with blood, and ceased contracting at the same time. The right auricle was more congested than the left, and continued longest contractile, sustaining, as usual, the pressure of the whole venous and capillary system. Present Dr. N.

The result of these experiments is perfectly consistent with the idea, that the contractile power of the parts is supported through a comparatively longer period, by the repletion of their cavities, and consequent congestion of their fibres with venous blood. This repletion of the right auricle, and of its venous sinus, in death from the cessation of the functions of the brain or lungs, must be more considerable than that of any other muscle of the body. The blood, which by the last contraction of the ventricle is propelled into the arteries, is by them conveyed to the capillaries in the various tissues of the body. The organic motions of these tissues continue for some time—the blood still moves onwards, and is impelled with a certain force by their actions into the general venous system. The veins are every where found distended, because the circulation is obstructed by the lungs, in which respiration has ceased. The pressure of this power must be divided between the terminations of the large veins in venous radiculæ in all the system, and their opposite terminations in the heart. The power, therefore, will be greater in the auricle than in any other portion of the body; and if congestion support the muscular power, that of the auricle ought to survive longer than that of any other organ, as experiment proves that it does.

In the following experiment, which is in other respects a repetition of that of Haller, the venous congestion was prevented from affecting the right cavities of the heart, and the result was consistent with the previous reasoning.

Exp. 18.—The chest of a rabbit was opened, the venæ cavæ tied, and then divided nearer the heart than the ligatures. The heart contracted vividly for some time, then gradually weakened. In ten minutes spontaneous contractions seemed to have ceased. It continued contractile without irritation to the thirteenth minute. The right ventricle and auricle were immotile to the stimulus of the galvanic battery, flaccid and empty, at the fifteenth minute. The stimuli were constantly applied, to ascertain the motive power of the different parts. At the twenty-fourth minute no contractions could be obtained from the left ventricle. At the twenty-eighth, the left sinus venosus was observed to contain a considerable quantity of blood, which had gradually accumulated from the large vessels of the lungs. The blood was evacuated by an incision, and speedily all contractility ceased. The voluntary muscles, however, continued vividly contractile at the end of one hour, when the experiment was interrupted.—Present, Dr. N.

These experiments are consonant with the idea, that the motive power of the right heart, in all cases in which it has been observed to continue longer than that of the muscles, has been preserved by the greater comparative supply of blood to its fibre, from the congestion of its cavities, and the consequent repletion of its small veins.

It would be difficult to determine whether much of this effect may not be owing to imbibition, by the open mouths of the small veins, from the blood contained in the cavities of the heart, thus supplying, by their peculiar action, the muscular tissue with the blood necessary to its contraction. Some experiments which I have performed seem to favour this idea. They have not, however, been so frequently repeated as to deserve mention here.

From these experiments, we may at least conclude, that the heart so far obeys the laws common to muscle, that an analogy, drawn from the influence of blood on the tissue of the muscles of voluntary motion, would be strictly applicable to the laws of the contractility of this organ. The blood of Asphyxia, so far, therefore, from having any positively noxious influence on the muscles of voluntary motion, or on the heart, is capable of supporting their motive power for a certain period. By what arguments, therefore, is the celebrated hypothesis of Bichat supported?

Bichat commences his inquiries on this subject, by noticing the theory of Goodwyn, (p. 211.) To this he objects, 1st. That if the dark blood paralysed the left heart by its presence in the ventricle, the action of the heart ought to cease first, and that of the organs to succeed, which is contrary to the fact. 2d, If the trachea of any animal be obstructed, (p. 213) any artery being divided, the blood which flows gradually assumes a darker colour, and at length becomes as dark as the venous. Notwithstanding this phenomenon, which is very conspicuous, the fluid continues still to jet forth, with an energy equal to that of the florid blood for some time. Therefore the heart acts vigorously with this blood in its cavity. 3d. The result of this experiment is the same, though the atmospheric air be in a great measure abstracted from the lung by means of a syringe. 4th. Venous blood injected into the left auricle and ventricle, by means of a syringe, does not weaken the contractions. He therefore inquires, (p. 217.) " quelles sont donc les causes qui interrompent la circulation dans le cœur à sang rouge, et dans les artéres, lorsque le poumon y envoie du sang noir?" He concludes without any further argument or proof, (p. 217.) "I think that the dark blood acts upon the heart in the same way as on all the other structures, as we shall discover that it influences the brain, the voluntary muscles," (which I have shown to be incorrect,) "the membranes, &c. in a word, all the organs which it penetrates, that is by permeating their tissue, by enfeebling each particular fibre; so that I am well persuaded that if it were possible to propel by the coronary artery, dark blood, whilst the florid circulates as usual in the aortic auricle and ventricle, the circulation would be almost as soon interrupted as when the blood penetrates the tissue of the heart by the coronary arteries, only after having passed the two cavities of arterial blood."

That the genius of Bichat erred in this conclusion is perhaps sufficiently demonstrated. We have before seen in experiment 3, &c. that the action of the left ventricle continues long enough to expel all the blood from its cavity, and that it contracts long after blood has ceased to flow from the coronary veins. Its contractions, therefore, survive the period when it is possible that the coronary arteries can receive the asphyxial blood. The theory of Bichat supposed the noxious qualities of this blood to be fatal to the heart, and that, from this cause, the arterial circulation ceased; but the heart in Asphyxia continues to contract vividly when no blood flows from a divided artery. The circulation is arrested by the suspension of respiration, and the consequent cessation of the functions of the lung, at the moment when Bichat supposed the circulation of dark blood to exercise a fatal influence on the heart, which, notwithstanding, continues its contractions vividly for a considerably longer period. But, we have before shown, that the contractions of the heart become less frequent after the supply of blood to the coronary arteries has ceased, in the same degree as the motive power of voluntary muscles is affected after an artery is tied. Other experiments have shown that this blood is favourable to the contractility of the voluntary muscles, and that its presence in the cavities of the heart maintains, during a certain period, the motive power of its fibres. Similar evidence may be obtained, though somewhat more obscurely, from the experiments of Bichat. In opposing the theory of Goodwyn, (p. 216,) he says, "Enfin il m'est egalement arrivé rétablir les contractions du cœur anéanties dans diverses morts violentes, par le contact du sang noir injecté dans le ventricule et l'oreillette à sang rouge, avec une seringue adapteé a l'une des veines pulmonaires," evidently by giving a new supply to the coronary arteries. In page 217, the comparison of two opposed passages appears unfavourable to his opinions. He asks, " Quelles sont donc les causes qui interrompent la circulation dans le cœur à sang rouge et dans les artéres lorsque le poumon y envoie du sang noir?" Now, in page 227, he says, " Toujours par consequent c'est dans le poumon que la circulation trouve son principal obstacle." The circulation, therefore, is not arrested in the heart; and since the obstruction is thus said to be in the lungs, the supply of dark blood to the heart cannot ensue, and one passage contradicts the other. Yet he concludes in the answer to the question quoted above, that the noxious qualities of this dark blood destroy the motive power of the heart.

An experiment is also detailed in page 217, which is irreconcilable with the theory. When the dark blood has flowed from a divided artery some time in Asphyxia, its impetus gradually becomes weaker, and at length ceases almost entirely; if then the stop-cock obstructing the trachea be opened, and respiration be allowed "il se retablit bientôt avec force." If in this experiment the circulation had ceased from the destruction of the motive power of the heart, on account of the noxious influence of the dark blood upon its fibres, the renewed circulation of the lungs on the admission of oxygen could have no sudden influence on the fibre whose contractility had been destroyed by a noxious fluid, which had gradually permeated and pervaded its tissue; yet the contractions are described to have been soon re-established with energy. This, however, may be readily conceived, since we have seen that the contractions of the heart cease from the want of a due supply of blood, on account of the obstruction of the pulmonary circulation. When, therefore, as in this experiment, the motive power has almost ceased, if respiration be restored, the circulation through the lungs will be re-established, the supply of blood to the heart re-commence, its fibre renew its contractions with vigour. The same arguments apply to the celebrated experiment of Hooke, and to the usual phenomena of resuscitation by the inflation of the lungs.

In the application of the same doctrine to explain the interruption of the functions in the other organs of the body, Bichat has also drawn similar conclusions from the same premises. Examining his argument in detail, we shall discover that it rests entirely on the supposed influence of the dark blood on the voluntary muscles, and the supposition that this blood continues to circulate a considerable period, and penetrates all the organs of the body, (p. 265.) We have observed, however, that the arterial circulation ceases in a very short time after respiration has been suspended. Bichat principally supports his opinion by the fact, that the tissues of the body become more livid than in ordinary death, and that dark blood oozes from them when they are divided.

Blood darker than the arterial certainly permeates the lungs, and is transmitted from the left ventricle during a short period to the various organs of the body. But the time during which this blood circulates when respiration has been suddenly suspended is so short, that we cannot suppose that it has any great influence in producing this colour, especially as the phenomenon is capable of an explanation more consonant with the facts detailed in this inquiry. In the variety of Asphyxia often observed in diseases of the lungs, especially when complicated with the extreme debility of fever, when the functions of the lungs are gradually impeded, the colour of the blood is changed in all the tissues of the body; but as death does not ensue, until, as in common Asphyxia, the circulation has been arrested from the cessation of the functions of the lung, this blood has no sudden noxious influence on the various tissues.

Hunter, however, discovered, that the colour of the blood in contact with any living tissue, gradually becomes darker, until it has assumed the venous colour. After death, on what lesion soever it may depend, we never discover bright arterial blood in any tissue of the body. The state of the vascular system differs also in Asphyxia from that observed in other kinds of death, as the blood is chiefly accumulated in the veins, and the radiculæ and minute vessels terminating in them. That the tissues therefore should assume a somewhat livid colour, is not so peculiar that it must be ascribed to an universal morbid change in the blood, which cannot happen when the respiration is suddenly interrupted; but it must be attributed to the strange influence of tissue upon blood, by which its qualities assume in a greater degree the venous characters, when surrounded by it, and to the peculiar state of congestion of the venous system, rendering this colour more obvious to the eye.

Bichat proceeds (p. 275,) to attempt to prove "that the dark blood is incapable of supporting the activity and the life of the organs which it penetrates, when the functions of the lung have ceased." The arterial blood, he remarks, is peculiarly adapted as a vital stimulus to the various organs of the body; (p. 275-276,) and

(p. 277) he speculates concerning the method by which it supports the various organic motions. He then proposes (p. 278) to examine how the contact of the dark blood with the structures occasions their death. The action of all the organs of what Bichat has termed animal life depends on the brain, and, supporting his opinion by his experiments concerning the influence of the dark blood on the brain, he supposes that it is through this medium fatal to them. "But when," he adds, "this fluid circulates in the general system, when all the organs are subjected to its influence, two other causes are added to this. 1. The nerves which are penetrated by it are no longer capable of establishing communications between the brain and the senses on the one hand, and on the other, between this viscus, and the locomotive and vocal organs. 2. The contact of the dark blood with the organs themselves destroys their action." For he asserts, if the dark blood be injected into the crural artery of an animal paralysis supervenes. He repeats these opinions in page 280. But its influence on the nerves rests simply on the opinion of Bichat, unsupported by experiment, and we have shown that it has no noxious influence on the muscle. Pursuing the argument, he remarks the difficulty of proving satisfactorily "that the secretions, exhalation, and nutrition, cannot obtain from the dark blood the materials necessary to support them, for this blood does not circulate in the arteries, during a period sufficiently long, to enable us to make experiments on these functions. He then remarks, that, after respiration had been suspended, he had never witnessed the flow of semen from the vas deferens, or of urine from the ureter, but he allows that no conclusion can be deduced from observations of this nature, made during the short sufferings of the animal. "It is therefore," he continues, "principally from the analogy of that which happens in other organs, that we determine that the functions of secretion, exhalation, and nutrition, cease when the dark blood penetrates their structures." But upon what analogy? The only positive experiments, adduced in support of these opinions, concern the effect of the dark blood on the muscle and the brain. The first we have shown to be erroneous; and concerning the second we can only at present remark, that, allowing the experiment to be correct, the fact that the dark blood supports and revives the contractility of muscle demonstrates that no analogy can be drawn between the brain and other organs. Analogy cannot therefore be adduced in aid of this opinion.

The argument of Bichat here ceases; and it is needless to follow him through the subsequent pages, in which he attempts to trace a vague accordance between his opinions and some of the obscure and even doubtful phenomena of Asphyxia.

To these opinions it must further be objected, that in young animals, as is proved by the experiments of Buffon and Edwards, and in animals of cold blood, life, with all its functions and phenomena, is supported for a considerable period by the presence of the dark blood; and as the hypothesis of Bichat is supported by no valid experiment or argument, we are inclined to the opinion, that, though the dark blood is doubtless less favourable to the action of the organs generally, than the arterial, yet its presence exerts no positively noxious influence upon them, but is even capable of supporting their actions for a certain period. The evidence of more decided experiment is desirable to confirm this opinion, as far as it respects the organic motions generally. Concerning muscle, the experiments detailed in this inquiry, are positive; and the blood being necessary to secretion and nutrition, it is a natural consequence, that, when the circulation is arrested, as in Asphyxia, these functions should cease.

## CHAP. IV.

From the facts adduced in the preceding chapter, it appears that when the entrance of atmospheric air into the lungs is prevented, the blood continues to permeate them for a very short time only, or one which may be considered commensurate with that which is necessary to deprive the air contained in the cells of all its oxygen. The blood then ceases to be arterialized, and its progress through the pulmonary structure is arrested.* The minute vessels of all tissues have peculiar sensibilities of organization, and it appears, contrary to the hypothesis of Bichat, that the vessels of arterial blood in the lungs, are incapable of conveying blood in

* In justice to my friend Dr. Williams, of Liverpool, I must remark, that he has drawn my attention to an able paper which he had previously communicated to the Edinburgh Medical and Surgical Journal, which anticipates one of the conclusions at which I arrived, by a very different experimental process. His paper is entitled "On the Cause and Effects of an Obstruction of the Blood in the Lungs." His conclusions, concerning this particular portion of the inquiry, are expressed in these words. "The obstruction of the blood in the lungs, on suspension of respiration, is not the effect of a mechanical cause." "The obstruction of the blood in the lungs, on suspension of respiration, arises from a deprivation of pure atmospherical air."

advanced stages of that venous degeneration, which ensues when the access of atmospheric air to the cells of the pulmonary structure is precluded. The blood, however, permeates the tissue with a progressively and a rapidly diminishing velocity, in small quantities, and for a very limited period, until it becomes at length so much changed, as to be incapable of exciting the action of the vessels of arterial blood, and the circulation is arrested in the lungs. In three experiments which were frequently repeated, it was shewn, that the blood entirely ceases to be transmitted from the lungs to the left cavities of the heart, in little more than three minutes and a half, after the air is excluded. Respiration is therefore necessary to the transmission of the blood through the pulmonary tissue, and when the inhalation of atmospheric air ceases, it is followed by an arrest of the circulation, in the capillary vessels of the lungs. If air be immediately readmitted into the pulmonary vesicles, or insufflation be, after the lapse of a short period performed, as in the celebrated experiment of Hooke, the blood undergoes changes in the vessels—carbonic acid gas is given off—it contains more oxygen, and less carbon proportionally than before, assumes the arterial hue—again penetrates the pulmonary structure, and is propelled by the left ventricle into the arteries. Hunter* sagaciously observes that this fact is subversive of the theory of Bichat; it is equally so of that of Goodwyn, who supposed that the circulation is arrested in Asphyxia, because the dark blood having permeated the lungs, destroys the contractile power of the left auricle by its presence in its cavity. This last hypothesis is however incompatible with the simplest and most obvious experiments, and in the preceding chapter it is demonstrated, that the presence of the dark blood in the cavities of the heart maintains their contractility, by occasioning venous congestion in their structure.

Bichat, however, observing that the circulation continues for a period, and reasoning thence, that venous blood must permeate all the tissues of the body, conceived that the functions of the various organs were destroyed by the positively noxious qualities of the blood circulated in their vessels. He attempted to prove, by direct experiment, that it produced this effect on muscular and nervous fibre. I discovered, on the contrary, when the artery supplying the muscles had been tied, and the contractile power had been, in consequence, after the lapse of some time totally extinguished, as in

* On the Animal Œconomy.

the experiments of Boerhaave, Stenon, Cowper, Legallois, Etchepare, &c., that on the injection of venous blood, the power of contraction revived —that in the absence of arterial supply it was maintained by venous congestion in the tissue, and that the irritability of the heart in Asphyxia is supported for a time, by the congestion of the venous blood in its cavities and veins. The right auricle, which is regarded by physiologists as the ultimum moriens, retains its contractile power, because its tissue is in the greatest degree congested with venous blood, (and perhaps because its cavity is longer supplied with its natural stimulant)* and it appeared that the order in which irritability deserts the various cavities of the heart, might be reversed, by maintaining the congestion of those which are ordinarily empty, and evacuating those which are generally full of venous blood.

The general conclusions concerning Asphyxia obtained from this investigation are, first, that the circulation is arrested after respiration ceases, because, from the exclusion of oxygen, and the consequent non-arterialization of the blood, the minute pulmonary vessels which usually convey arterial, are then incapable of conveying venous blood, which therefore stagnates in the lungs.

* Haller. Elementa Physiologiæ.

Secondly that the arrest of the circulation is sudden when the lungs are entirely deprived of air, and that blood ceases to flow from them into the left cavities of the heart, even in the smallest quantities, in about three minutes and a half. Thirdly, that even supposing a great quantity of venous blood were transmitted through the lungs, and permeated the heart and muscles, it would not impair their contractility : but on the contrary, that it is even capable of supporting this power for a certain period. Venous blood does not possess any noxious quality, by which the organic functions of these tissues can be destroyed, but is simply a less nutritious and stimulating fluid than arterial blood. The functions of muscular fibre cease in Asphyxia, because the circulation, and consequently that supply of vital fluid which is necessary to life, is arrested in the lungs.

The quantity of venous blood which permeates the lungs before animation is suspended, must now be ascertained, and in this chapter I shall inquire whether this fluid destroys the functions of the brain and nervous system in Asphyxia as was supposed by Bichat. This inquiry is of great importance, since these still continue to be the opinions of all modern physiologists. Beclard*

* Elemens d' Anatomie Générale, p. 644.

thus says, " Asphyxia, whose cause has been so much sought in the obstruction of the transit of the blood through the lungs—(Haller) in the stagnation of the venous blood in the left ventricle —(Goodwyn) in the penetration of the muscular structures of the heart by this blood—(Bichat) results much rather from the transfusion of the nervous structure by dark blood," and Dr. Alison, in his recent admirable work on Physiology, admits the doctrines advocated in the paper which I published in the Edinburgh Medical and Surgical Journal, but he says, that *" the experiments of Bichat, Brodie, and others have satisfactorily shewn, that a quantity of blood sent from the right side of the heart to the lungs, although not arterialized there, passes on to the left side of the heart, and is propelled into the arteries ; and that as soon as this venous blood reaches the brain, the animal becomes insensible, and generally convulsed." " It appears," he repeats " from these facts, that in death by Asphyxia, the deleterious influence of venous blood is exerted first on the nervous system ; next, and most fatally, on the circulation in the capillaries of the lungs, and, in a less degree only, on the heart and other muscular parts."

* Alison's Outlines of Physiology, p. 194.

I consider it therefore important to ascertain the truth or fallacy of these opinions.

When respiration is arrested, the lungs still contain a considerable volume of air, which continues to impart its oxygen to the blood, until it is consumed. M. Berger, of Geneva,* collected and analyzed a portion of this air when expelled from the lungs, a short time after immersion, in a great variety of different animals, and uniformly found that it had lost nearly the whole of its oxygen. As long therefore as the blood obtains oxygen from the air-cells, it continues to circulate through the lungs, and in the first moments it may be considered almost duly arterialized, and then permeates the pulmonary structure with undiminished velocity. The obstacle to the circulation ensues in consequence of the cessation of the change from venous to arterial blood, and is proportioned to the degree in which the blood, contained in the capillary arteries of the lungs, assumes the venous character. †Bichat, however, asserts that if respiration be interrupted immediately after an inspiration, the colour of the blood issuing from an artery, or observed in the pulmonary veins is obscured in thirty seconds—becomes decidedly

* Essai Physiologique sur la cause de l' Asphyxie par submersion. (1803)

† Sur la Vie et la Mort, p. 241.

dark in a minute, and exactly resembles venous blood in a minute and a half or two minutes. This change he affirms is more rapid, if respiration be arrested, immediately after an expiration. Venous blood, he affirms, permeates the lungs, and is propelled into all the structures of the body, during a period, and in quantities sufficient to arrest their organic motions by its presence. Having discovered that the former part of this theory was defective, I was led by the want of precision and congruity in the experiments of the celebrated French physiologist, to examine these opinions. For this purpose, I performed the following experiments. As a preliminary measure I ascertained, that in a rabbit of about the ordinary size, nearly seven drachms and three quarters of blood would escape from the divided aorta, when respiration was unobstructed.

Exp. 19.—A rabbit (six or eight months old) was secured, and a ligature was passed under the trachea. The abdominal aorta was laid bare in the centre of the abdomen, separated from its vein, and then tied. I placed my watch beside me, and observing the minute hand, I tied the trachea so as to prevent the admission of air into the lungs. At the end of twenty-five seconds, I divided the aorta immediately above the ligature. Arterial blood of a somewhat duller hue than usual issued, and seven drachms were collected in a graduated drachm glass. In this experiment the lungs still contained a considerable quantity of oxygen—the blood permeated them almost duly arterialized—and the quantity which issued from the divided aorta, almost equalled what would have escaped, if the free access of air to the lungs had been permitted.

Exp. 20.—A rabbit of the same age was secured. The abdominal aorta having been laid bare and tied, a ligature was placed beneath the trachea. Observing my watch as before, I tied the trachea, and when a minute and a half had elapsed, divided the aorta immediately above the ligature. The blood which issued had a slightly venous hue, it retained still much of the arterial character. Fully five drachms were collected in the graduated glass.

In this experiment, the oxygen contained in the lungs was evidently not yet exhausted, and the blood which permeated them, still received a considerable quantity, and in consequence, underwent a change of colour, though it did not assume the perfect arterial redness. The difficulty of permeating the pulmonary tissue had, however, commenced, and four drachms of blood, somewhat changed in character, issued.

Exp. 21.—A full grown, strong, and healthy rabbit was secured. The same arrangements were made as in the preceding experiments, and observing the time, I tied the trachea. After a minute and three quarters had elapsed the aorta was divided in the abdomen. The blood which issued was of a duller hue than that collected in the last experiment, but was brighter than venous blood. Four drachms and a half were collected in the graduated glass.

This rabbit was much larger than either of the former. The blood collected was therefore less in proportion to the size of the animal than in the last, shewing a progressive diminution in quantity, as the time of dividing the artery was postponed. The lungs evidently still contained oxygen, and the blood therefore permeated them with considerable freedom, though in smaller quantity than before.

Exp. 22.—Finding that the blood had not lost all its arterial character, at the termination of a minute and three quarters, I postponed the period of dividing the artery to the termination of two minutes and a half. The blood which issued from the divided aorta was darker, but still differed from venous blood. Four drachms were collected.

Exp. 23.—The experiment was repeated in all its circumstances as before, excepting that the period of dividing the aorta was postponed to the expiration of the third minute. The blood then appeared in a great degree to have assumed the venous hue, though, as far as I was able to judge, still imperfectly. Only two drachms issued from the divided artery. As we may, however, be liable to mistakes in estimating by the eye only the degree of change which ensues, it may be proper to consider this last portion as venous blood.

These experiments were frequently repeated. Owing to various circumstances, such as the age of the animal, its size, the relative capacity of the chest, the degree of its expansion at the moment when air was excluded, &c. &c. the results varied, but the experiments given above may be taken as a fair representation of the mean of these varieties.

When three minutes and a half have elapsed after tying the trachea, the blood generally ceases to flow from the divided artery. These experiments therefore prove that when the inhalation of air is prevented, the blood circulating through the lungs gradually loses its arterial redness, and, as its colour graduates, sensibly through various shades of venous degeneration, its progress is impeded, it permeates the tissue more slowly, and in smaller quantities, and when the oxygen is consumed the pulmonary circulation is arrested. The moment before the left auricle and ventricle cease to receive blood, it is poured into them in small quantities, and as the peculiar function of the arteries of the lungs is, to circulate arterial blood only, we are led a priori to suppose, that their organic sensibility will be first impressed by any change in the character of that fluid, and that therefore they will not permit venous blood to be transmitted through them, in such quantities as to prove positively deleterious to the function of any tissue.

Nevertheless, we consider it important to examine the facts and arguments from which Bichat concludes that in Asphyxia, venous blood permeates the cerebral structure in stages of its venous degeneration, and in quantities which destroy the functions of the brain. His first experiment is thus detailed.*

"I opened, in an animal, the carotid and jugular; I received into a syringe, heated to the temperature of the body, the fluid that the latter poured forth, and I injected it into the brain by the former, which I had tied on the side nearest to the heart, to avoid hæmorrhage. Almost immediately, the animal became agitated; his respiration hurried, he appeared to suffer from dyspnœa

* P. 223.

similar to that which occurs in Asphyxia: he soon exhibited all its symptoms; animal life was entirely suspended, the *heart continued still to beat, and the circulation to proceed during half an hour*, at the termination of which, death extinguished also the organic life. The dog was of a middle size, and about six ounces of dark blood were gently injected, lest the effect which resulted from the nature of the fluid, should be attributed to a mechanical shock." This experiment is liable to many objections.

To maintain the integrity of the cerebral functions, a normal relation between the contents of the arterial and venous capillaries is required. The brain is contained in an osseous case, which it exactly fills. The openings into this cavity are closed by the medulla oblongata, the vessels, nerves, and intercellular tissue so exactly, as to render it impossible to introduce additional fluid into the structure without a compression of the whole mass. The force which is exerted by the heart whether in health or disease, is however incapable of producing such an effect. Causes increasing the impulse of the arterial or impeding the return of the venous blood do not produce apoplexy by occasioning a compression of the whole mass of the brain.*

* Abercrombie, Pathology of the Brain and Spinal Cord.—Kellie on Death from Cold.—Edinburgh Medico-Chirurg. Society's Trans.—P. 100, Vol. i.

When the impulsive power is too great, the caliber of the arterial capillaries is increased at the expense of the minute venous system, which suffers a relative diminution of capacity. The effects are reversed when apoplexy is occasioned by obstructions impeding the return of the venous blood. In both cases the quantity of blood circulating through the cerebral mass in a given time, (and therefore the supply of stimulus and nourishment,) is diminished, and apoplexy ensues. Since the integrity of the cerebral functions requires so delicate a balance between the arterial and venous capillary circulation, the brainular mass cannot be rudely interfered with by the injection of fluid. The force of the arm of a man is applied continuously, and not with the pulsatory motion of the heart, and though the greatest caution be observed in avoiding violence, a slight increase of power, or deviation from the method by which arterial blood is propelled by the heart into the tissue, will produce apoplexy.

In this experiment, it is worthy also of observation, that though six ounces of venous blood were injected into the brain, life was not extinguished until half an hour had expired. The animal existed in a state resembling apoplexy. Had the experiment *even proved the noxious influ-*

*ence of venous blood on the cerebral structure,* it by no means demonstrates that this fluid occasions the interruption of the cerebral functions in Asphyxia, since the blood then circulated, though *darker than arterial is not so dark as the venous fluid,* and because *six ounces of venous blood* were in this case injected into the brain in a continuous stream, and the effects even then were not immediate.*

The next experiment of Bichat is related as follows:—" Divide in a dog the trachea, and close it so that no air can enter ; at the expiration of two minutes dark blood flows into the system of red blood. If you then open the carotid, and receive into a syringe the blood which issues from the opening, in order to propel it into the brain of another animal, this last soon falls with an embarrassed respiration, sometimes with plaintive cries, and soon dies."

The blood which would escape from the divided artery in this experiment would differ in some degree from venous blood, having somewhat more of the arterial character. In the last moments only during which the blood flowed would it assume the perfectly venous hue. These two experiments contradict each other ; the same effects are said to be produced by blood which is, as we

* P. 227.

have shewn, in different states of arterialization, and are referred in both to the absence of the arterial qualities; the only circumstance common to both, capable of producing the effects, is the manner of introducing the fluid into the system.

Dissatisfied therefore with this evidence, I determined to examine the question experimentally. In order to avoid the effects of mechanical force, on the delicate organization of the brain, I used a very small syringe, having a beak with a capillary bore. I chose a small animal, in which the carotid artery was minute in comparison with the size of the capillary vessels of the brain, and I used the utmost caution to avoid the effects of pressure, in dilating the arterial vessels of the brainular mass.

Exp. 24.—Two small rabbits, five months old, were secured. The carotid artery of one was laid bare—the pneumogastric, the descendens noni, and the sympathetic nerves were detached from it. It was secured, somewhat higher up, by a pair of forceps, held by an assistant, and was then divided. The delicate capillary loose beak of a small syringe was introduced into it, and secured, and about a drachm and a half of arterial blood were allowed to escape, when its flow was stopped by compressing the artery with the forceps. The vena cava of the other rabbit was laid bare in the centre of the abdomen;—it was separated from the aorta and divided. The venous blood which issued into the warm cavity of the peritoneum was drawn into the syringe, the forceps were removed from the carotid artery, and when the loose beak was observed to be full of arterial blood, the syringe was inserted into it, and its contents were gradually and gently injected through the carotid artery towards the brain. This was repeated several times, until about three drachms and a half of venous blood had been thus introduced.

The animal exhibited no signs of uneasiness whatever, but appeared perfectly well.

The aorta of the other rabbit was divided, and the whole quantity of blood which issued from the aorta and vena cava, including that injected into the carotid of the second rabbit, amounted to seven drachms and a half; so that nearly half the quantity of blood which escaped, from this free division of the main trunks of the circulating system, was, in this experiment, injected towards the brain. I avoided producing any great plethora, by allowing nearly two drachms of blood to escape from the carotid, and observed great care in preventing any air from being impelled into the artery.

The rabbit, after the experiment, seemed very languid, and suffered much muscular weakness, but gradually recovered in the course of the day. The next day it was quite vigorous and vivacious.

Exp. 25.—Two rabbits, nearly full-grown, and in good health, were secured. The carotid artery was laid bare in one, and the beak of the syringe inserted, as in the former experiment :—the artery was divided,—a drachm and a half of arterial blood were allowed to escape, and the artery was again secured by an assistant, with the forceps. Venous blood was obtained, from the division of the abdominal cava of the other rabbit, and fully four drachms of it were injected towards the brain, into the carotid artery of the first. When more than three drachms had been injected, the animal exhibited no signs of suffering, but in filling the syringe again with fresh venous fluid, I discovered that some obstacle resisted the propulsion of the blood into the artery, and probably some coagula had collected in the capillary beak of the syringe. In the rapidity of the action required by the nature of the experiment, I was tempted to use considerable force to overcome the resistance, the clots suddenly yielded to the pressure, and the blood entered with much greater velocity and impulse than before. The animal immediately struggled, and its limbs quivered. The nervous system seemed to suffer from the increased pressure on the arterial capillaries. I thought for a moment that it would die. It recovered; but after the experiment, was weaker and less inclined to move than that on which the first experiment was performed. It remained very languid and feeble during the whole of the following day; it then appeared to revive, it took food and moved about with more freedom. On the following day it exhibited signs of some important lesion of the brain. It was subject on attempting to move, to an apparently involuntary circular motion towards the right side, as in the experiments of Majendie, Flourens, Serres, &c. Still it seemed likely to recover for some time, but afterwards it became weaker, languid, and inert, and died at the end of ten days.

I felt persuaded that I had ruptured or seriously injured some part of the brain. I therefore removed the superior portion of the cranium. The anterior and middle lobes of the left hemisphere of the cerebrum were of a pale greenish yellow colour externally, and softer than usual, and on cutting into them, I discovered that a large abscess full of purulent matter occupied them; all the symptoms of disease, and the death of the animal were thus explained. The venous blood, though injected in very large quantities, did not destroy life, though its effects were complicated with a serious lesion of the cerebral structure, which ultimately terminated fatally.

Exp. 26.—This experiment was repeated in all respects as before. When the vena cava was divided, the blood flowed very slowly, and some time elapsed before a sufficient quantity could be obtained to fill the syringe. After one syringe-ful had been injected into the carotid, on attempting to introduce a second, the blood began to coagulate in the beak, and when one drachm and a quarter had passed, it was impossible to proceed without using considerable force, and driving the coagula into the brain. The animal suffered little from the experiment.

Exp. 27.—This experiment was repeated in all respects as before on two rabbits. Four drachms of venous blood were introduced into the carotid artery. No signs of uneasiness were exhibited by the animal:—it remained weak and languid for some hours after the experiment, and then recovered.

These experiments exhibit the difficulty of avoiding undue pressure on the brain in injecting fluid by the carotid artery, and the danger of driving coagula into the cerebrum together with the injected fluid. They prove also, that though venous is a much less nutritious and stimulating fluid than arterial blood, it may circulate through the cerebral mass without producing, by its *contact* with the brain, a sudden suspension of the functions of the nervous system.

I conceive that it must be regarded, as a fluid capable of only slightly nourishing and stimulating the nervous system. Its presence in the vessels of the brain, even for a short time, occasions langour and feebleness, and if its circulation were prolonged, we may imagine that sensation and voluntary motion would become still further impaired; but it does not destroy life by contact with the brain, and in Asphyxia, small quantities of it are transmitted, and for a short period only, to the cerebral structure.

Evidence against the positively noxious qualities of that portion of blood transmitted to the brain in Asphyxia, might however be obtained from some of Bichat's experiments, and we shall therefore proceed with our analysis of his inquiry. After the last of his experiments which we examined, viz. that of injecting the blood which flows from a divided artery, in an animal, two minutes after its trachea has been tied, he adds.

" I have performed an experiment resembling this last, which however gives a somewhat different result. It requires two dogs, and consists, 1st.—In inserting a stop-cock into the trachea of the first, and the extremity of a silver tube into its carotid. 2ndly.—In introducing the other extremity of this tube into the carotid of the second, on the side nearest the brain. 3rdly.—In tying those portions of each artery into which the tube is not inserted in order to avoid hæmorrhage. 4thly.—In allowing the heart of *one of these dogs* to propel red blood into the brain of the other. And 5thly.—In shutting the stop-cock, and thus making dark blood succeed to that which flowed before."

Now we have before shewn, that only a small quantity of venous blood would, in this experiment, be propelled into the brain, but chiefly blood less perfectly arterialized than usual. It must also be observed, that besides all the blood which issued after the stop-cock was closed, an indefinite quantity of arterial blood was allowed to pass into the brain, and plethora must certainly have been produced.

The history of the consequences is exactly what might have been anticipated.

" After some time had expired, the dog which received the fluid appeared confused, (étourdi) agitated, its head declined, it appeared to lose the use of its external senses, &c.; but these phenomena were *longer in being developed* than when dark blood taken from the venous or arterial system was injected. If the transfusion be arrested, the animal may *revive and even live after the symptoms of Asphyxia are dissipated*, whilst on the other hand, death *invariably ensues* when the syringe is employed to propel the same fluid, be the degree of force employed what it may."

"I may observe," he also remarks, "that for the success of this experiment it is necessary that the dog whose carotid propels the blood, should be *vigorous and even larger than the other*, because the impulsion is diminished when the heart becomes penetrated with venous blood."

Eight or ten ounces of blood, at least would be transmitted to the brain in this experiment: its results therefore resemble those which follow too large an injection of blood into the veins of animals. Speaking of an animal on whom transfusion of blood was performed (even though it was nourished by this method only) to the extent of eight or ten ounces—

Dr. Blundell says* "the pulse became irregular and intermitted frequently; there was languor, general tremor, and sometimes, but not invariably, a disposition to sleep."

It is also to be remarked, that the effect described in the experiment of Bichat did not ensue *until*

* Blundell's Physiological and Pathological Researches, p. 77.

*after some time*, or until plethora was produced, and that it was necessary for this effect that the dog from whose heart the fluid was propelled should be vigorous and larger than the other, and moreover that the animal *soon recovered and lived;* that is when its system had accommodated itself to the great quantity of blood which it contained.

When these circumstance are considered, in combination with the *great abstraction* made from the quantity of the *natural stimulus* usually transmitted to the nervous system, and the substitution of a fluid capable of sustaining its action *only for a limited period*, the effects are such as might have been anticipated; they do not, however, give any evidence of the existence of *noxious* qualities in the venous blood.

Another experiment which he relates is strongly confirmatory of the views which I have taken of Asphyxia. "Whilst Asphyxia is in its first stage in an animal, I have observed that by transfusing towards the brain red blood, by means of a tube adapted to the carotid of another animal and to its own, motion gradually revives, the cerebral functions are in some degree re-excited, and even often sudden agitations of the head, the eyes, &c., announce the first contact of the blood; but these good symptoms *soon disappear, and the animal relapses, if the cause of the As-*

*phyxia continue, if, for example, the stop-cock fixed in the trachea remain closed.*"

The supply of blood from the heart to the brain being, as we have shewn, speedily interrupted in Asphyxia, nothing can so immediately revive the sensorial functions of the animal, as the tranfusion of arterial blood from the carotid artery of another animal towards the cerebral mass. But if dark blood *extinguished* the functions of the brain by its poisonous qualities, we cannot conceive that its expulsion from the tissue could be so rapidly completed as to permit the sudden reanimation which occurs in the experiment.

If however we conceive dark blood to be only a fluid *exceedingly less capable of nourishing and stimulating the nervous system* than arterial blood, we may discover how, when it has circulated through the brain, the propulsion of a more nutritious and stimulating fluid into the tissue, may revive the phenomena of life.

After apoplexy has been produced by the forcible injection of venous blood by a syringe, this result does not ensue. Apoplexy cannot be relieved, but would rather be confirmed by this measure. We discover therefore that Bichat adds "that the experiment does not succeed after the injection of venous blood by a syringe. Then" he says, "though the cause of Asphyxia has ceased to operate after the injection, although arterial blood be propelled by the same opening, whether by transfusing it from the artery of another animal, or by injecting, after having taken it from an open artery and filled a syringe with it, the animal exhibits only feeble signs of sensibility; often none are discernible, and death is always inevitable." We regard this admission as demonstrating that the death which ensues when venous blood is injected towards the brain, is not occasioned by the noxious qualities of that blood, but chiefly by the force used in the injection, combined with the great abstraction of the natural stimulus.

When respiration is suddenly arrested, the first symptoms of disturbance of the cerebral faculties ensue as soon as the quantity of fluid circulating is decidedly diminished, and motion and sensation are at an end before the circulation ceases. These effects we conceive to be owing to two circumstances, first, the *quantity* of blood circulating in the arteries is exceedingly *diminished*, and secondly, that fluid has lost, in a great degree, its arterial character, and has therefore become *less capable of maintaining the perfect phenomena of life, and especially the organic motions of the nervous system.*

The symptoms of cerebral disturbance are coincident with the progress of the changes which ensue in the colour of the blood, because those changes gradually occasion *the interruption of its passage through the lungs;* and because, at the same time a *less nutritious fluid circulates in the nervous system.* The same symptoms are observed in excessive hæmorrhage, in which, as in Asphyxia, the supply of blood to the brain is gradually diminished. Dr. Blundell* describes "*the usual symptoms*" of hæmorrhage to be "dyspnœa, struggling, cessation of the circulation, relaxation of the abdominal muscles, and a complete Asphyxia." In a sheep, in Dr. Kellie's experiments, in his paper on †Death from Cold, "ten minutes after the carotid had been opened, the breathing was hurried and laborious, and the animal was slightly convulsed. The blood, for ten minutes, trickled more slowly down the neck; the eye became heavy and listless, and the breathing more oppressed; and at twenty minutes from the commencement of the experiment there was general convulsion, and the animal instantly expired." "In sheep slaughtered" in Dr. Kellie's presence "by the butcher, the blood rushed out in torrents. In one minute after the infliction of the wound, the animal became convulsed, and

* Researches, p. 82.

† On Death from Cold.—Edin. Medico-Chirurg. Trans.—P. 107.

in two minutes died." (P. 109.) Another sheep, bled from the jugular vein, he describes to have had "strong convulsion and uneasy respiration." (P. 111.)

Asphyxia, from the cessation of the respiratory function, differs from Asphyxia from hæmorrhage, because in the former the quantity of the blood remains undiminished—the venous system is congested—certain quantities of imperfectly arterialized blood have circulated for a short time through the capillary system. After these circumstances have transpired, life can by various means be restored. Death is for some time apparent, not real; but it remains to be investigated whether some means of resuscitation used in the latter, can be applied with success to the former mode of death.

I rejoice that I am not obliged to rely solely either on the positive or negative method of demonstration adduced in this chapter. The experiments of Edwards on Asphyxia in reptiles and in young mammiferous animals are exact and comprehensive, and afford collateral support to the conclusions advanced. They prove that venous blood, though incapable of supporting life for an indefinite period, exerts no positively noxious influence on the nervous system of animals.

When respiration is suspended, the circulation continues whilst the lungs contain oxygen. During this period the blood which permeates the lungs gradually abstracts the oxygen they contain, and, as the quantity of this gas diminishes, possesses less and less of the arterial character. Much blood almost duly arterialized, circulates in the first moments after inspiration ceases; and the quantity passing in a given time diminishes as its colour becomes darker, until in those moments which precede the arrest of the circulation, it closely resembles the venous fluid, and is propelled into the arteries with languor, and in inconsiderable quantities.

Venous blood appears to be capable of supporting the functions of the nervous system for a short period only. Were this fluid to circulate freely through the brain its functions would, ere long, be totally suspended from the want of stimulus and nourishment, and its propulsion into the brainular mass soon produces languor and feebleness. The venous blood does not however exert a positively noxious influence on the nervous system, nor destroy its faculties by mere contact, like a foreign fluid.

In Asphyxia, the imperfectly arterialized blood which circulates through the brain, is less conducive to the maintenance of its functions than arterial blood: but those functions and life are abolished, because the circulation is arrested in the lungs when the respiratory phenomena cease. The fluid which is then propelled into the nervous tissue, though less capable of developing its powers than arterial blood, can maintain for a time imperfect motions of the vital parts, and contribute to the evolution of an inferior order of vital phenomena.

This inquiry has important relations to most interesting subjects of investigation. The functions of the pneumogastric nerves appear to be in no slight degree elucidated by it, and we may hope to derive from it important information concerning the succession of physiological phenomena in death from coma. Other questions arise out of it which are still more intimately connected with it, but to which, after having made so great a demand upon the attention of the reader, I must forbear adverting.

## CHAP. V.

Asphyxia may be produced by wounds in the parietes of the chest, which admit air freely into the cavities of the pleural membranes, thus permitting the resilient power of the lungs to occasion the contraction of these organs. The laws which govern the admission of air into the cavities of the pleura are not self-evident, and have been the subject of much interesting controversy. As this subject is important, both from its reference to various operations in the performance of which air is necessarily permitted to enter the chest, and to those accidents by which the thoracic parietes may be lacerated, and the collapse of the lungs occasioned, I shall proceed to discuss the effects of wounds penetrating the cavities of the pleuræ, and of extensive lacerations of the abdominal muscles, as well as of the other motive powers concerned in respiration.

Dr. Carson, of Liverpool, published in 1822 a series of Physiological and Practical Essays, in which he proposed a very novel expedient for the cure of tubercular consumption. When tubercular deposition was found to have occurred in one of the lungs, he suggested that an opening should be made into that side of the chest, and that the lung should be permitted to collapse. He hoped, that in a state of repose, the progress of disease in the pulmonary tissue might be arrested, and that, in process of time, the lung might even recover its function, and again fill the cavity of the chest. Afterwards if disease were discovered in the opposite lung, he proposed that it should be subjected to a similar operation. Insuperable pathological objections to this scheme must, in the present state of medical science, occur to the mind of every well informed professional man. We have no reason to believe that tubercular deposition would cease if the lung were permitted to remain in a state of rest, because, in organs to which the supply of blood is not great, and which are not disturbed as the lung is, that process goes on with great rapidity. Moreover a lung, in which considerable tubercular accretion had occurred, would, in the parts affected by disease, diminish but little in volume on the admission of air into the cavity of the pleura. Experiments related in this chapter will also shew, that even were the lung permitted to collapse, it would so speedily recover its former size, that its repose would be quite transient and inefficacious.

My friend, Dr. Williams, of Liverpool, with great acuteness, met the proposition of Dr. Carson with an important practical objection, in a series of well devised experiments, performed in the presence of Dr. Traill and several other scientific men. In these experiments he shewed* that the lungs will not collapse, when the external respiratory apparatus is unimpeded, if only small openings (such as it would alone be safe to propose in the human subject) are made in the chest. When openings, one inch in length, were, in his experiments, made on each side of the chest, between the sixth and seventh ribs of dogs, and the edges of the wounds were separated, or a silver catheter inserted, the lungs only partially collapsed—air entered the orifices and was expelled—the breathing of the animal was embarrassed; but though these wounds were in one experiment kept open ten minutes, and in others five, the dogs, though they appeared weak after the operation, gradually recovered. A very beautiful natural law is disclosed by these experiments. A moderate linear perforation into the cavity of the chest, when it is not violently held apart so as to make the wound greater than the trachea, has the effect of establishing a double inspiration

* Edinburgh Medical and Surgical Journal.

and expiration. During inspiration, air enters the chest, both by the trachea into the interior of the lungs, and by the orifice in the parietes into the cavity of the pleura: and during expiration it is expelled through both these orifices. So long as a considerably greater portion of air is inspired through the trachea, than through the orifice in the parietes of the chest, though, from the resilient powers of the lungs, there will be a constant tendency to an increase of the quantity of air contained in the cavity of the pleura, yet, if the experiment be continued only a short time, this increase will not be very great, especially as the lung will be constantly forced into the orifice at the close of each expiration, and will act as a valve during a considerable portion of each succeeding inspiration, and will thus prevent the ingress of air. If the orifice be not also constantly and with great care kept open, the intercostal muscles will drag the sides of the wound together, and diminish or obliterate the opening. When a catheter or the sheath of a trocar is inserted, it is constantly liable to be closed by the lung, which covers it and acts as a valve. But in Dr. Williams's experiments, when a finger was interposed in the wound between the ribs to prevent their approximation, and when the wound was also of considerable size—the air entered immediately—

the lungs collapsed—and the animal died. Dr. Williams justly concludes from his experiments, that the admission of air into the cavity of the chest through moderate wounds in its parietes, even when these wounds are kept open by small tubes, will not occasion the collapse of the lungs, if the auxiliary respiratory organs are unrestrained.

Were the operation proposed by Dr. Carson likely to be practically useful, the lung might be made to collapse, by thrusting the sheath of a trocar into the chest, through an opening in the intercostal spaces, and then mechanically forcing air into the cavity of the pleura. Even then, a healthy lung would speedily recover its former volume—the consolidated portions of a diseased lung would not collapse—and it is probable, that those parts into which the air still penetrated freely, would, even in a partially diseased lung, be rapidly re-expanded.

From some other conclusions contained in Dr. Williams' paper—entertaining as I do great respect for its author—I am compelled to differ. In the series of experiments which form the subject of the two preceding chapters, I was frequently obliged to open one side of the chest. The animals used in the inquiry were rabbits, and in very numerous experiments, I observed that whenever a free opening was made into the cavity of the chest, the lung collapsed, with a rapidity which showed that it was possessed of an active resilient power. When the parietes of the chest are removed on the left side, the action of the lung on the right side of the chest can be plainly seen through the transparent mediastinum. The lung may be perceived accurately to fill the cavity of the pleura, following the diaphragm in its descent, and returning, without any apparent corrugation, rapidly to smaller dimensions as the diaphragm ascends, in such a manner as to impress the mind with an idea of the active resilient power of the lung during expiration—an impression which is confirmed by a more accurate examination of the mechanical phenomena of respiration.

In ordinary respiration, the abdominal muscles are doubtless used, especially in the erect posture, when they support the bowels and their contents, and raise them during the ascent of the diaphragm in expiration. Physiologists attribute the ascent of the diaphragm, however, solely to the contraction of the abdominal muscles compressing the contents of the abdomen against its concavity, and protruding it upwards, so as to diminish the cavity of the chest and expel the air. The diaphragm nevertheless ascends, and carries the liver upwards with it, even when the abdominal muscles are cut away close to the margins of the false ribs and ensiform cartilage, throughout their whole extent on both sides. I had frequent opportunities of observing this fact in the course of the experiments related in the preceding chapters. Now it is evident that the form and structure of the diaphragm preclude the possibility of its being raised, by any power inherent in itself, and the only forces acting upon it, when the abdominal muscles are detached, and the stomach and intestines are not recumbent upon it, are those contained in the cavity of the chest. What these forces are, is evident from watching the process of breathing with the right lung, through the mediastinum from the left side of the chest, when the abdominal muscles are removed.

In the experiments on Asphyxia, the animals were confined on their backs. The reader must suppose that the ribs on the anterior and lateral portions of the right side of the chest have been removed—that the right lung has collapsed, and contracted into a very small volume, about the root of the bronchi and pulmonary vessels—that the transparent pericardium, containing the heart, is laid bare, which organ is beating violently in the lower portion of the chest; and that through the mediastinum, the motions of the lung on the opposite side of the chest may be accurately observed. The phrenic nerve passing down the mediastinum, is seen like a minute thread distributed in digitations on the surface of the diaphragm. The reason of this passage along the mediastinum, and of the distribution of its digitations, enclosed and protected by the laminæ of the two pleural membranes, on the surface of the diaphragm, becomes evident on an attentive examination of the descent of that muscle. When the diaphragm has attained its greatest elevation, the digitations lie flat upon its surface, but, during its descent, the mediastinum is stretched, the digitations rise from the surface of the muscle, and only touch it with their extremities, where they become less obvious to the eye. This distribution is, therefore, a provision to prevent the phrenic nerve from being stretched and injured, during the descent of the diaphragm.

If the reader will further suppose, that the abdominal muscles have been cut away close to the margins of the ribs throughout their whole extent, he will still witness the phenomena of respiration proceeding in the right lung, accompanied by the uninterrupted ascent and descent of the diaphram. The bag of the pleura lining the right side of the chest and the superior surface of the diaphragm, and forming one lamina of the mediastinum, he will perceive to be elongated during the descent of the diaphragm, and to return, accurately, without any corrugation to its previous state, when, the contraction of the muscle being finished, its ascent to its former position in the chest occurs. He will also observe, that the lung fills the right side of the chest, and accurately adheres to the superior surface of the diaphragm during its descent and ascent. All these phenomena cease, on making a puncture in the mediastinum. The lung then rapidly contracts into a small volume, and the motions of the diaphragm are immediately at an end. No one witnessing these events can refuse to acknowledge that while respiration is continued in one lung under these conditions—one side of the chest having ceased to move—the abdominal muscles being cut away—and the intestines not being permitted to press on the concavity of the diaphragm; that the ascent of the diaphragm is occasioned by the resilient power of the left bag of the elongated pleura, by that of the other lamina of the mediastinum, and also by the contractile power of the pulmonary tissue of the left lung. Unless these powers operate, the ascent of the diaphragm is, under the circumstances related, quite inexplicable.

If the animal be raised from the recumbent posture to the erect (the liver being then dependent on the right side of the diaphragm) the phenomena of respiration continue. So that the resilient power of the right pleura and right lung are capable of elevating the diaphragm and liver, after they have been depressed by the contraction of that muscle.

Before the mediastinum is perforated, during the violent efforts made by the right side of the chest to supply oxygen to the circulation (previously exposed to the influence of the air on both sides of the chest) the left lung, as is stated by Dr. Williams, may be occasionally observed to move synchronously with the respiratory efforts in the right lung, but, on careful examination, it will be found, that the slight expansion observed in it occurs during the expiration of the right lung; and its collapse during the inspiration. On grasping the trachea between the finger and thumb immediately after an inspiration, so as completely to prevent an expiration, the left lung suddenly expands and collapses. This alternate expansion and contraction of volume is produced by the instinctive convulsive respiratory motions of the right side of the chest, made in the agony of suffocation, and which motions force air from the right lung through the branches of the bronchi into the left lung, and afterwards abstract it, by the sudden descent of the diaphragm and expansion of the chest.

This fact is of considerable service in the explanation of some other phenomena observed in diseases of the chest, and also of certain recorded physiological facts. In Dr. Williams' and Dr. Carson's experiments, when air had been admitted into the chest through wounds in its parietes, and when the animal was killed a few days afterwards, the lung was invariably found nearly if not quite filling the cavity of the pleura, the air having been absorbed. *Enormous collections of fluid, whose existence and quantity are detected by the stethoscope, are also often rapidly absorbed, the lung being as rapidly expanded to its former volume. The same result sometimes occurs, when these collections are rapidly let off by the operation of paracentesis, and when air is introduced in their stead. In such cases, after a certain period, if not bound down by a thickening of the pleura, the lung is gradually expanded, and again fills the whole cavity as before. This expansion is accomplished in the following manner:—after a deep inspiration has been taken, the glottis is closed, just as it is before

* Andral. Clinique Médicale.

the effort of coughing necessary to the expulsion of sputa from the lungs, and the expanded lung being compressed, by the contraction of its parietal circumference; air is expired from one lung into the other, whose volume is thus, by successive efforts enlarged, until it occupies the whole cavity of that side of the chest.

## CHAP. VI.

Ever since it was discovered, by the inquiries of Dětharding, Felix, Plater, and Waldschmit, that death occurs in submersion from the deprivation of air, and not from the oppression of the water swallowed, insufflation of the lungs has been the chief means proposed for the recovery of persons in a state of suspended animation. Goodwyn conceived that the circulation ceased because the blood, not being exposed to the influence of the air in the lungs, retained its venous character, and, by contact with the interior of the left cavities of the heart, destroyed their contractile power. He therefore proposed insufflation of the lungs "to* change the quality of the blood in the pulmonary veins, sinus venosus, and auricle, to fit it for exciting their contractions. This," he adds, "must be done by introducing the air so deep into the lungs, that it may exert a chemical action on the blood in these cavities. For this purpose, a great quantity of air must be introduced at each inflation; for if

* Goodwyn. The Connection of Life with Respiration, p. 111.

only twelve cubic inches be injected at a time, this small quantity will occupy the larger branches of the bronchi, and consequently only a small number of the pulmonary vessels will be exposed to its action: but if a much greater quantity of air be forced at each time, some of it will pass into the more remote cells, and when they are thus uniformly distended, the pulmonary veins, the sinus venosus, and the left auricle will be exposed, as much as possible, to its action, and some of the altered blood may be forced into them from the smaller vessels." "On this account," he continues, "we should introduce upwards of one hundred cubic inches of air into the lungs of an adult at each inflation, and it must be carefully drawn out again before more be introduced."

For this purpose he recommends the use of a syringe, capable of holding one hundred cubic inches of air, the tube of which being inserted into the trachea, air may be alternately introduced into the lungs and withdrawn.

Kite,* supposing that "the stoppage of the motion of the lungs was the immediate cause" of the arrest of the circulation, and Coleman, believing that this was determined by the collapse of the lungs, and the consequent mechanical

* Duncan's Medical Commentaries, Vol. xiv.

impediment to the passage of the blood through these organs, both earnestly recommended artificial insufflation. Kite, however, chiefly depended on electricity for the renewal of the pulmonary motion, and thought all other remedies subordinate to it. Coleman likewise considered the inflation of the lungs and the removal of the supposed mechanical impediment to be of little importance, provided the heart were not at the same time stimulated by electrical shocks. "We* should," he says, "first expand the lungs, and when the collapse is removed, stimulate the heart by a shock of electricity. The heart from this is made to contract; there is a free passage for the blood and air in the lungs to produce a change; therefore if any irritability be left in the heart some blood must enter the lungs. We now perfectly collapse them, and of course this blood will be conveyed into the trunks of the pulmonary veins and left auricle, and the circulation will go on. The lungs are again immediately distended, and kept so, until another shock be passed as before." He directs a pipe to be inserted into the trachea, either through the glottis, as recommended by Monro, or by the operation of bronchotomy directly into the windpipe, and that

* Coleman. Dissertation on Suspended Respiration, p. 178.

the lungs should be inflated with the double-valved bellows. When inflation is commenced, he says, "the* bellows are now to be employed until the chest is elevated." Desgranges† gives similar instructions concerning forcible inflation.

These directions suppose the introduction, at each inflation, of a considerable quantity of air, and consequently a resort to no slight force in the operation. Since the publication of these works, though both theories were superseded by that of Bichat, the same means were adopted, and the writings of Bichat add his authority to that of Haller, Kite, Hunter, Goodwyn, Coleman, &c., in favour of forcible inflation of the lungs, as a process of little danger, and of the greatest value in restoring suspended animation.

Since the discovery of the chemical changes produced in the air by respiration, the inflation of the lungs with pure atmospheric air has been properly preferred to the introduction of the carbonized air expired from the lungs of the operator. The use of the inflating apparatus, and consequently the forcible introduction of air into the chest has become more general, especially of late years, and Majendie‡ shows, from the records

* Coleman. Dissertation on Suspended Respiration, p, 202.

† Instructions sur les secours à donner aux personnes Noyées.

‡ Journal de Physiologie. Tome ix. p. 104.

kept in the city of Paris of the results of means employed for the recovery of persons drowned, that the greater prevalence of the practice of insufflation has been coincident with a decrease of the number restored to life. The following is a table of the number of persons taken from the Seine—of those who had aid—and of those restored to life, during some recent years :

| Year. | Taken from water. | Received aid. | Restored. |
|---|---|---|---|
| 1821 | 309 | 50 | 37 |
| 1822 | 353 | 64 | 40 |
| 1823 | 288 | 53 | 46 |
| 1824 | 308 | 51 | 49 |
| 1825 | 315 | 73 | 57 |
| 1826 | 361 | 77 | 54 |
| | 1835 | 368 | 283 |

Thus, in six years, 1835 persons in a state of suspended animation were taken from the water; 368 of whom received aid, and 283 were restored. From a comparison of this report with those given sixty years previously, it appears that the number of persons resuscitated from apparent death was much more considerable at the early period. *From 1772 to 1788, *l'echevin de Paris,* Pia, the founder and director of the Parisian establishments for recovering persons from Asphyxia, restored 813 individuals in a state of

* Détails des succès de l' Etablissement que la Ville de Paris a fait en faveur des Noyés.

suspended animation out of 934: or, in other words, he saved eight-ninths, whilst, at the present day, according to official documents, only two-thirds of those on whom the usual means are tried are restored, and one-eighth only of those taken from the water recover. The instructions circulated at all the stations of the Parisian Society are generally sagacious, but contain no sufficient caution concerning the danger arising from insufflation of the lungs. Majendie* thinks that the most limited conclusion to be deduced from these facts is, that insufflation of the lungs, as it has been recently performed in attempting to restore cases of Asphyxia, has not increased the efficiency of the means employed for this purpose, and may even have diminished the probability of resuscitation. The facts from which this result is derived are of such a nature, that an approximation only to a correct conclusion can be obtained from them. The records now kept are not sufficiently minute in their details and contain no reference to the state of the patients, nor any account of the nature of the measures adopted.

The researches of Leroy,† however, satisfactorily shew that this operation has been recom-

* Journal de Physiologie. Tome ix. p. 105.

† Ibid. Tomes vii. et viii.

mended with too great confidence, and employed without the requisite caution, and consequently with the most pernicious results. Leroy discovered that brisk inflation of air into the trachea killed rabbits, foxes, goats, sheep, and other animals, even when the force employed was that of an expiration from the human lungs. To some other animals, however, such as the dog, the operation is not so obnoxious. They experience great dyspnœa, and continue in a state of suffering some days after insufflation, but gradually recover.

The directions issued regarding this operation must therefore be received with some caution. This discovery reveals a sad retrospect of absolute evil produced, by the want of caution with which these means have been applied for the recovery of persons apparently dead, and shews how presumptuous has been the interference of the most benevolent.

Air briskly introduced into the lungs generally ruptures some portion of their tissue, and issuing into the cavity of the pleura, occasions their collapse, and thus fatally interferes with the process of respiration. The lungs cannot be re-expanded unless the air be removed from the cavity of the pleura, which can only be accomplished by pushing a trocar through the intercostal spaces, and then reinflating the lungs by the trachea. Thus, in the imminent danger, in which alone the operation is used, an insurmountable obstacle is interposed to the continuance of the circulation, by the forcible compression of the pulmonary structure. In order to prove, that the introduction of large quantities of air into the cavity of the pleura was sufficient to account for the death of the animals on which the experiments were made, air was injected through an opening in the intercostal spaces of another animal, and its immediate death ensued. This additional fact was however scarcely necessary, as on opening the bodies of animals killed by brisk insufflation, the diaphragm was found to be protruded into the abdomen, forming an elastic salient tumour in that cavity; and the lung was seen contracted into a small volume in the chest. Leroy and Magendie also revived some animals by making a puncture in the parietes of the chest, immediately after brisk insufflation had been practised, and thus permitting the effused air to escape from the cavity of the pleura. The animals thus treated recovered, though they experienced much embarrassment in breathing for some hours.

The effusion of air into the cavity of the pleura was the most frequent result of brisk inflation, but some animals died in which this effect was not produced. Occasionally, bubbles of air were found throughout the whole sanguiferous system, which were evidently introduced by some rupture of the pulmonary vessels, a phenomenon which had been previously observed by Bichat. At other times, the cause of death was not apparent, but perhaps some of these cases may be explained, by supposing that air was effused into the cellular tissue of the lungs, and that the air cells were thus compressed; or that the organic nerves of the lungs were paralyzed by a pressure inconsistent with the exercise of their functions. On examining the bodies, ecchymosis and effusion of air beneath the pleura were generally observed.

Leroy endeavoured also to determine whether similar causes would produce the same consequences in man, and both he and Majendie report that they frequently occasioned a rupture of the pulmonary tissue, and a consequent escape of air into the pleural cavity, by forcible inflation in the human subject.

From these facts, it appears that insufflation, performed by the ignorant, inexperienced, or rash, is an operation frequently attended with a fatal result. The dangers are so great, that it is evidently not sufficient to diffuse a knowledge of them through the community, and to depend on the caution which this acquaintance with them may inspire, but it is desirable to have an apparatus, which may be more safely entrusted to those who are not distinguished by eminent professional sagacity and prudence. Leroy recommends the double-valved bellows of Hunter, to the handles of which he has adapted the graduated arc of a circle, by which the quantity of air injected into the lungs and removed by each successive motion of the bellows may be determined. The quantity of air admitted into the chest in ordinary inspiration is very small—the motion of the diaphragm and of the parietes being so gentle, as to be scarcely perceptible. In a man of middle age and moderate stature this quantity has been variously estimated. Menzies and Goodwyn supposing it to be twelve cubic inches; Jurin twenty; Cuvier sixteen or seventeen: Gregory only two; Davy about fifteen, and Thompson thirty-three. The quantity of air inspired during deeper respiration, as after violent exercise, cannot serve as any indication of that which it may be proper to supply, by an inflation of the lungs, resisted by the weight of the parietes of the chest, and by the pressure of the contents of the abdomen on the diaphragm.

Leroy ingeniously measured with his bellows the quantity of air expired without effort into a bladder at different ages, and marked upon the arc of the circle attached to the apparatus, the point to which the elevated handle of the bellows was raised. The quantity of air to be introduced into the chest at successive ages being thus determined, he reduced the opening at the extremity of the curved tube to a size which prevented the air being introduced more rapidly than it is usually inspired. The diameters of the tubes and of their orifices were adapted to the ages of the patients, and the quantity of air which ought to traverse them in a given time was thus regulated.

This apparatus is simple, and ought, in my opinion, to be adopted, as verbal directions often fail to impress the mind with a due sense of the dangers attending such an operation; especially when it must be performed in such excitement and confusion, as cannot fail occasionally to diminish the caution even of experienced operators. These instruments would however remove much of the danger attending insufflation, which might then be more safely performed by persons of ordinary skill.

Leroy also proposed a new application of the galvanic current in Asphyxia. Galvanism and electrical shocks have chiefly been applied to the region of the heart, to the intercostal muscles, and to the epigastrium; but the difficulty of directing this powerful agency, in such a manner as to excite the motive powers of the respiratory apparatus efficiently, and in regular succession has prevented its general adoption. Dr. Ure recommends that the phrenic nerve should be laid bare in the neck, and that one wire of the galvanic pile be connected with it, and another with the skin of the epigastrium, in order that the motions of the diaphragm may be stimulated by the galvanic current. The method proposed by Leroy is, however, of a much simpler character, requiring less anatomical knowledge and manual skill for its performance, and is unattended with any danger. He introduced acupuncture needles a short distance into the fibres of the diaphragm, on each side, and so situated, that they might easily be connected with the opposite poles of a galvanic battery. When the galvanic circle was completed, the diaphragm contracted, depressed the abdominal viscera, and enlarged the cavity of the thorax. When the contact of the wires ceased, the diaphragm, urged by the weight of the abdominal viscera, and assisted in its motion by gentle pressure made on the abdomen with the hand, returned to its former position, and expiration occurred. This experiment was tried on animals apparently dead from submersion, and when they had not been under water more than five minutes, they were often restored to life.

Whether this restoration was the consequence of the means thus used to produce artificial respiration must of course be a subject of reasonable doubt. But artificial respiration was continued for some time by thus alternately producing a contraction and relaxation of the diaphragm, until the natural respiratory movements gradually supervened. These experiments were witnessed, and their result was confirmed by Majendie,* who was appointed by the Academy of Sciences, to report on the papers presented to it by Leroy.

A very small apparatus only is necessary for this operation, and batteries consisting of a few plates might be kept at all the stations of the Royal Humane Society, with the other instruments recommended by that society to be used. The only danger encountered in resorting to these means would be that of losing time, which, when the proper instruments for inflating the lungs are at hand, might be more usefully employed in performing that operation. Time should be economised with the greatest care, but with acupuncture needles and a small battery at each station, and a proper fluid always ready to charge the trough, no delay need occur. A person possessing little skill might insert the needles, arrange the galvanic circle, and conduct the

* Journal de Physiologie. Tome IX.

operation. But if no one competent to superintend this process be present, no time should be expended in attempting it, since the period in which any means can be applied with the slightest hope of success is so very short. The simplest methods have the greatest claim on the attention of the inexperienced, and should alone be resorted to by them.

These considerations induced Leroy to inquire, whether the natural respiratory motions might not be imitated, in some degree at least, by applying pressure to the abdomen and to the elastic parietes of the chest, alternated by a relaxation of that pressure, during which the natural elasticity of the parietes would occasion an enlargement of thoracic cavity, and the weight of the contents of the abdomen would drag down the diaphragm. Whilst pressure is made on the abdomen and thorax, the vitiated air contained in the lungs is expelled, and when the pressure ceases and the chest enlarges, purer air is inspired. This is proved, by connecting with the trachea one end of a curved glass tube, the other extremity of which is plunged into a vessel of water. During the alternation of pressure and repose, the water may be observed to rise and fall in the tube, as the air is expelled from the chest or reinspired. Leroy also supposes, that some advantage may accrue, during the employment of this method, from the impulse given to the blood stagnating in the large vessels of the abdomen and chest, but, I fear, that the congestion in these vessels is generally so great, that no advantage can be expected from any increased pressure on them. In some experiments, performed by Leroy and witnessed by Majendie, the contractility of the diaphragm appeared to be directly excited by these means. Its motions were resumed, at first convulsively, but afterwards in a more regular and continuous manner.

This method of producing artificial respiration may be most easily applied by means of a bandage recommended by Leroy, and more particularly described by the Royal Humane Society, and of which also I have given an account in the Letter prefixed to this Treatise. This bandage, for a description of which I refer to this Letter, and to the plate at the end of this volume, may be easily made on the spot from a sheet or piece of strong flannel. Artificial respiration by pressure may thus be employed with advantage from the first moment after the body is dragged from the water, during the preparation of any other apparatus from the use of which more beneficial results may be expected. After immersion followed by insensibility, every moment is of the utmost value for the use of restoratory measures, and much of this important time is often lost, in seeking or in arranging the instruments necessary for any operation proposed. This time may now be economised by applying this means of attempting to restore life.

Asphyxia and syncope differ in some important respects. In syncope, the first morbid impression is received by the general nervous system, affecting secondarily the organic innervation of the heart. The motions of this organ are interrupted, at the same moment that the activity of the capillary system employed in returning blood through the veins to the right cardiac cavities is impaired. The circulation is thus suddenly arrested from the cessation of the heart's motion, and from the diminution of the activity and power of the capillary vessels. In syncope, therefore, the blood does not proceed through successive stages of venous degeneration—there is little accumulation of blood in the right auricle, sinus venosus, pulmonary artery, and vena cava. Moreover, in syncope, a considerable volume of air remains in the lungs, which imparts, by slow degrees, small quantities of oxygen to the feeble tide of blood which still circulates through them—for the heart's action, though very feeble, and much interrupted, still occasionally impels very small quantities of blood into the vessels. On the contrary, in Asphyxia, the blood, from the want of a supply of air to the lungs, rapidly loses its arterial character, until, at length, it becomes so much deteriorated, that it is incapable of exciting the organic sensibilities of the pulmonary vessels, which therefore refuse to transmit it through the tissue. The blood by degrees accumulates in the pulmonary artery, in the right cavity of the heart, and in the vena cava, until they are completely gorged, and the whole mass of this degenerated fluid is an obstacle to the supply of better oxygenised blood by transfusion. The nervous system also, in syncope, is primarily affected by a morbid influence, which suspends its functions for a time, but which does not fatally oppress its powers. That morbid influence being removed, the brain and organic nerves gradually regain their power—aided by them, the heart resumes its motions, and the capillaries supply from the various tissues fluid, which has undergone little change, and which, subjected to the oxygen still remaining in the air-cells, is propelled into the sanguiferous system, and restores the phenomena of life. In Asphyxia, on the contrary, the nervous system is secondarily affected, venous blood, deficient in stimulating and nutritious qualities, circulates for some time through the tissue of the nerves—gradually, the supply becomes of a still less healthy character and diminishes in quantity, until, at length, the circulation is arrested, at the moment when this fluid, almost exhausted of its vital qualities, has permeated the minute vascular system. Deprived of all stimulus, the powers of the nervous system can only be revived by the afflux of arterial blood. The introduction of oxygen into the air-cells and the renewal of the capillary action of the lungs are, therefore, the direct indications in the treatment of Asphyxia—whilst the excitement of the brain and the pneumogastric nerves by appropriate stimuli is the best method of restoring vital phenomena in syncope.

Seldom, or never, can a person immersed five minutes in water be restored to life; but syncope may continue for a much longer period without any sign of life being manifest, and complete restoration may then speedily ensue. Hence, it is probable that those singular examples of apparent cases of Asphyxia from submersion, whose recovery after protracted insensibility has been attested by indisputable authorities, were restorations from a form of syncope, which had occurred in consequence of the mental shock experienced at the moment of submersion. In the first report of the Parisian establishment for the recovery of the drowned, a case is related to have recovered after having been immersed three quarters of an hour. Some recoveries* from apparent death in consequence of submersion are recorded as having taken place, very long after the phenomena of life were extinguished. Thus Morgagni, in a letter to Langhans, published at Göttingen in 1748, mentions the extraordinary case of the resuscitation of a young man who had been immersed nearly half a day, and for whose recovery no means were used beyond the the application of spirits of ammonia to his nostrils. In animals, life can seldom or never be restored when five minutes have elapsed after respiration has been arrested, and it is therefore most probable, that the remarkable resuscitations, reported to have taken place after a much longer duration

* "There are cases on record," says Dr. Good, "of recovery from drowning after a submersion of some hours, but these are rare and wonderful, and some of them altogether incredible; for we have histories of recovery after eighteen hours, (1) four and twenty hours, (2) and even three days, (3) while some retailers of the marvellous have stated intervals of fifteen days, and in one instance, (4) related with much gravity, not less than seven weeks. From all which, however, we may learn the useful lesson of the necessity of redoubling our exertions when called upon for medical aid, and of not despairing very early." (*Study of Medicine, vol.* iii. *p.* 560.)

(1) Pechlin. De aeris et alimentorum defectu et vita sub aquis, Kiel. 1676. 8vo.
(2) Lepi, Submersos per horas 24 vitam protrahere posse. Rom. 1670.
(3) Eph : Nat : Cur : Dec. i. Ann. vj· vjj. obs. 20.
(4) Id : observ : 125, 130, 192.

of apparent Asphyxia, have occurred in forms of syncope having few if any of the characteristics of Asphyxia. Leroy considers it desirable that some means of distinguishing syncope from Asphyxia should be discovered. It is most probable, however, that, when syncope has continued a considerable period, the state of the capillary circulation may acquire more of the characteristics of Asphyxia, and that some congestion may occur in the large veins. In the absence of any correct means of diagnosis, it is proper to neglect all attempts to distinguish the two diseases, and to employ for the restoration of all cases of suspended animation, with caution but with zeal, the means used in Asphyxia.

Notwithstanding the dangers attending insufflation, it is a remedy of too efficient a character to be abandoned, in attempting to remove so terrible a condition of the organs as occurs in Asphyxia. But this operation ought never to be entrusted to inexperienced persons, and when performed by the most skilful, the utmost caution is requisite to prevent the pernicious consequences of too rapid and too copious an introduction of air into the lungs. Hunter's bellows with two valves should be used, but improved by the adaptation of Leroy's graduated arc to the handles, by means of which the quantity of air to be introduced at different ages may be determined. The bellows should not be employed without the tubes recommended by Leroy, and which have been described. Tracheotomy is unnecessary in Asphyxia, since an operator who is possessed of ordinary skill may introduce these curved tubes into the glottis, and an unskilful person should not be permitted to perform so serious an operation as tracheotomy. If the nozzle of the bellows be thrust into the divided trachea, the operation is barbarous, since a wound is thus produced of the most dangerous and distressing character; and because when the bellows are thus used, it is difficult to avoid the employment of too much force, since the escape of air at each side of the nozzle renders a certain briskness of inflation necessary. Yet, it is difficult to see how inflation could be accomplished through the divided trachea, unless the parts were subjected to such rough usage as would put in jeopardy the patient's life, if he recovered from insensibility. This operation must, therefore, be considered as placed beyond the pale of professional sanction, and ranked with offences against the person. It has, however, been performed by the most intelligent and humane surgeons, and recommended by the highest authorities in the art. But since the dangers attendant on brisk inflation of the lungs have been discovered, the laudable anxiety of affording efficient relief to the patient will less frequently prompt the practitioner to employ means which render it difficult to avoid the hazards attending this operation. Instead of dividing the trachea, Leroy's curved tubes should be introduced through the glottis into the larynx. To facilitate the introduction of these tubes Leroy has devised a simple instrument, by which the root of the tongue may be depressed, and the epiglottis elevated. This instrument is described in the explanation given of the engraving at the end of this volume.

The lungs of infants appear, from Leroy's experiments, to be less liable to be ruptured by inflation than those of adults. In Asphyxia, in new-born infants, insufflation may therefore be performed with less risk than at a later period of life, when the lung has lost that fleshiness and firmness which distinguishes its tissue in very young children.

In Asphyxia from submersion Louis* conceived that fluid is frequently inspired into the bronchi. Déth
arding, Senac, Wepfer, and Conrad maintain that the glottis is spasmodically

* Memoire sur la Bronchotomie. Par M. Louis. Memoires de l' Academie de Chirurgie. T. xii. Edit. 12mo.

closed in drowning, and that the epiglottis is depressed upon the glottis. On the contrary, Morgagni, Haller, and De Haen contend, that the glottis remains open. Louis drowned animals in coloured fluids, and found that they frequently inspired water in such quantities as to fill the air-cells and bronchi with a frothy fluid. Louis also examined the bodies of men who had perished by submersion, and reports that he discovered the same appearances in them. Goodwyn was led by his experiments to believe;* "that the whole quantity of fluid found in the lungs of drowned animals is inconsiderable, and that it is generally composed partly of the natural mucus of the lungs, and partly of the fluid which passes into them, during the efforts to inspire." In cats drowned in quicksilver, the greatest quantity of mercury found in their lungs was five drachms. But, two ounces and a half of water introduced into the lungs of a cat, confined in an erect posture, did not produce great inconvenience during several hours, and the whole quantity of water was found in the lungs when the cat was strangled and examined. Kite† and Coleman‡ support Goodwyn's opinion by

* Connexion of life with respiration. P. 16.

† Duncan's Med. Commentaries, Vol. IV.

‡ Dissertation on Suspended Respiration.

their experiments; but, on this subject, authorities differ widely. Berger* and Larry sustain the opinion of Louis. Waldschmit, Becker, Détharding, &c. are opposed to it. Morgagni did not discover any spumous fluid in the lungs of guinea pigs which he drowned. Evers and Desgranges† make the same report concerning their observations, and Piorry‡ says, that if the animal drowned remain beneath the water from its immersion until death, no spumous matter will be found in its lungs. Orfila§ thinks that much of the frothy fluid found in the bronchi is produced by the congestion of the lungs and air passages during the agony of death, which occasions the exudation of mucus and serum, as is observed in some cases of epilepsy and death by hanging. Morgagni had observed, that the quantity of fluid found in the bronchi depends in a great measure on the position of the body while immersed, and when taken from the water. If the head be dependent, he says, less fluid will generally be found in the bronchi than if the head be buoyant; and sometimes a considerable quantity of fluid has been observed by Orfila,

* Essai Physiologique sur la cause de l' Asphyxie par Submersion, 1803.

† Instructions sur les Secours à donner aux Personnes Noyées.

‡ Journal Hebdom. de Méd. Tome iii. p. 556.

§ Archives Gen. de Méd. T. xiv. Diction. de Médicine.

to flow from the mouth and nostrils, when the head was lower than the trunck on bringing the body to land. He does not, however, distinguish cases which had been long immersed from recent deaths by drowning.

Orfila believes that a greater or less quantity of water is generally inspired during the agony of drowning, and that the existence of froth in the bronchi depends, in a great measure, on the circumstance of the animal's having risen to the surface and respired air once or twice previously to its final submersion. In dogs plunged into water coloured with ink, mud, or soot, Orfila invariably found that some water penetrated their lungs, and he says that more is invariably found when the dog is brought out of the water with the head elevated; and that whenever the animal has risen to the surface to respire, a frothy fluid is discovered in the trachea and bronchi, which may sometimes be distinguished by the naked eye beneath the pleura, and which may be expressed from the lungs through the trachea. Probably, some part of the spumous fluid found in the lungs of such animals was produced by the prolongation of the agony of death, consequent on the partial supply of oxygen obtained by these successive inspirations.

Notwithstanding the observations of Orfila, I am inclined, from what I have observed, to believe, that water generally enters the bronchi in such small quantities as in no respect to interfere with the process of respiration, and that it is generally excluded by the spasmodic action of the glottis. In several drowned persons who had not remained long in the water after death, which I have examined, the quantity of fluid found in the lungs has been inconsiderable. Dr. Roget* is, I perceive of the same opinion, and his authority deserves great respect. It must likewise be observed that the cases examined by Orfila had generally been under water long before they were examined. Orfila† however observes, "I have opened at the Morgue many bodies of persons drowned, which had not been in the water more than a few hours, and I have often found "*écume ou un liquide écumeux*" in the trachea and bronchi; in a small number of cases only, I have observed nothing of this nature, but it must be remembered that the men are accustomed to remove the bodies with the head downwards from the cart in which they are brought." Bodies remaining under water some hours cannot however be legitimately compared with those removed from it after the lapse of a few minutes, especially as Dr. Edward

* Cyclop. of Practical Medicine, p. 174.

† Dictionaire de Medicine. Tome xx. p. 25. Art. Submersion.

Jenner Cox* has rendered it exceedingly probable that water seldom penetrates the lungs before the last moments of life, when the glottis loses that organic sensibility, which generally prevents the entrance of a foreign fluid into the trachea.

These latter observations of Orfila furnish, in my opinion, a clue to the explanation of those previously recorded. The bodies exposed at the Morgue have generally remained beneath the water very long, and in such cases we may naturally expect to find, that when the organic sensibilities of the parts have become extinct, water should freely enter the lungs. From this fact, of which I think abundant evidence is given, additional proof of the extreme importance of an early removal of bodies from the water may be derived. But from the latter facts, it appears that water is seldom found in the lungs, when the bodies are removed soon after sense and motion cease.

When much water is inspired and mingled with air and mucus, so as to obstruct the air passages with spumous fluid, no hope of recovery can be entertained. The division of the trachea has been proposed in such cases, and attempts to remove the fluids by suction with the mouth or

* North American Medical and Surgical Journal, October, 1826.

with a syringe have been encouraged. But when the fluid fills the minute ramifications of the bronchi, it could not be removed by these means even were the trachea divided, and the instrument of Desgranges used. In cases in which the spumous matter exists in smaller quantities, and only in the trachea, efforts for its removal by the introduction of a large canula into the glottis, and by suction with the mouth or with a syringe, may be of service, but when this accumulation is great, the case is beyond the present resources of the art.

Pelletan,* Desault,† Burns,‡ unite in recommending the introduction of the curved canula into the glottis, as an operation exceedingly preferable to tracheotomy, and, with the aid of Leroy's instrument, this may be so easily accomplished, that all excuse for the latter operation is removed.

In this chapter the methods of attempting to excite artificial respiration by instruments, by the bandage, and by galvanism, have been described. The dangers attending this operation have been fully discussed, its utility and importance enforced, and the means by which it

* Clinique Medicale. Tome i. p. 29.

† Œuvres Chirur. Tome ii. p. 239.

‡ Surgical Anatomy of the Head and Neck, p. 384.

may be safely performed explained. The necessity of continuing the resuscitative process for a very considerable period, even though no evidence of vitality should transpire, has been insisted upon. The question whether fluid enters the bronchi after immersion in water has been entertained, and directions given concerning the examination which it is desirable should be made, and the best means of removing any collection of mucus or water which may have taken place.

Some of the most important parts of the resuscitative process employed in the simpler forms of suspended animation, have thus been discussed.

The degree of warmth to be applied to the body, and the best method of applying it—the utility of friction—the employment of stimulants and the description of those cases in which bleeding is desirable would yet remain to be considered, if these subjects had not been treated at great length in the letter preliminary to this treatise. Perhaps, some observations might have been introduced, which would have obtained from men of science a more cordial concurrence in the opinions of the author, if those subjects had been discussed in the body of this work, rather than in a letter in which he was constrained to treat them in a popular manner. But much of what is necessary to the elucidation of the question of temperature has been explained in the second chapter of this work, and to avoid unwelcome repetitions, the author is obliged to content himself with a reference from this portion of the volume to the preliminary letter, addressed to his Grace the President of the Royal Humane Society, for the explanation of his opinions on the other important parts of the treatment of Asphyxia.

## CHAP. VII.

In the preceding chapter, the difference between syncope and Asphyxia was explained. This difference is rendered still greater, when syncope results from excessive hæmorrhage. The large vessels are then drained of blood, and the quantity of this fluid circulating in the tissues is much diminished. There are points of resemblance, however, between these two states, which ought not to be neglected. In both, the powers of the nervous system fail from the want of a due supply of blood. The large arteries are empty in both, and the chief difference is discovered in the venous system. In Asphyxia, the veins are distended with blood—in death from hæmorrhage, they are empty.

It is, however, important to observe, that the only obstacle to the transmission of the blood which distends the veins in Asphyxia, from the right side of the heart, through the lungs to the arteries, and consequently the only hindrance to the restoration of the balance of the circulating system, is the quality of that blood. Nay, it is even probable, that, could a certain quantity only of arterial blood be transmitted through the lungs, that would be sufficient to restore the respiratory movements, by rousing the brain and nervous system, to which this fluid would then be distributed by the arteries.

If arterial blood were transfused into the veins in Asphyxia, it would be mingled with the whole mass of the venous blood existing in the heart and vena cava, and would lose much of its distinguishing properties by this admixture. Truly, a large portion of this mass of blood might often be withdrawn, by making a free opening in the jugular vein, and by pressure on the chest and abdomen, so applied as to urge the volume of blood in the vena cava upwards, and to cause it to flow through this opening; or a canula might be introduced into the vein, and a considerable quantity might be removed by a syringe. It is however probable, that neither of these methods would sufficiently prepare the body, to make the transfusion of arterial blood an efficient remedy in Asphyxia; and we may very reasonably doubt, whether science will ever afford us the means of accomplishing this result. Nevertheless, the barrier does not appear so great as to be insurmountable, and a history of the origin and progress of transfusion, may serve to shew, that this operation has relations to Asphyxia which ought not to be overlooked.

The operation of transfusing the blood of one animal into the veins of another gave rise, about the middle of the seventeenth century, to one of the most celebrated controversies which ever agitated the professors of medicine. Transfusion was then supposed to be a recent discovery, and the most extravagant notions concerning its value prevailed. The honour of its invention was contested by the French and English; though passages in the classics not obscurely indicate that it was known to the ancients, and Libavius (in defensione Syntagmatis Arcanorum Chymicorum contra Heningam Schneumannum, Actione 2, p. 8. Edit. Francof. A. 1615.) thus plainly describes the method by which it was performed, fifty years previously to the origin of the French and English controversy. "Adsit juvenis robustus, sanus, sanguine spirituoso plenus: Adstet, exhaustus viribus, tenuis, macilentus, vix animam trahens. Magister artis habeat tubulos argenteos inter se congruentes, aperiat arteriam robusti, et tubulum inserat muniatque, mox et ægroti arteriam findat, et tubulum fœmineam infigat. Jam duos tubulos sibi mutuo applicet, et ex sano sanguis arterialis, calens et spirituosus saliet in ægrotum, unaque vitæ fontem afferet omnemque languorem pellet."

Boyle, in his celebrated work on the usefulness of experimental philosophy, relates experiments performed by Dr. Christopher Wren—Savillian professor in the University of Oxford—in which medicated infusions were injected into the veins of animals. Wren's method consisted in putting a ligature on a vein, and, having made an opening between the ligature and the heart, in introducing the beak of a slender syringe, or a quill fastened to a bladder containing the matter to be injected, and then propelling it into the current of the circulation. Lower afterwards connected the carotid artery of one animal with the jugular vein of another, by means of a tube; and whilst blood was thus transfused, he also permitted it to flow, from time to time, from a tube, inserted into the upper portion of the jugular vein of the animal on which the transfusion was practised, in order that the plethora might be relieved. The operation was continued, until the animal from which the arterial blood was taken died, at the side of that into which it passed. This experiment, Dr. Lower frequently exhibited in the universities, and the dog which had received the fresh charge of blood generally leaped from the table immediately after the operation, shook himself, and ran away without ailment. Dr. Lower proposed, in a letter addressed to Mr. Boyle, that experiments should be made to ascertain the effects of exchanging the blood of the old and young—of the sick and healthy—of the hot and cold-blooded—and of tame and wild animals. He expected that the exchange of blood would alter the nature of the animals in which it was made. "The most probable use of this experiment," he says, "may be conjectured to be that one animal may live with the blood of another; and consequently that those animals that want blood may be supplied from others, with a sufficient quantity of such as is good, provided that the transfusion be often repeated, by reason of the quick expense that is made of the blood."

The operation was introduced into Germany by the writings of Major, professor of medicine at Kiel, and in 1666 it was first performed on man in France by Denis and Emmerets. In the succeeding year, their example was followed by Lower and King, and in 1668, two Italian physicians, Riva and Manfredi, repeated the experiment.

In Paris, transfusion of the blood of animals into the human subject occasioned the most violent excitement. A fierce controversy was directed by Lamartinière and Perault against Denis and Emmerets, which was scarcely extinguished by the decision of the authorities, which forbade transfusion, unless the permission of the faculty of Paris were previously obtained. Each party engaged in this dispute committed extravagant excesses. The promoters of transfusion laid claim to the discovery of an universal remedy which would restore health, youth, and vigour—assuage diseases of the mind—calm the most violent dispositions—and might even prolong life beyond its natural term. Their opponents contended, that not only were these pretensions false, but that the operation was always dangerous, and sometimes fatal. The whole controversy degenerated into a contest of the most virulent abuse; in which each party degraded itself, in the attempt to overwhelm its rival with reproach, by denouncing it with every ignominious epithet. The whole city was agitated by this contest; it became the topic of the day—and as it occasioned eager debate in every circle of society, from the courtier to the humble student of science, some account of experiments which attracted so much notice may not be useless or uninteresting here.

Denis and Emmerets performed transfusion, by connecting the artery of the emittent animal with the vein of the recipient—blood having been previously abstracted from the latter animal. Their first experiments were made on brutes. The blood of three calves was transfused into three dogs, without any evil consequences; and that of four wethers into a horse twenty-six years old, and it was said to have derived much strength from the operation. A dog, blind with age, was reported to have derived surprising vigour, from the transfusion of blood from a young animal of the same species.

From these experiments on brutes, they proceeded to a moderate transfusion of blood into the human subject. Calves or sheep were, from some hypothetical notions concerning the qualities of their blood, preferred for these experiments; and the first trials were said to have been made without evil consequences. From the method employed however, the quantity of blood transfused in each trial could not be accurately ascertained, and it is probable, that the eager character of the inquirers led them to imagine, that greater quantities passed in each experiment than were actually transfused. Some fatal cases soon occurred. M. Gasper de Gurie de Montpoly relates two; the first of which gives ample proof of the extravagant expectations indulged by the promoters of transfusion. Baron Bond, son to the first minister of state of the King of Sweden, being affected with a malady which terminated in mortification of the intestines, underwent the operation twice—was reported to have been strengthened by it the first time, but died soon after the second operation. The other instance was that of a dog, in a trial made by M. Gayen. He drew three large dishes of blood from the dog which was intended to receive the fresh charge, and he weighed the dog that was to supply it. When the operation was over, he weighed the latter again, and found him two pounds lighter; so that, making allowance for some excretions which occurred during the operation, and for some blood spilled, at least one pound and a half of blood were transfused. But the recipient dog, though well dressed and fed, died five days afterwards; the emittent dog being then alive.

Denis performed his first experiment on the human subject on the fifteenth of June 1667, on a young man of fifteen or sixteen years of age, who had been weakened by repeated bleedings. He had become languishing, torpid, and slightly dropsical. Denis reports that the first operation restored him to perfect health.

The first experiment, of transfusing the blood of animals into the human subject, in England, was made on the 23rd November, 1667, by Dr. Lower and Dr. King, on a man named Arthur Coga, at Arundell House, in the presence of many persons of distinction and intelligence.

Having prepared the carotid artery in a young sheep, a silver pipe was inserted into it, and the blood was permitted to flow freely out into a vessel. In the space of a minute, about twelve ounces of sheep's blood escaped, and this fact guided them in judging of the quantity afterwards transfused. A rough approximation only could thus be obtained, and even this was vitiated by the subsequent employment of a smaller tube. The arterial pulse, it was observed, had been communicated to the vein in the arm of the man for two minutes, and then the experiment terminated. Due allowance being made for the diminished size of the pipe, nine or ten ounces of blood were supposed to have been transfused. The man professed to have received great benefit from this operation, and it is asserted that no ill consequence ensued.

The crisis of the controversy was brought about, by an experiment performed by Denis on an insane man. The insanity of this unfortunate man was periodical, and was attributed to severe disappointment. He had during the seven or eight preceding years alternately recovered and relapsed, but the fit generally lasted eight or ten months. He had been bled in his feet, arms, and head eighteen times—had bathed forty times—numerous applications to his forehead and potions had been tried—but the remedies seemed rather to exacerbate than relieve his malady.

His last relapse had occurred four months before the operation was tried, at a place about twelve leagues from Paris. He had been confined but contrived to escape, and ran away to Paris, in a dark night, quite naked. He was said to have spent these four months without sleep; rending his clothes; running naked about the Marais du Temple, and endeavouring to burn everything that he could lay his hands upon. M. de Montnor proposed to Denis and Emmerets that this man should be subjected to a trial of transfusion. They encouraged the experiment, saying that they "could indeed give good assurance for his life, and that the operation was incapable of causing the death of any one if discreetly managed;" but professing to doubt whether it would relieve his malady. They however encouraged the hope that some improvement might be expected from transfusing the blood of a calf, which might by its mildness and freshness, as they thought, allay the heat and ebullition of the patient's blood.

The operation was performed on the 19th of December, before many spectators distinguished by rank and professional eminence. Emmerets opened the crural artery of a calf, and made every other necessary preparation in their presence; and after having drawn from the patient abóut ten ounces of blood, only five or six ounces of the blood of the calf could be introduced, on account of the constrained position of the patient, and the pressure of the spectators. The operation was discontinued because the patient complained that he was about to swoon. He supped two hours afterwards, and passed the night singing and whistling, and committing his ordinary extravagant follies. During the following days, little change occurred in his symptoms, and the absence of improvement was attributed to the small quantity of blood transfused. Eager to perceive some advantage, they imagined that his violence had in some degree subsided, and determined to repeat the experiment once or twice. The second trial was made on the Wednesday following the first experiment, in the presence of Bourdelot, Lallier, Dodar, De Bourges, and Vaillant; all very able physicians. As he was very thin and meagre, having been wandering through the streets, in nakedness and hunger, for some months, it was thought proper to abstract only two or three ounces of blood from him, and to transfuse a pound. The quantity was much more considerable than in the first experiment, and the effects, which were immediate and very sensible, are thus described. As the blood entered his veins, he felt heat along the arm, and in both axillæ. His pulse speedily rose, and a copious perspiration covered his face. Immediately afterwards, his pulse became very irregular; he complained of pain in his loins, that he was sick, and that he should choke unless released. The pipe was therefore removed, and during the closing of the wound he vomited freely food which he had taken about half an hour previously. He also vomited much and was frequently purged during the early part of the night; but fell asleep about ten o'clock, and did not awake until the following morning at eight o'clock. Denis reports that "he then shewed a surprising calmness and great presence of mind." He made a glassful of black urine. He confessed himself to M. De Veau with much propriety, and was drowsy during the day and unwilling to be disturbed. Next night he slept well. On the following morning, he filled another urinal with water as black as that of the preceding day, and bled so freely from the nose, that it was considered proper to take two or three small vessels of blood from him. Next day he again confessed himself, and was admitted at his own request to the sacrament by M. Bonnet; it being then a time of jubilee. After this day, his urine was restored to its natural colour. His wife came to Paris, after having vainly sought him elsewhere: he received her with joy, and told her all that had occurred to him. He treated her with much kindness, and she rejoiced in his manifest improvement. Denis was not immediately satisfied with the symptoms of his patient, and from what he observed, thought that a third transfusion would be necessary to his cure; but, as he gradually improved, the operation was deferred, and sanguine hopes were entertained that he would be permanently restored.

He continued in this promising condition two months, at the expiration of which period, having indulged in various excesses, he was attacked by a violent fever. Denis and Emmerets were importuned by his wife to try the operation again, and though they professed to have been perfectly satisfied with the result of the previous trial, were only induced to repeat it with great difficulty, and in consequence of the continued importunity of the woman, who had previously resorted to various remedies without effect. "When the operation was attempted the third time," says the sentence given at the Chastelet, "it was at the urgent request of the madman's wife; those that were to perform the operation refusing to do it without permission of the Solicitor-General; that some days afterwards the operation was begun, but that as scarcely any blood issued either out of the foot or the arm of the patient, a pipe was inserted, which made him cry out, though it appeared not that any blood of the calf passed into his veins; that the operation was stopped, and that the patient died the next night." From other accounts it appears, that as soon as the transfusion was commenced, the patient was seized with shivering, and complained of great oppression, crying out, " Arretez —je me meurs—je suffoque." Lamartinière accuses the transfusers of disregarding his cries, and continuing the operation until he died in their hands. Denis, on the other hand, affirmed that little or no blood entered the man's veins—accused the wife of having administered poison to him—demanded that the body should be examined, and the inspection being refused, applied to the magistrates to be heard in his own justification. Meanwhile the enemies of the operation united, and are said to have offered money to the woman to give evidence against the transfusers. These contests were closed by the sentence of the Chastelet, which decided: " that the operation had succeeded well the first two times; and had not been undertaken the third, but at the earnest request of the woman, who otherwise, had ill observed the orders of those that had made the operation, and who was suspected to have caused the death of her husband" &c.: and then that for the future no transfusion should be practised upon any human body but with the approbation of the physicians of the Parisian faculty.

This sentence was fatal to the practice of transfusing the blood of animals into man. Probably, the patient, whose death occasioned this declaration against the operation, died from the admission of air into his veins; but the experiment had in no case been followed by an auspicious result, though, in some, it had produced no evil consequences. It had been applied to no rational purpose—had not been supported by any well-devised experiments—had sometimes been pernicious, and once, at least, fatal. Transfusion was therefore proscribed—in France, by a decree of the court of the Chastelet, and elsewhere, by public opinion. The extravagant notions entertained by the promoters of this operation, that it could remove disease and prolong life, as their promulgation had elevated public expectation to the highest pitch, so their dissipation rendered the prostration of the credit of this remedy greater and more permanent; and no inquiry was made, whether there remained not purposes of a humbler, but of a more reasonable character, to which so powerful an agent might be applied.

Dr. Harwood, professor of Anatomy in the University of Cambridge, attempted to revive the inquiry concerning the utility of transfusion, by making it the subject of his Thesis in 1785. He performed many experiments on animals, which he subsequently exhibited, in his lectures on comparative anatomy, in the schools of the University.

In the abridgment of the transactions of the Royal Society edited by Drs. Hutton, Shaw, and Pearson, the following note occurs relating to Dr. Harwood's experiments. *" Dr. Harwood, the present professor (1809) of anatomy at Cambridge, having perused the accounts of Lower and others concerning the transfusion of the blood, and being equally dissatisfied with the mode in which the former experiments had been conducted, and the superstition and prejudice which occasioned the subsequent relinquishment of the practice, was induced in the year 1785 to make it the subject of his Thesis; preparatory to taking his M. B. degree in that year. Upon this occasion, the professor made a number of

* Abridgment of the Phil. Trans. P. 185 note. Vol. i.

very interesting experiments, which he has since repeated in a great variety of forms; some of them having been privately conducted, and others publicly exhibited at his lectures on comparative anatomy in the schools of the University. From a great number of very curious experiments, the following have been selected, and we have the professor's permission to lay them before the public.

"Experiment 1. A dog of middling size, from whose jugular vein eight ounces of blood had been previously evacuated, was supplied with an equal quantity from the carotid artery of a sheep. During the operation the dog showed evident marks of uneasiness, but was little affected in any other way, till about twenty-four hours after the operation, when he had a shivering fit, succeeded by a considerable degree of heat, thirst, and the usual symptoms of fever, all of which disappeared in the course of the next day, and the dog remained afterwards in perfect health. The experiment being several times repeated, and the quantity of transfused blood, being occasionally increased or diminished, the feverish symptoms were observed to be more or less violent, in proportion to the quantity of arterial blood introduced into the vein of the recipient animal. It now occurred to Dr. H.

that the uneasiness of the animal during the operation, and the febrile disease with which he was attacked some hours afterwards, might probably arise from the preternatural degree of stimulus, occasioned by the introduction of the highly oxygenated arterial blood into the right side of the heart.

"Exp. 2. The experiment was therefore repeated with this difference, that the blood was conducted through the tube from the jugular vein of the sheep, instead of an artery. The result was exactly what the operator expected it to be; the animal was perfectly composed during the operation, and did not suffer the smallest inconvenience at any time afterwards.

"Exp. 3. Two pounds of blood were taken from a large pointer who had been previously weighed, and three pounds of sheep's blood from the jugular vein were introduced. Dr. Harwood had been in the habit of letting out the superabundant blood when any of the animals had received too much, but in this experiment, it was suggested by Mr. Midcalf, then fellow of Christ's College, that it would be curious to observe the effect which would follow such an extraordinary degree of artificial plethora, as the introduction of an additional pound of blood (into the circulating system of an animal which had not naturally more than five) must necessarily occasion. The vein was accordingly secured in the usual way, and the dog being released ran into the court, and attempted to relieve himself from this unusual plenitude by every possible evacuation. His efforts to accomplish this purpose not proving successful, he became still more uneasy and restless, and afterwards drowsy and stupid. These symptoms were succeeded or rather accompanied by a considerable degree of fever, which terminated in a copious evacuation of blood by stool, by urine, and by vomiting. He took no nourishment for three days after the operation, except pure water, and was more reduced than Dr. H. ever saw an animal in that space of time. He now drank a little milk, and afterwards some broth, from which time he gradually recovered his appetite and strength, and remained in good health for several years.

"Exp. 4. All the blood of a pointer was let out (as far as it was possible to evacuate it) till the animal was in convulsions on the table, and apparently expiring. The blood was then transfused from the jugular vein of a sheep into the correspondent vein of the dog, and in less than half a minute after the introduction of the tube, he began to respire, and as soon as he had received a quantity of sheep's blood equal to what he had lost of his own, he leaped from the table and walked home, without experiencing any apparent inconvenience either then, or at any subsequent period. The experiment was performed before a very crowded meeting at the public schools in the Botanic Garden of the university. It has been frequently repeated since, and a variety of other animals have been subjected to the same experiments, and with equal success."

The great defect in most of the experiments yet related is the want of precision in ascertaining the quantity of blood transfused. Concerning the majority, it cannot be confidently affirmed that any considerable quantity was received by the animals subjected to the operations. When the blood of a different species was injected, much temporary disturbance often occurred in the health of the recipient animal, but it generally recovered from a moderate transfusion. This constitutional derangement must be attributed to a difference in the qualities of the blood in the animals employed—occasioning an unnatural excitement that gradually subsided, as the blood was assimilated to that of the recipient animal.

Little is known concerning the distinguishing qualities of the blood of animals, and for what is known we are chiefly indebted to the investigations of *Prevost and Dumas. The sources of this variety chiefly consist, in a difference in the proportion of the serum and the globules; and in the form of the globules, which are either elliptical or spherical. They are spherical in all mammiferous animals, and their size varies in different animals. Hewson† even says that these particles have not an equal diameter in the same animal, and that in some animals these molecules change their size according to age. They are elliptical in birds,‡ and differ little in size in this class of animals, a change which is only observable in the greater diameter. They are also elliptical in all cold-blooded animals. Arterial blood contains a greater quantity of globules than venous, and they are found in a greater relative proportion in the blood of birds, than in that of any other animal—then follow the mammiferous animals, and of these, the carnivorous appear to have more than the herbivorous. In general, the number of the globules has a certain relation to the development of animal heat. In cold-blooded animals, fewer globules are found than in any other genera.

* Annales de Chimie et de Physique. Vol. xviii., p. 288.

† Phil. Trans. Vol. xliii. p. 230. &c.

‡ Prevost and Dumas. Op. cit.

An animal bled to complete syncope—when every muscular motion has been extinct, and the action of the heart and respiration suspended, even for some minutes—may be revived by the transfusion of blood from an animal of the same species. But if the blood be transfused from an animal of another species, but in which the globules are of the same form, though differing in size, the animal is only imperfectly restored, and can seldom be kept alive more than six days. In those animals on which this experiment was tried by Prevost and Dumas the pulse became quicker, the respiration remaining undisturbed; but the heat of the body fell with remarkable rapidity when it was not artificially sustained. After the operation, the dejections were mucous and bloody, and continued so till death. If blood containing spherical globules be injected into a bird, the animal dies as if it were poisoned, with violent symptoms of distress of the nervous system; an effect which occurs whether the animal have been previously copiously bled or not. The transfusion of sheep's blood, in the experiments of Prevost and Dumas, restored cats and rabbits from death after excessive hæmorrhage for a few days; but in ducks it excited rapid and violent convulsions, followed by death.

The investigations of chemists have, however, failed to discover many causes of difference existing in the blood of animals, but of a nature so subtile as to elude their researches. The sense of smell detects in the halitus of the blood; the eye discerns in its colour and consistency; and observation on the time in which changes occur in it when at rest, and on the nature of the changes themselves, expose sensible varieties in this fluid, the source of which no analysis has yet determined.

Physiology and practical medicine are deeply indebted to Dr. Blundell, for his ingenious and laborious researches concerning this interesting subject. Having, in the course of his extensive obstetrical practice, witnessed many distressing cases of death after hæmorrhage from the removal of the placenta, when the flow of blood itself had been quite arrested, he conceived that by the transfusion of human blood, the exhausted energies might be recruited. Before adventuring the operation on the human subject, he performed a series of experiments on animals, which form a most valuable contribution to medical science. From these experiments, it appears that after respiration has ceased, and the abdominal muscles are relaxed, little time elapses ere an animal becomes irrecoverable, by the process of transfusion. Dr. Blundell however succeeded in reviving a dog by transfusion, which had ceased to respire during five minutes. He also nourished a dog three weeks by the mere transfusion of blood into the external jugular vein —having, in this period, injected nearly eighty-four ounces of blood from other animals of the same species.

Dr. Blundell's experiments on the transfusion of blood from animals of different species, are quite consistent with those of Prevost and Dumas. He concludes, that the blood of one genus cannot be substituted, indifferently and in large quantities, for that of another. Thus several dogs which might have been revived after copious hæmorrhage, by the injection of blood from animals of their own species, died when considerable quantities of human blood were substituted for that lost by bleeding. Dr. Leacock had also previously published similar facts in his Thesis in 1817. The experiments of the old transfusionists, and those of Dr. Harwood, however, shew that small quantities of the blood of animals of some species, may be introduced into the circulation of animals of certain other species, without occasioning death, though the operation is generally followed by unpleasant effects. Human blood has recently been injected into a dog by Mr. Goodridge, of Barbadoes, and though the operation was followed by unfavourable symptoms, the animal survived.

From Dr. Blundell's experiments it also appeared, that blood might be received into a cup and passed through a syringe, without being thereby rendered unfit for the purposes of life, though it seemed to undergo some slight deterioration.

Practical medicine is indebted to Dr. Blundell for introducing the only reasonable application of transfusion which has yet been proposed; viz. to replenish the system in cases of severe and sudden hæmorrhage, when the larger vessels have been drained of blood, and death is imminent. These cases most frequently occur in obstetrical practice, when from the partial separation of the placenta and imperfect contraction of the uterus, &c. sudden and violent hæmorrhage frequently hurries the patient to the brink of the grave. When great quantities of blood have thus been lost, and the hæmorrhage has ceased; when the pulse is quick and thready—the face hypocratic—the animal heat greatly reduced, and jactitation has supervened—stimulants and food are frequently rejected, and often little chance of recovery remains. Though some extreme cases of this kind have been known to struggle through, they have remained long afterwards in a state of miserable weakness :—suffering from diarrhæa, cachexia, and distressing nervous maladies, and the constitution has not unfrequently received a shock which has proved, not remotely, fatal. Generally the victims have no such respite—and at this last crisis, when life seems about to ebb away, Dr. Blundell proposes to replenish the system by transfusing blood from a healthy man.

For this purpose, Dr. Blundell invented an apparatus which he has denominated an impellor, consisting of a syringe and tube ;—and another called a gravitator, a particular description of which instruments is unnnecessary here. The blood undergoes some deterioration from lying in the cup and passing the syringe, but suffers no change incompatible with life, if due caution be observed. Dr. Blundell has even continued to impel by the syringe blood rushing from an artery into the venous system of an animal for twenty or thirty minutes, during which period, nearly all the blood in its body must have passed through the apparatus. Yet the animal did not appear to suffer materially in consequence of the operation. Care ought to be taken to prevent the entrance of air or clots into the apparatus, and the blood should remain in the basin as short a time as possible. Performed by a cautious and skilful surgeon, the operation is simple and not attended with great danger, and is certainly justifiable in cases of extreme collapse from the loss of blood.

Since Dr. Blundell has revived this operation, it has not unfrequently been tried. Among the earliest and most earnest of its patrons, Messrs. Waller and Doubleday are distinguished; and to their fearless support, the degree of credit which the practice has attained is, in a great degree, to be attributed. Many eminent surgeons in this country and on the continent have since successfully performed it; and evidence has at least been given, that the dangers attending it have been exaggerated. Doubtless, it has been applied to some cases which might have recovered without such interference, but every operation in surgery is liable to the same imputation. The facts on record prove, at least, that in cases of extreme exhaustion from hæmorrhage, which, without such interference, might have terminated fatally, the operation has produced a more rapid restoration than could have been attained by ordinary means; and that, without the production of any materially unpleasant symptoms. Cases which were apparently in the last stage of a fatal exhaustion have been revived, when, in the opinion of practitioners of the greatest skill and experience, they could not have been restored by any other agent. The distressing secondary consequences of extreme exhaustion from hæmorrhage are said to have been avoided, and a more rapid restoration of health to have occurred, when the operation has been employed, than could have been expected, even if the case had revived without this last resort.

In the present state of our knowledge, however, transfusion ought never to be performed, excepting when all other remedies have failed. So many hidden dangers are discovered by experience, that prudence is one of the chief signs of wisdom, and rashness, of ignorance and folly. An astute practitioner will be careful also, not to expose a remedy of such power to unmerited reproach, by lightly resorting to it, in cases in which a favourable termination is still within the limits of hope. Having commenced, what must still be regarded as a new operation, only the greatest ignorance or the most wanton folly will ever be suspected, of a want of that watchful scrutiny during its progress, both into the symptoms of the patient, and the details of the operation itself, which can alone ensure its success.

The shock given to the nervous system by severe hæmorrhage is somtimes so great, that even if transfusion be performed before sensibility is extinguished and respiration has ceased, it is incapable of restoring the patient. In such extreme collapse, the mechanical supply of blood to the large vessels is not capable of restoring the powers of the exhausted brain, and the patient inevitably sinks. If the last agony of life has commenced, there are no facts to prove that the transfusion of blood has the power of restoring its phenomena, though it appears probable, from the testimony of those practitioners whose names are associated with the operation, that when such a state was certainly approaching patients have been rescued from its very verge.

It has been necessary, in treating on artificial respiration, to show that states of syncope induced by terror immediately before immersion, may be mistaken for Asphyxia, and that it is not improbable that they occur more frequently than we have hitherto believed. It may be very difficult to ascertain, and the present state of our knowledge affords us no data to determine, what modifications syncope undergoes,* during the

* One of the most remarkable cases of Asphyxia on record, both as respects its duration and its treatment, is related in the Archives Generales for November, 1826. I quote the following account from the Lancet of January 27th, 1827. "*Royal Academy of Medicine, Paris. Sitting of the twenty-sixth of December*. M. Bourgeois de Saint Denis read an account of a case of Asphyxia by submersion. This physician,

immersion of a body plunged into water after swooning. But the influence of the water on the nervous and muscular systems; the abstraction of that moderate supply of air which would otherwise enter the lungs from the agitation of the atmosphere, and from the constant exchange of the warm air contained in these organs, for that of the colder external medium;—and the entire exclusion of its influence on the skin;—these are important circumstances, by the influence of which we may conceive that states of syncope may be so much modified, as to

in the month of July last, going over one of the bridges (Pont des Arts), observed some persons carrying a man just taken out of the water to the bureau, where aid is afforded to the drowned; those who carried the drowned person kept his feet high and head low, and were inflicting hard blows over his chest, loins, and posteriors with the palms of their hands. M. Bourgeois proceeded instantly to the bureau, directed the person to be placed in the horizontal posture, and began to administer assistance himself, although the man did not show any signs of life, and had been under the water for the space of twenty minutes. The means used to recal life, consisted in dry frictions of the whole body, moderate inflation of air into the mouth and lungs, tickling of the sole of the foot, hypochondria, excitement of the nostrils by the smell of liquid ammonia, injections up the rectum of warm water, with some salt in it, and then *into one of the veins of the left arm. The vein, on being opened, did not at first furnish any blood. Every effort appeared for a while fruitless; when after the lapse of an hour, the flow of blood from the opened vein showed that the circulation began to re-establish itself.* A ligature was immediately placed on the arm, and, in a few minutes, ten ounces of blood were obtained. From that time the circulation and respiration returned, the chest evidently showing that the latter function was restored. But just at the moment when the symptoms of Asphyxia approach very closely in their characters to Asphyxia.

In the commencement of this chapter, I observed, that it is extremely doubtful, whether science will ever provide us with the means of rendering a transfusion of arterial blood available for the relief of Asphyxia. It is improbable that we shall be able to remove the great quantity of venous blood which fills the vena cava, the heart, and the pulmonary artery, and which would prevent the introduction of a quantity of arterial blood sufficient to restore suspended animation. But as it is certain, that states of syncope exist, so modified by long immersion in water, as to re-

were disappearing, and restoration to life becoming more and more evident, an attack of the most horrible convulsions and tetanus threatened the destruction of the individual. Sixteen ounces of blood were immediately drawn, and notwithstanding every effort to arrest the flow of blood, it continued to run until this convulsive state was followed by one of syncope, and afterwards profound coma, which lasted for twelve hours. The person was taken to the Charité, and with one more bleeding was perfectly restored. On the following day the patient was quite well. M. Bourgeois presented this fact as a fresh instance of the efficacy of the trial of means after submersion of a considerable time, and when the drowned person was apparently beyond the possibility of recovery. From this fact, M. Bourgeois concludes, that hopes of restoration should not be abandoned until decomposition of the body has commenced. Amongst the best restorative means, he considers the cautious inflation of air into the lungs, and the abstraction of blood, the air being breathed by the mouth of some person into the lungs. M. Bourgeois considers the warm air particularly suited to the lungs under that state, and that its warmth compensates for its impurity."

semble Asphyxia, without partaking of some of its most fatal features, though they cannot be distinguished from it by any external indication; it becomes interesting to inquire, whether the transfusion of arterial blood may be employed, as a means of resuscitation in such states. Thinking this inquiry by no means beyond the limits of legitimate investigation, I have endeavoured, by a history of transfusion, to place before the reader, at once the errors of those who formerly promoted false hopes of the efficiency of this remedy, and the reasonable views of the modern patrons of this operation, in order that this inquiry may be commenced, without undue expectations of success.

Disgust with physiological experiments, arising from too great a conversance with their harrowing details, has induced me to relinquish the pursuit of an inquiry into this subject, for the illustration of which this history was prepared as a preliminary study. The few experiments which I reluctantly performed on this question were, however, attended with such results, as to induce me to expose in this chapter, the drift of my speculations on this subject, confiding their future prosecution to those, who may enter this field of investigation with fresher feelings than those, with which I am compelled to retire from it.

## CHAP. VIII.

The general phenomena of suspended animation having been discussed in previous chapters, and a particular description given of death by drowning, and of that form of Asphyxia to which children are liable after birth, as well as an account of the effects of wounds in the parietes of the chest—certain other modifications of this state remain to be considered, especially strangulation, and another condition of the system, of which an account has generally been included in the history of Asphyxia—death from cold.

Strangulation may result either simply from the pressure of a ligature round the neck, or the effects of this pressure may be complicated with other consequences, resulting from the cord having to sustain the weight of the whole body dependent upon it. These varieties may, therefore, be conveniently considered under the heads strangulation and suspension—the first being the simpler, and the second the more complicated condition.

The older physiologists supposed that death was produced in strangulation, by the pressure of the cord on the jugular veins, which interrupted the return of blood from the brain, whilst it was still supplied by the vertebral arteries, and thus produced apoplexy. Thus, according to Aristotle, the ligature or compression of the internal jugular veins produced insensibility. Galen however demonstrated that no such effect followed this operation; and experiments, similar to those which he performed, were made by various physiologists, from Galen to Valsalva, with the same result. Morgagni* critically examines the labours of his predecessors, and though he regards some of their experiments with considerable suspicion, those of Desnoves and Lamure convince him that the external and internal jugular veins may be tied without any disastrous effects. Dr. Kellie† tied the common jugular and the recurrent veins low down in the neck in two dogs—one appeared to suffer no inconvenience, and the second, though rather dull and heavy for two days, speedily recovered. I have frequently included the carotid arteries and internal jugular veins on both sides of the neck in ligatures, in a series of experiments performed on dogs, with the hope of elucidating the nature of *ramollissement du cerveau.* The circulation

* De Sedibus et Causis Morborum. Lib. ii. Epist. xix.

† Edin. Medico-chirurgical Trans. Vol. i. p. 162.

carried on by means of the vertebral arteries through the spinal canal was sufficient to maintain life in these animals. In some experiments, in which I included both the carotid and vertebral arteries in ligatures, the animals once or twice recovered, though they were exceedingly weak for some time after the operation. Meanwhile, the functions of the brain must have been supported only by the blood supplied through the anastomosis of the arteries of the spinal canal, and of the smaller vessels in the neck. Van Swieten* tied the carotid arteries, and, after an interval of eight days, the internal jugular veins in a dog, without any ill effect; and Dr. Kellie† tied all these vessels and the recurrent veins at the same moment, and though the dog was rather sleepy for two days, he then recovered. Notwithstanding the result of this experiment in animals, we could not hope to perform such an operation with impunity on man. The common carotid has, however, been very frequently tied in man without the slightest injury to the functions of the brain, and this operation is even performed to relieve the vascular turgescence of external tumours, without any apprehension of deranging the circulation within the

* Commentaria in Aphorismos Boerhaavii. Tome i. p. 173.

† Edin. Medico-Chirurgical Society's Trans. Vol. i. p. 165.

head.* The internal jugular veins have also been tied in man by Mr. Simmons† and Dr. Simson,‡ and the common carotid and internal jugular§ have been obliterated by the pressure of tumours, without any ill effects having been produced. Galen having discovered that the ligature of the carotid arteries and jugular veins was not fatal, attributed death from hanging to the lesion of the pneumogastric nerves, and thought that the function of no other part was disturbed. Death from strangulation was, however, until very recently, attributed to the pressure exerted by the rope on the jugular veins, whereby the return of the blood, transmitted to the brain by the vertebral and carotid arteries, was prevented, and apoplexy produced. The constriction of the trachea by the cord, and the obstacle to the entrance of air into the lungs occasioned by this cause, seem to have been entirely neglected by the earlier writers. Even Morgagni, who gives a most elaborate history of the opinions of his predecessors, in commenting on the experiments of Galen, says, that if the

* Medico-Chirurgical Transactions, Vols. ii. and vi: Operations of Mr. Travers and Mr. Dalrymple, for the cure of Aneurism by Anastomosis.

† Medical Facts and Observations, Vol. viii.

‡ Edin. Medical Essays, Vol. v.

§ Edin. Med. and Surgical Journal, Vol. iii. Edin. Med-chir. Society's Trans. Vol. i.

pressure on only one of the veins and nerves does not speedily occasion fatal accidents, it is otherwise when these parts all suffer, at the same time, the constriction of a cord which encircles the neck. He only throws out a suggestion that it may perhaps be desirable, in considering the causes of death, to add the constriction of the trachea to that of the other parts.

The congestion of the brain from an interruption of its circulation could not, perhaps, be made so perfect by any means in our power, as to occasion death as suddenly as it occurs from strangulation. Certainly, this result could not be produced by the pressure of the ligature on the soft parts of the neck. After death from hanging, the scalp and integuments of the head and neck are found congested with blood; there is vascular turgescence of the mucous surfaces of the eyes, nostrils, and lips; and not unfrequently, blood exudes from the nose and mouth. These external signs of plethora were long considered sufficient evidence of the congestion of the cerebral mass. But Valsalva, Morgagni,* and De Haen,† though their attention was long directed to the investigation of this subject, did not discover any signs of congestion in the brains

* De Sedibus et Causis Morborum. Epist. xix.

† De Submersis. Tome viii. par. ii.

of persons perishing by suspension. The following experiment of Coleman supports their opinion: *" the trachea of a dog was laid bare, and secured by a ligature"; " in less than four minutes he ceased to struggle." " A portion of the cranium was removed, and the veins of the head were evidently less distended than natural." The observations of Dr. Monro and Dr. Kellie,† on the bodies of criminals who had perished on the gallows, coincide with those of Morgagni. No sign of congestion of the brain was discovered in any of the cases examined by them. Dr. Monro found the brain extremely soft, especially internally, in a woman hung at Montrose, and in other criminals; but in the brain of a pirate hung at Leith no sign of congestion could be detected. No appearance of brainular congestion is discovered when animals are killed after a ligature has been placed on both the internal jugular veins, nor when these vessels have been obliterated by the pressure of tumours.

Abundant evidence is thus afforded, first, that the ligature of the vessels of the neck does not occasion immediate death, and then, that the constriction of the cord on the neck in hanging does not produce congestion of the brain. It is

* On suspended respiration, p. 137

† Edinburgh Medico-Chirurgical Trans. Vol. i. p. 131.

wonderful that the interruption of so important a function as respiration should ever have escaped the attention of physiologists, even in the earliest periods of the science.

The chief cause of death from suspension is the interruption of the respiratory function. The duration of life is, however, affected by various accidents, such as the manner in which the rope is placed round the neck of the victim, and his weight, combined with the height and rapidity of the fall. By a careful adjustment of the rope, and by giving a twisting motion to the body at the moment that it was cast into the air, Louis found that the Parisian executioner could generally occasion death without a struggle, by rupturing the ligaments which unite the altas to the second vertebra, or those which confine the processus dentatus, and thus producing a pressure on the spinal cord. Sometimes the executioner attempts to accomplish the same result by springing on the shoulders or head of his victim, at the moment that he is launched into the air.

Generally, however, convulsions occur when sensibility is lost, and death supervenes in a longer or shorter period, as the obliteration of the air-passages is more or less complete. The face, the conjunctiva, and the mucous membranes of the mouth and nose are bloated by the turgescence of their vessels with blood. The eyes are prominent and stare; and the whole of the superior portion of the trunk is congested. Not unfrequently, the surface is discoloured with ecchymoses, or blood issues from the mouth mingled with a frothy mucus.

Sometimes, as Deslandes has observed, the rope is placed between the lower jaw and the larynx, and in this and other positions, it may not occasion a perfect obliteration of the air-passages; a result which may also be prevented by the rigidity of the cartilages of the larynx. A meagre supply of air may thus be afforded the victim—insufficient to maintain life, but capable of prolonging his tortures. Those who perish by their own hands, not unfrequently, from their ignorance or recklessness, thus encounter the most miserable and protracted agony; and the signs of congestion in the head and in the superior portion of the trunk are more evident in them. In all such cases, the actual disturbance of the balance of the circulation in the brain is certainly greater, than when death takes place at an earlier period, but there is no evidence that this congestion occasions apoplexy, and life is generally extinct before such a result could ensue, from the gradual accumulation of blood in the brain. That the chief cause of death in hanging is the interruption of the respiratory function, appears from the well known experiment of Dr. Monro.* He suspended a dog, having previously made an opening into his trachea, below the place where the cord encircled the animal's neck. Through this aperture the dog breathed freely, and continued thus suspended three quarters of an hour, and having then been cut down, he appeared not to have sustained serious harm. When, however, the cord was placed below the orifice through which the animal had respired, he soon died when thus suspended. Mahon† relates an attempt to save the life of a criminal by this expedient. A butcher whose name was Gordon was, in the commencement of the last century, sentenced to die on the gallows, for highway robbery. This man had become very rich by the success of his adventures, and was thus enabled, by the offer of a large bribe, to induce a young surgeon to attempt to defraud the law of its victim. The means employed resembled the method adopted in Dr. Monro's experiment. The professional accomplice secretly made an incision in the neck, and introduced a tube into the trachea, thus providing an orifice through which respiration might proceed, whilst

* Obs. p. 71. Vide Exp. of Brodie. Paris and Fonblanque, vol. 2. p. 48.

† Medicine Legale et Police Medicale. Tome iii. p. 62.

the upper part of the neck was constricted by the cord. The man was, however, very heavy, and it is probable that other accidents besides the interruption of respiration were produced by his fall, for, when the body had hung the usual time, having been cut down and given to his relations, the surgeon drew blood from the jugular vein, and used the utmost exertion to restore life; but only slight evidence of vitality transpired. Once, the malefactor opened his eyes, and sighed; but after that, no sign of life occurred.

A woman named Snetta de Balsham, in the reign of Henry the Sixth, having been condemned to death, was hanged, and remained suspended one whole night, when she was cut down and was found to be still alive. This appeared so wonderful that she was pardoned. Dr. Plott however, who relates this extraordinary circumstance,* affirms that she was preserved by an ossification of her larynx, which resisting the constriction of the cord, the air-passages remained pervious, and respiration proceeded. Some other similar facts are described by Bonet† and Fallopius.‡

* Natural History of Staffordshire, p. 292.

† Bonet. Lib. vii. sec. xii. obs. 2.

‡ Fallopius. Tom. i. obs. 6.

" The most extraordinary instance of this kind, and one well authenticated, is that of Margaret Dickson, of Musselburgh, who was tried and convicted in Edinburgh in the year 1728, for the murder of her child; her conviction was accomplished by the evidence of a medical person, who deposed that *the lungs of the child swam in water;* there were however strong reasons to suspect the justness of the verdict, and the sequel of the story was well calculated to cherish a superstitious belief on the occasion. After execution, her body was cut down, and delivered to her friends for the rights of interment; it was accordingly placed in a coffin, and sent in a cart to be buried at her native place, but the weather being sultry, the persons who had the body in charge stopped to drink, at a village called Peppermill, about two miles from Edinburgh; while they were refreshing themselves, one of them perceived the lid of the coffin to move, and uncovering it, the woman immediately sat up, and most of the spectators ran away with every sign of trepidation; a person, however, who was in the public-house immediately bled her, and in about an hour she was put to bed, and by the following morning, was so far recovered as to be able to walk to her own house, after which she lived twenty-five years, and had several children."*—*Paris and Fonblanque. Medical Jurisprudence. Vol. ii. p.* 91.

Though, however, death from suspension must be attributed to the interruption of respiration, yet the condition of the sanguiferous system is considerably modified in this form of Asphyxia, and the circulation of the brain somewhat affected, though congestion is not produced. The sphincters are frequently relaxed, and the urine and fæces escape, and another more unequivocal sign of disturbance of the brain occurs—the erection of the penis and the emission of semen. Orfila† attributes this symptom to the traction of the spinal cord, consequent on the extension of the ligaments of the vertebral articulations. In support of this opinion, he says that erection is a frequent consequence of traumatic affections of the cord; and cites a case in which it occurred in consequence of the luxation of the fifth cervical vertebra.‡ I am inclined to attribute this symptom to some vascular disturbance of the cerebellum. The extension of the ligaments of the vertebral column may be so great as to occasion death by suspending the functions of the spinal cord. Beclard was accustomed to insist

* Maclaurin's Crim. Ca. p. 71.

† Dictionnaire de Medicine. Tome xix. p. 543.

‡ Bulletin de la Société Anatomique.

on this in his lectures, and to shew that in rabbits and cats the articulation between the first and second cervical vertebræ is so feeble, that if these animals be stretched lengthwise, they die from a suspension of the functions of the spinal marrow. Orfila refers also to a case recorded by Ansiaux, professor of Liege, in which the ligaments connecting the first and second cervical vertebræ in a woman who hung herself, were so stretched, as to lead him to suppose that she had died from suspension of the functions of the medulla spinalis. Further observations are necessary to support the opinion of Orfila, concerning the possibility of extending the ligaments of the spinal column to such a degree as to occasion death, but it is well ascertained that the processus dentatus is sometimes dislocated, and, resting on the anterior part of the altas, destroys life by its pressure on the cord. Doubtless, this accident not unfrequently occurs in this country from the violence of the shock which the criminal encounters when launched from the scaffold. In such cases, death would immediately ensue, and no hope could be entertained, that any means could be successfully employed to restore life when dislocation or fracture of the vertebræ had occurred.

Much local injury is often done to the soft parts of the neck* in death by suspension; such as rupture of the muscles and effusion of blood into the cellular substance—severe injury to the larynx, the luxation or fracture of its cartilages &c. &c. and apoplexy has sometimes been produced, as is demonstrated by the unequivocal sign of an effusion of blood in the substance of the brain, described by De Häen† and other authors.‡ But these are rather the accidents with which death by hanging is complicated, than features of this form of Asphyxia.

Mr. Brodie is of opinion, as we are informed by Dr. Paris,§ that if an animal recover "from

* "1. Valsalva a remarqué la rupture des muscles qui unissent l' os hyoïde au larynx et aux parties voisines, de sorte que cet os était séparé du larynx; et dans un autre cas il a trouvé les muscles sternothyroïdiens et hyothyroïdiens déchirés et le cartilage cricoïde rompu; 2. Weiss a rencontré le cartilage crocoïde brisé en plusieurs petits morceaux, et la partie supérieure de la trachée-artère entièrement détachée du larynx; 3. Morgagni et Valsalva ont observé la rupture du larynx: à la verité Morgagni note qu' il ne l' a jamais vue sur de jeunes sujets dont le larynx est plus flexible et moins cassant; 4. d' après Cornélius, la veine cave se rompt quelquefois sur les animaux étranglés; 5. Littre a trouvé du sang épanché à la base du crâne et dans les ventricules cérébraux sur une femme que deux hommes avaient étranglée en lui serrant le cou avec les mains, et dans une autre circonstance il a vu la membrane du tympan déchirée et beaucoup de sang épanché dans l' oreille; 6. Nanni, disséquant un voleur qui avait été pendu, rencontra le sinus longitudinal déchiré."—Orfila, Leçons de Médicine Legale. Note, p. 361, Tome ii.

† Rat. Med. Continuat. Tom. i. part. ii. 8vo.

‡ Hooper—Paris and Fonblanque. Vol. ii. p. 43.

§ Paris and Fonblanque. Medical Jurisprudence. Vol. ii. p. 44.

the direct consequence of strangulation he may probably suffer from the effects of the ligature on the nerves afterwards. Mr. Brodie passed a ligature under the trachea of a Guinea pig, and tied it tight on the back of the neck with a knot; the animal was uneasy, but nevertheless breathed and moved about; at the end of fifteen minutes the ligature was removed; on the following morning however the animal was found dead. On dissection, no preternatural appearances were discovered in the brain, but the lungs were dark and turgid with blood, and presented an appearance similar to that which is observed after the division of the nerves of the eighth pair." "I do not," observes Mr. Brodie, (in the M. S. notes of a lecture from which Dr. Paris quotes,) "positively conclude from this experiment that the animal died from an injury inflicted on the nerves of the eighth pair, but I think that such a conclusion is highly probable, and it becomes an object of inquiry whether a patient having recovered from hanging, may not, in some instances, die afterwards from the injury of the par vagum."

The chief modification to be observed in the treatment of Asphyxia from suspension arises from congestion of the head, occasioned by the constriction of the neck by the cord. The ligature should be removed from the neck as soon as possible, and the head and shoulders of the body should be raised considerably higher than the trunk. As the victim has not been plunged into a cold medium it is not necessary to apply a temperature higher than 68° Fahr., and, in mild weather the body should therefore be stripped and exposed as freely as possible to the air. *Friction may be employed as recommended in the directions given for the recovery of the drowned, and artificial respiration should—with a due observance of caution—be resorted to at the earliest moment.

Bleeding is seldom requisite in Asphyxia from submersion; but it is prudent after suspension to relieve the vessels of the scalp, and of the integuments of the face and neck from their turgescence, which otherwise might increase the tendency to congestion in the brain, as well as that disturbance of the circulation within the cranium which does exist to a certain extent. Blood should be abstracted from the external jugular vein, but not in quantities greater "than† may be sufficient to relieve the vessels of the head, without weakening the powers of life." The quantity necessary to this result has, I think,

* Preliminary Letter, p. 63.

† Royal Humane Society's Report for 1833, p. 105.

been considerably over estimated, and the abstraction of blood in this form of Asphyxia should be performed only by the most experienced practitioners. "After* recovery, blood may be, and often is required to be taken in a much larger quantity, than previously to the renewal of respiration."

In some of the preceding chapters, the important relations of external temperature to the human organization have been exhibited. The nervous system is directly affected by this agency, and we have seen how powerful it is in modifying the state of the constitution, as respects the increase or diminution of the faculty of producing heat. When the external temperature is rapidly elevated,† vascular action and the mobility of the nervous system are exceedingly stimulated, and an intense activity of the capillary vessels of the tissues occurs, by which every organ undergoes an excitement that soon terminates in exhaustion. On the contrary, the sudden application of a very low temperature depresses the powers of the nervous system, and is speedily fatal by an abstraction of vital energy. The healthy condition of the animal functions can be

* Royal Humane Society's Report for 1833, p. 105.

† Experiments of Duhamel, Blagden, Fordyce, Delaroche. &c.

preserved, only within a certain range of temperature, for any considerable length of time. The human body is especially incapable of enduring a long continued elevation of temperature greater than its natural warmth. The compensations made by the cutaneous and pulmonary transpiration, and by the secretions poured from the various excretory organs, when combined with the most careful attention to clothing and diet, cannot enable man to sustain the influence of a mean range of external temperature greater than his own animal warmth, and the mean atmospheric heat of no climate reaches this standard within ten degrees.

On the contrary, men inhabit regions in which the mean external temperature is depressed below the zero of Fahrenheit's scale;—the faculty of evolving caloric being supported by proper food, and the dissipation of heat prevented by suitable clothing. When the human body properly nourished and well clad has been gradually subjected to the influence of a continually lessening external temperature, like that which occurs in the change from summer to winter, or the gradual removal from a warm to a colder climate, the faculty of producing heat is invigorated, and the power of resisting the influence of external cold consequently strengthened.

When cold is also applied for a short time only*—as in the use of the cold bath, the *douche*, or the shower bath—if the constitutional powers be not previously enfeebled, it rouses the capillary actions, equalises the vascular distribution, and invigorates the body. The temporary application of cold should not however be permitted without due regard to the state of the constitution, since, when the calorific functions are enfeebled, a sudden abstraction of heat may have the most injurious influence on the economy.

The functions of every tissue depend chiefly on the integrity of its nervous and vascular systems. If the supply of blood be diminished the vital power is enfeebled, and if this supply be entirely cut off, life is extinguished—the part sloughs off, having no longer any vital connection with the rest of the economy. Innervation is equally necessary to the life of the various tissues, and though it is extremely difficult to isolate any portion of the body from the influence of the cerebro-spinal and organic systems of innervation, yet the effects of a partial abstraction of nervous influence sufficiently prove that it is necessary to the integrity of the functions, and even to the nutrition of the organs. The ex-

* Dr. Currie. Medical Reports on the Effects of Water, Cold and Warm, as a remedy in Fever. 8vo. Liverpool, 1797.

periments of Majendie* on the section of the fifth pair show how necessary the influence of that nerve is to the healthy condition of the functions of the different senses, and to the nutrition of the structures of the eye.

Intense cold, locally applied, depresses the vital energies of the part, first depriving it of the influence of the nervous system. Sensibility is speedily benumbed and then destroyed—the motive power of muscular structures is enfeebled—the actions of these organs become weak, irregular, and trembling, or even complete paralysis occurs. At the same moment, the bulk of the tissue exposed to this influence is diminished; the minute vessels are contracted, their activity impaired; the circulation is enfeebled, the quantity of blood distributed through the tissue is diminished; and these changes proceed until the vital current stagnates in the capillaries, and nutrition, secretion, and the calorific process being extinguished, the structure becomes rigid and congeals. These effects of the local application of intense cold may ensue without any injury being inflicted on the internal structures of the body, and the extremities are often thus lost in cold climates, because these parts are

* Journal de Physiologie.

remote from the centres of innervation and vascular action, and much exposed to the influence of the external temperature. These effects of the local loss of heat are to be combated by friction, which should be applied at first with great caution and gentleness. Great care should, moreover, be taken not to raise the temperature of the part affected too suddenly; as, if any vitality remain, it must be so feeble that it may be extinguished by the sudden application of any undue stimulus. Friction itself may prove too sudden a stimulus, and may exhaust the sensibility and organic irritability of the structure, if it be not employed with the utmost caution. It is therefore customary to commence this restorative process by gentle frictions with snow or immersion in cold water;* by which means the risk of exhausting the vital power, or of producing so sudden and violent a return of vital energy to the part as to destroy it by the excess of reaction, may be avoided.

The effects thus described may occur in any of the external structures, whose life may thus be destroyed. If, however, the cold be not too great, nor so long applied as to overcome the vital power resisting its influence, a healthy

* Fabric. Hildan de Gangrænâ et Sphacelo. Van Swieten Comment. Tom. i. De Gangræna. Cap. xiii.

reaction ensues, accompanied with a glowing sensation of reviving vascular energy, and often with pain, from the turgescence of the vessels of the part, and the abnormal actions of the sentient nerves. This reaction may become so violent as to give rise to inflammation; and one of the common consequences of intense cold is the irregular distribution of vascular energy, which, especially if it be followed by an injudicious exposure to an elevated temperature, occasions sudden and violent inflammations, which destroy the structure of the organs.

The effect of cold on the respiratory function and the organic sensibility of the lungs is controlled, by the constant admixture of the air inspired with that contained in the lungs, and whose warmth is equal to that of the body. A considerable period must therefore elapse, before the air contained in the pulmonary cells and in the bronchi can be cooled down to the temperature of the external atmosphere, especially as a fresh supply of carbonic acid gas, having the warmth of the body, is constantly emitted from the capillary vessels of the lungs. Contemplating however the gradual depression of the nervous energy, both of the cerebro-spinal axis and of the organic centres of innervation; and the diminished action of the whole vascular system—

of both which it will immediately be necessary to speak more particularly—it becomes apparent that a period must arrive, when the organic innervation of the lungs must be so much enfeebled, and the temperature of the air contained in their cells so much reduced, that the meagre tide of blood circulating through them must cease to undergo those changes, which usually occur in it from respiration. Legallois and Dupuytren have, in my opinion, satisfactorily shewn that the pneumogastric nerves exert a marked influence over the changes which usually occur in the blood during respiration, even when these nerves are only divided in the neck, an operation which merely deprives the organic centre of pulmonary innervation of the influence derived from the cerebral system. The experiments of our own astute surgeon and able physiologist Brodie* prove, that the organic innervation of the lungs is not immediately destroyed by this operation, and that the changes which usually occur in the blood may proceed for some time, even after an animal is decapitated, provided artificial respiration be carefully maintained. But it is evident, that by both these operations the organic centre of the pulmonary nerves is only secondarily affected; and

* Phil. Trans.

as it is discovered that the injury which these nerves thus sustain is so serious, that the changes occurring in the lungs become gradually less and less perfect until, after a certain period, they cease, sufficient proof is I think obtained that the function of respiration is, like every other function, subjected to the influence of the nervous system. The experiments of Edwards* shew that cold exceedingly depresses the nervous energy, but in estimating the influence of extremely low temperature on the animal economy, though death from this cause has been classed with Asphyxia, the effects of cold on the pulmonary innervation have seldom or never been considered. When, however, this nervous influence is weakened, and the air in the lungs cooled, nearly to the temperature of the external medium, it is evident that the pulmonary system of nerves cannot resist that benumbing influence which paralyses every other power.

The body is most easily affected by external cold when exhausted by fatigue or undue excitement, or when the vital energies are subdued by the depressing passions. The rapidity with which caloric is abstracted depends on various external circumstances—thus a strong, cold wind, loaded

* Sur l'action des agens sur la vie.

with snow or sleet, occasions a very rapid loss of temperature, even when the thermometer does not indicate an intense degree of cold. Shipwrecked mariners clinging to the rigging of the stranded vessel, over whom the wind rushes loaded with spray—now immersed in the waves, and then uplifted to be exposed to the current of the gale—are soon benumbed, lose their hold, and perish in the water; or, if lashed to the rigging, become exanimate from the effects of cold on their nervous system.

* Exposed to such influence, the capillaries of the surface are constricted, and its nervous influence benumbed. The blood retreats inwardly, and accumulates in the viscera—the minute vessels of these structures being loaded, the great venous and arterial trunks become congested with blood. The limits of the circulation being restricted by the diminished vascular energy of the surface, and impeded by the congestion of

* We are much indebted to Dr. Paris for making us acquainted with the unpublished opinions of Mr. Brodie on this subject. "Mr. Brodie classes the effects of cold in the following order. 1. It lessens the irritability, and impairs the functions of the whole nervous system 2. It impairs the contractile powers of the muscles. 3. It causes contraction of the capillaries, and thus lessons the superficial circulation, and stops the cutaneous secretion. 4. It probably destroys the principle of vitality, equally in every part, and does not exclusively disturb the functions of any particular organ."—M. S. Notes quoted in Paris and Fonblanque's Medical Jurisprudence. Vol. ii. p. 61.

the internal organs, the action of the heart is embarrassed. The nervous system is, however, especially affected by cold, upon which this agent appears to exert a specifically pernicious influence. Sometimes, this occurs suddenly, and tetanic convulsions ensue, followed by rigidity and immediate death—an effect which the French surgeons describe to have frequently happened during Napoleon's retreat from Moscow. At other times, a sudden loss of muscular power occurs, leaving the victim exposed to the fatal influence from which he cannot fly. More frequently, these fatal accidents are preceded by weakness, muscular tremor, or, on the contrary, rigidity of the muscles, spasms, and cramp, and difficulty in breathing, arising from loss of power in the motive parts of the respiratory apparatus.

The depression of the nervous energy is, however, especially manifested in the diminished power of the intellectual faculties, and the tendency to somnolency. The senses are gradually benumbed—the sight, touch, and hearing become more and more feeble—the weakness of the muscular powers, and the mental hebetude combine to render the individual indifferent to his fate. An incontrollable desire to lie down and permit the torpor that benumbs his mind to extinguish his sufferings possesses him, against which, at length, he ceases to struggle, and, as a willing victim, meets his fate. The recent expeditions in search of a north-western passage have furnished ample evidence of these facts, if it had not previously been furnished by the narrative of Sir Joseph Banks and Dr. Solander in Terra del Fuego.

The external appearance and pathological condition of persons perishing from cold is thus described by the late lamented Dr. Kellie of Leith. *" In reviewing the appearances observed in the dissection of these two bodies, our attention cannot fail to be arrested by the striking resemblance which the one, in almost every particular, bears to the other. In both, we observed the same soundness and freshness of the bodies,—in the abdomen the same congestions of the viscera,—and especially the same remarkable redness of the small intestines from the turgescence of their blood-vessels—the same absence of fœtor, putrescency, and tympanites,—the same perfection of the other viscera, with the exception of the pancreas of the woman;—in the head, the same bloodless state of the scalp,—the same turgidity of the vessels on the surface of the brain,—the same congestion of the

* Edinburgh Medico-Chirurgical Trans. Vol. 1. p. 91.

sinuses,—the same soundness of the cerebral texture,—and the same serous effusion, *amounting, in the one, to nearly four ounces, in the other to about three.*" Similar appearances were described by Quelmalz.* Cappel† also found great congestion of the internal viscera; and Rosen‡ discovered that the vessels within the cranium were much distended with blood. Parat and Martin confirm the observations of Dr. Kellie as far as their investigations extend. All agree in the congestion of the pectoral and abdominal viscera, the bloodless state of the surface, and its perfect integrity. Perhaps the most remarkable circumstance observed in these post mortem examinations is the great effusion of serum into the ventricles of the brain. Many nosological authorities have classed death from cold with comatose diseases, and Dr. Cullen considers this condition a species of apoplexy. The lethargy with which the whole nervous system is benumbed in the first moments of death from cold, differs from the condition of this system in apoplexy, which disease chiefly depends on the loss of the balance between the venous and arterial capillaries in the brain, or on the sudden effusion of

* Progr. quo frigoris acrioris in corpore humano effectus expedit, Lipsiæ 1755. Halleri Disp. Medic. Tom. vi. Lausannæ 1758.

† Observ. Anat. dec. i. p. 2.

‡ Rosen. Anat. p. 142.

blood or serum within the cavity of the cranium.

The torpor which affects the cerebro-spinal axis, when subjected to the influence of extreme cold, also impairs the mobility of the nervous centres of organic life, and the oppression of the brain does not appear remarkably to precede that of the ganglionic* system, for the first symptom of the effects of cold is not unfrequently embarrassment in breathing. Nevertheless, ultimately the cerebral circulation is exceedingly disturbed, as is proved by the extravasation of so much serum in the short period that elapses between exposure and death. And in considering this circumstance, a remark made by Dr. Cullen appears to me to possess considerable value. "Whatever takes off or diminishes the mobility of the nervous power, may very much retard the motion of the blood in the vessels of the brain, and that perhaps to the degree of increasing exhalation, or even of occasioning rupture and effusion; so that, in such cases, the marks of compression may appear upon dissection, though the disease had truly depended on causes destroying the mobility of the nervous power." The effusion which occurs in cases of death from cold may, perhaps, be attributed to the combined influence of many concurring

* Actes de la Soc. de Santé de Lyons, T. i. p. 300.

causes. The interruption of the respiratory function, from the loss of nervous influence consequent on the embarrassment of the circulation and the loss of power in the heart, together with the constriction of the vessels of the surface and extremities, may greatly increase the tendency to congestion in the brain, already established by the want of mobility in the vessels of its mass. From these combined causes, we may perceive how the balance of the circulation may speedily be destroyed, and effusion from the vessels occur.

*Treatment of the effects of excessive cold.*— When the torpor, with which the organs of motion and the mental faculties are affected after exposure to cold, commences, the utmost efforts should be made to prevent its increase. If the mental hebetude be not overcome, the victim will perish. The excessive lassitude and feebleness experienced by him can only be removed by such exertion, as by exciting the vascular actions shall restore the organic motions of the extremities and of the organs affected. The feet should be stamped upon the ground; the hands rubbed against each other; the arms thrown with force across the chest; and the extremities protected, as much as possible, from the effects of the cold. Hay or straw, if it can be procured, should be wrapped round the feet and legs, if woollen clothing is not to be obtained.

Very small quantities of spirits or stimulating liquors should be taken, as they have a tendency to exhaust the enfeebled nervous power, which is best invigorated, if the circulation be restored by exercise.

When cold has produced apparent death, the body should be placed in a room without a fire, and rubbed steadily with snow or cloths wet with cold water; whilst, at the same time, inflation of the lungs is steadily and cautiously performed, according to the directions given, in the letter preliminary to this treatise.* This treatment should be continued a long time, although no signs of life appear; for some persons have recovered who appeared lifeless for several hours.

When the limbs only are affected by cold they should be rubbed gently with snow, or bathed in cold water with ice in it† until the feeling and

* Vide p. 56.

† En Sibérie, dit Samuel George Gmelin (Voyage en Sibér trad. fr. par Keralio, Paris, 1767, Tom. i. p. 381), les membres gelés et blancs, privés de sentiment, sont d' abord frottés avec de la neige; des qu' ils commencent a devenir sensibles on y substitue de l' eau chaude. S' ils sont gelés depuis peu de temps, le plus prompt remède est de les frotter avec une étoffe de laine. Les Jakoutes emploient un autre procédé que les Russes ont pris d' eux; ils enduisent le membre gelé, avec de la bouze ou de l' argile, ou ces deux matières mêlées, pour rappeler le sentiment. C' est aussi un remède preservatif, selon eux, et dont ils se

power of motion return. The friction must be very gentle at first, but may be, by slow degrees, applied with a somewhat greater force. When sensibility and the power of motion return to the parts affected, the bathing or the rubbing with snow should be repeated once every hour, and continued a longer or shorter time, as the pains are more or less violent.

platrent les mains et la figure quand ils ont à voyager au froid. Il parait que la térébenthine appliquée sur un membre gelé, qu' on expose ensuite graduellement à la chaleur pour faire fondre cette résine, afin qu' elle pénètra le plus chaud qu' il est possible, est aussi un moyen utile pour les membres gelés; on les enveloppe bien ensuite jusqu' à parfaite guérison."—Diction. des Sciences Medicales. Tome xvii. p. 70.

## CHAP. IX.

CHEMISTRY makes us acquainted with twenty-five different permanent gases, and of these twenty-five there is not one which can support life. Oxygen itself requires, as we have seen,* to be mingled with azote, whether for the purpose of being presented in a milder form to the blood circulating through the lungs, or because the nitrogen is also necessary to the processes of animalization has not yet been determined by physiologists. But it is probable, that even slight changes in the proportions of the constituent elements of the atmosphere would be exceedingly injurious to health, if they did not ere long prove fatal. Nor is it necessary that the gases should be respired in a pure state in order to destroy life, it is sufficient that they be mingled in certain quantities with the atmospheric air, and we shall perceive, that in some instances, the quantities necessary to produce fatal results are comparatively small. It is impossible to trace all the minute shades of difference in the effects produced by the respiration of gases

* Page 3.

mingled in various proportions, and brevity requires that our attention should be confined to the effects of those gaseous combinations from the respiration of which accidents most frequently occur. I shall moreover restrict myself, as much as possible, to an account of their pathological effects, and of the remedial processes which it is necessary to employ for their removal.

Air may be contaminated by respiration in a confined apartment, until it becomes unfit to support life. The symptoms induced by the respiration of an atmosphere thus contaminated, are partly derived from the effects of the abstraction of oxygen from the air which is inspired, and, partly, from an increase of the quantity of carbonic acid gas, which exerts a pernicious influence on the nervous system. One hundred and forty-six Englishmen were imprisoned in a dungeon twenty feet square in Fort William,* at Calcutta. This room was pierced by only one small window, and, during the night on which they were thrust into this terrible place of torture, all perished excepting twenty-three. Their sufferings were of the most frightful character, being combined of the effects of gradually increasing suffo-

* Hollwell. Narrative of the Deplorable Deaths of the English Gentlemen and others who were suffocated in the Black Hole at Fort William.

cation and of the inhalation of a poisonous gas. In 1742, the keeper of the round house of St. Martin's confined twenty-eight people in a room only six feet square, and not quite six feet high, and four were suffocated.* Of such consequence is it that the constituent elements of the atmosphere should be supplied in their due proportions, and in sufficient quantity to support the phenomena of respiration.

The gases are divided into two classes by the effects which they produce when respired. The first class consists of those which occasion Asphyxia, simply by their negative qualities; being themselves incapable of supporting life. The second includes those which when respired have a positively pernicious influence on the nervous system, and extinguish life by their poisonous qualities. In this latter class, the effect produced is sometimes to be ascribed, partly to the imperfect supply or absolute want of oxygen; and partly to the noxious influence of the gas which is substituted for it.

The gases which exert merely a negative influence on the system are seldom collected in sufficient quantity to extinguish life, and their effects differ little from those of simple suffoca-

* Smith's Principles of Forensic Medicine, p. 221.

tion. Nitrogen, when injected into the veins, appeared to Nysten* to have a sedative influence on the heart; but from such an experiment no inference can be drawn concerning its effects when inspired. Dupuytren† also found that sometimes azote forms a great part of the gaseous matter exhaled from the "fosses d' aisance" at Paris; and which occasions one of the most sudden and fatal forms of Asphyxia. Hydrogen is sometimes spontaneously disengaged from the earth; as for example‡ in the environs of Barigazzo, near Modena, as we are informed by Spallanzani. It is likewise evolved from vegetable and animal matters in a state of putrefaction. But Asphyxia has never been produced by this gas excepting artificially, and its effects are not distinguished by any peculiar features, unless, perhaps, the blue colour imparted to the surface be sufficiently marked to establish a distinction. Hydrogen gas may be breathed for a short time without inconvenience, when the lungs contain their ordinary quantity of air; but if a considerable bulk of this air be expelled, by a forcible expiration, before inspiring the hydrogen, it can be inhaled only twice or thrice, and not without

* Recherches de Physiologie et de Chimie Pathologiques.

† Dictionnaire de Medicine. Tom. iii. p. 80.

‡ Ibidem. Tom. iii. p. 81.

great feebleness and much embarrassment in the chest being induced. The tone of the voice is changed by respiring it, but this effect ceases, immediately after the person on whom the experiment is made ceases to breathe it.* In treating persons asphyxiated by the inhalation of the negative gases, the same means should be employed as in suffocation without violence. Insufflation should be practised at the earliest moment, in order that the gas existing in the air-cells may be removed as soon as possible. The temperature of the body being little diminished, cold water should be dashed on the head and chest, to excite the respiratory system of nerves, and to reduce the temperature to a degree of warmth more consistent with the maintenance of vital action when animation is suspended. The body should be freely exposed to the atmosphere at about 70° Fahr. and friction and the other remedies appropriate to the recovery of the drowned should be employed with the utmost assiduity.†

Dr. Christison‡ judiciously divides the poisonous gases into two groups, the first comprehending the irritants and the second the narcotics. Among

* Journal of Science, Vol. ix. p. 182.

† Royal Humane Society's Report for 1833, p. 106.

‡ Christison on Poisons, p. 586.

the irritant gases he includes nitric oxide gas and nitrous acid vapour, muriatic acid gas, chlorine, ammonia, sulphurous acid, and some others less important.

Workmen in chemical manufactories, and in print and bleachworks, are chiefly in danger of suffering from the influence of these gases. Flannels are bleached by being exposed in close chambers to the influence of sulphurous acid gas, and in the flannel district, in the north-east of Lancashire, I have not unfrequently seen great pulmonary irritation induced in the workmen who are obliged to enter these chambers, and sometimes sudden inflammation of the lungs which it has been very difficult to subdue. Similar effects from the inhalation of chlorine, and sulphurous and muriatic acid gases, have come under my observation in certain chemical works in Manchester. This form of Pneumonia, whenever I have witnessed it, has been accompanied by great irritation of the kidneys, indicated by severe pain in the loins and derangement of the renal secretions. Twice, I have seen bloody urine, with shooting pains in the direction of the ureters, and great irritability of the bladder; and at other times symptoms less peculiar. Constant exposure in chemical manufactories to the inhalation of an atmosphere strongly impregnated with these gases renders the lungs almost insusceptible of their influence, excepting when they are respired in an almost undiluted state. Workmen thus employed frequently can live without inconvenience, immersed in air, which would immediately produce spasm of the glottis in persons unaccustomed to breathe so irritating an atmosphere.

The effects produced by nitric oxide, when inhaled by Sir Humphrey Davy, may serve to indicate the consequences of breathing the irritant gases. The nitric oxide, or bin-oxide of nitrogen as it is termed by Dr. Turner,* is a colourless gas. When it is mixed with the atmospheric air, or any gaseous compound containing oxygen in an uncombined state, dense, irritating vapours of a deep orange colour are produced, which are denominated nitrous acid vapours. "Having observed," says Sir Humphrey Davy,† "that no painful effects were produced by the application of nitrous gas to the bare muscular fibre, I began to imagine that this gas might be breathed with impunity, provided it were possible, in any way, to free the lungs of common air before inspiration, so as to prevent the formation of nitrous acid.

* Elements of Chemistry, p. 246.

† Researches Chemical and Philosophical, concerning Nitrous Oxide Gas, p. 475.

"On this supposition, during a fit of enthusiasm produced by the respiration of nitrous oxide, I resolved to endeavour to breathe nitrous gas; one hundred and fourteen cubic inches of it were accordingly introduced into a large mercurial air-holder; two small silk bags of the capacity of seven quarts were filled with nitrous oxide.

"After a forced exhaustion of my lungs, my nose being accurately closed, I made three inspirations and expirations of nitrous oxide in one of the bags, in order to free my lungs as much as possible from atmospheric oxygen; then, after a full expiration of the nitrous oxide, I transferred my lips from the mouth-piece of the bag to that of the air-holder, and, turning the stopcock, attempted to inspire the nitrous gas. In passing through my mouth and fauces, it tasted astringent and highly disagreeable; it occasioned a sense of burning in the throat, and produced a spasm of the epiglottis, so painful as to oblige me to desist immediately from attempts to inspire it. After removing my lips from the mouthpiece, when I opened them to inspire common air, nitrous acid was immediately formed in my mouth, which burnt the tongue and palate, injured the teeth, and produced an inflammation of the mucous membrane, which lasted for some hours." Sir Humphrey Davy then remarks that if he had succeeded in taking a full inspiration of the nitric oxide, and if, because the lungs were filled with nitrous oxide gas, no fumes had been immediately formed, yet, it is improbable that he would have been able, by breathing nitrous oxide, so completely to have freed his lungs from the nitric oxide, as to have prevented the formation of nitrous acid in them, when he again inspired common air. Desgranges* records the case of a chemical manufacturer, who breathed the fumes of nitrous acid for some time, whilst removing a hamper in which some bottles containing it had burst. On respiring the gas, great feebleness ensued, accompanied with an acrid sensation of heat in the throat, irritation of the stomach and chest, a sense of constriction at the epigastrium, with a difficulty in respiring which threatened suffocation. He was seized in four hours with symptoms of inflammation in the throat and stomach. At night the urine was suppressed; the skin afterwards became blue; at last he was seized with hiccup, acute pain in the diaphragm, convulsions and delirium; and he died twenty-seven hours after the accident. More common symptoms† are intense pneumonia,

* Corvisart's Journal de Méd. T. viii. p. 487.

† Bulletins de la Soc. Med. d' Emulation. Oct. 1833.

and inflammation of the throat and air passages, accompanied by extreme constitutional irritation, rapidly tending to a fatal oppression of the vital powers.

Nysten* injected this gas into the veins, and exposed an absorbing surface to its action; and discovered that it produced results as fatal as those which are observed when it is respired. As it made the blood brown, he conceived that it induced Asphyxia by decomposing the blood, and he thus explained the feebleness of the pulse, the extinction of the motive powers, and the remarkable loss of heat observed in this form of Asphyxia.

Among the narcotic or sedative gases, I shall chiefly direct the attention of the reader to the effects of two—the sulphuretted hydrogen and carbonic acid gases—because, at the same time, allusion may be conveniently made to the effects of other gases, whose properties resemble theirs; and because they are the most frequent sources of accidents to man.

Sulphuretted hydrogen is naturally produced by the decomposition of animal and vegetable substances, but it is especially disengaged from common sewers and receptacles of excrementi-

* Recherches de Physiologie et de Chimie Pathologiques.

tious matters, such as the "fosses d' aisance" of Paris. Chaussier* found it by experiment extremely injurious to animal life, and even fatal when merely injected into the cellular tissue, into the cavity of the pleura, the rectum, or when the skin alone was exposed to its influence. Thenard and Dupuytren† made a series of experiments on this gas, in which they discovered that the presence of 1-1500th of sulphuretted hydrogen in the air is immediately fatal to a small bird; that 1-800th will kill a dog of the middle size, and an atmosphere containing 1-150th of its volume was fatal to a horse. When the gas is inspired pure, it is instantly fatal: both Thenard and Chaussier report that, as soon as it is respired, the animal utters a plaintive cry and falls motionless, involuntarily voiding his urine. The contractile power of the muscles is extinguished, the blood is fluid and black, and in all the soft parts the tonicity of the fibre is lost: it tears on the application of the slightest force, and putrefaction promptly supervenes.

Nysten‡ discovered that though this gas is so extremely deleterious, it may be injected in small

* Expériences sur les animaux avec le Gas Hydrogéne Sulphuré. Sedillot's Journal de Med. Tome xv. p. 28—34.

† Orfila, Toxicologie Generale. Tome ii. p. 479.

‡ Recherches de Physiologie et de Chimie Pathologiques. p. 118.

quantities into the veins, without producing fatal effects. Hence, he is inclined to suspect, that its fatal qualities have been exaggerated. Its effects, when injected into the veins, are however probably mitigated by the exhalation of a great quantity of the gas from the capillaries of the lungs, before it has been transmitted to the brain and spinal cord, on which its specific influence is exerted. His experiments on the effects produced by the injection of this gas into the cellular tissue and into the cavity of the pleura, as well as when absorbed by the skin, confirm the experiments of Chaussier, to which allusion has already been made. Experiments performed by Drs. Christison and Turner shew that this gas is extremely injurious to vegetables, appearing to "exhaust† the vitality of plants, and to cause in them a state analogous to narcotic poisoning in animals. Four cubic inches and a half, diluted with eighty volumes of air, caused drooping of the leaves of a mignionette plant in twenty-four hours, and the plant, though then removed into the open air, continued to droop till it bent over altogether and died."

The gases formed in the "fosses d' aisance" of

* Recherches de Physiologie et de Chimie Pathologiques, p. 123.

† Christison on Poisons, p. 590. Also Edin. Med. and Surgl. Journal. Vol. xxviii. p. 361.

Paris, consist chiefly of combinations of ammonia, sulphuretted hydrogen, and nitrogen. These exhalations produce the most fatal effects. Often the individual exposed to them perishes in a moment, his head and arms falling, and the trunk being doubled up from the instant loss of muscular power. If death does not immediately occur,* the victim, when he recovers from the first effects of this exposure, is affected with pains in the head, nausea, fainting fits, severe pains in the stomach and limbs, constriction of the throat; sometimes he utters involuntary cries, or lapses into delirium accompanied with the sardonic laugh and convulsions; or tetanus ensues. The face is pale—the pupil dilated and motionless—the mouth filled with a white or bloody froth—respiration convulsive—the pulsation of the heart irregular—the skin cold; until at length complete Asphyxia and death terminate this scene of suffering. When the individual has been exposed to a less concentrated combination of the gases, fainting, nausea, violent headache, colic, or comatose affections occur, from which he may recover.

As I have no opportunity of making an immediate reference to †Hallé's work, I shall quote an

* Adelon. Dict. de Médicine. Article Asphyxie, T. iii. p. 87.

† Recherches sur la Nature du Méphetisme des Fosses d'Aisance. 1785.

interesting passage from Dr. Christisan's admirable volume, to which I have made previous reference. *"In order that the reader may comprehend the exact cause of these accidents, as it is not easy for an Englishman to comprehend how a person may be suffocated by the fumes of a privy, it is necessary to explain, that in Paris the pipe of the privy terminates under ground in a pit, which is usually contained in a small covered vault, or is at the bottom of a small square tower open at the roof of the house; and that the pit is often several feet long, wide, and deep. Here the filth is sometimes allowed to accumulate for a great length of time, till the pit is full; and it is in the process of clearing it out that the workmen are liable to suffer. M. Hallé has given an interesting narrative of an attempt made to empty one of these pits in presence of the Duc de Rochefoucault, the Abbé Téssier, himself, and other members of the Academy of Sciences, who were appointed by the French government to examine into the merits of a pretended discovery for destroying the noxious vapours. The pit chosen was ten feet and a half long, six wide, and at least seven deep; and repeated attempts had been previously made without success to empty it. For

* Christison on Poisons, p. 591.

some time the process went on prosperously; when at last one of the workmen dropped his bucket into the pit. A ladder being procured, he immediately proceeded to descend, and would not wait to be tied with ropes. 'But hardly,' says Hallé, 'had he descended a few steps of the ladder when he tumbled down without a cry, and was overwhelmed in the ordure below, without making the slightest effort to save himself. It was at first thought he had slipped his foot, and another workman promptly offered to descend for him. This man was secured with ropes in case of accident. But scarcely had he descended far enough to have his whole person in the pit except his head, when he uttered a suppressed cry, made a violent effort with his chest, slipped from the ladder, and ceased to move or breathe. His head hung down on his breast, the pulse was gone; and this complete state of Asphyxia was the affair of a moment. Another workman descended with the same precautions, fainted away in like manner, but was so promptly withdrawn that the Asphyxia was not complete, and he soon revived. At last a stout young man, secured in the same way as the rest, also went down a few steps. Finding himself seized like his companions, he re-ascended to recover himself for a moment; and still not discouraged, he resolved to go down again, and descended backwards, keeping his face uppermost, so that he was able to search for his companion with a hook, and withdraw the body.' It was found impossible to go on with the operation of clearing out; and the pit was shut up again. The first workman never shewed any sign of life; the second recovered after discharging much bloody froth; all the persons in the vault were more or less affected; and a gentleman, who in trying to resuscitate the dead workman, incautiously breathed the exhalations from his mouth, was immediately and violently seized with the convulsive form of the affection."*

Carburetted hydrogen, though less suddenly fatal than sulphuretted hydrogen gas, is extremely injurious to animal life. Sir Humphrey Davy's attempt to breathe it is thus related.† "Mr. Watt's observations on the respiration of diluted *hydrocarbonate* by man, and the experiments of Dr. Beddoes on the destruction of animals by the same gas, proved that its effects were highly deleterious." "In the first experiments, I breathed, for nearly a minute, three quarts of hydro-carbonate, mingled with nearly two quarts of atmospheric air. It produced slight giddiness, pain in the head, and

* Hallé. Recherches, &c. p. 50.—Christison on Poisons, p. 593.

† Researches on Nitrous Oxide Gas.

a momentary loss of voluntary power; my pulse was rendered much quicker and more feeble. These effects, however, went off in five minutes, and I had no return of giddiness. Emboldened by this trial, I introduced into a silk bag four quarts of gas nearly pure, which was carefully produced from the the decomposition of water by charcoal an hour before, and which had a very strong and disagreeable smell. My friend Mr. James Tobin, junior, being present, after a forced exhaustion of my lungs, the nose being accurately closed, I made three inspirations and expirations of the hydro-carbonate. The first inspiration produced a sort of numbness and loss of feeling in the chest, and about the pectoral muscles. After the second, I lost all power of perceiving external things, and had no distinct sensation, except that of a terrible oppression on the chest. During the third expiration, this feeling subsided, I seemed sinking into annihilation, and had just power enough to cast off the mouthpiece from my unclosed lips. A short interval must have passed, during which I respired common air, before the objects around me were distinguishable. On recollecting myself, I faintly articulated, '*I do not think I shall die.*' Placing my finger on the wrist, I found my pulse thread-like, and beating with excessive quickness. In less than a minute, I was able to walk, and the painful oppression on the chest directed me to the open air. After making a few steps, which carried me to the garden, my head became giddy, my knees trembled, and I had just sufficient involuntary power to throw myself on the grass. Here the painful feelings of the chest increased with such violence as to threaten suffocation," &c. He continued to suffer during the rest of the day from extreme feebleness, vertigo, nausea, loss of memory, and deficient sensation, followed by severe pain in the forehead, and transient pains in the chest and extremities. This gas is not unfrequently encountered by miners, who sometimes perish by breathing it; but its effects are much mitigated by dilution, for Sir Humphrey Davy breathed it with but slightly unpleasant consequences when mixed with common air, and in mines it is generally found thus mingled with large quantities of air.

Carbonic acid gas is much more frequently the cause of fatal accidents, than either of the sedative gases whose effects I have described. It is often encountered in caverns, mines, and deep wells: it is produced in great quantity in lime kilns,* and in the huge vats, in which fermenting liquors are

* Lancet, 1828-9, Vol. ii. p. 725.

contained, in the large brewing establishments—it is evolved in great quantity in the ordinary process of combustion, and hence it may collect in a confined apartment in a proportion sufficient to destroy life. It is especially produced from the slow combustion of charcoal, in the choffers which are, especially on the continent, often used to heat rooms, and which cannot be safely employed in small and close apartments.

Plants also in the night evolve nitrogen and carbonic acid gases which render the atmosphere of confined apartments unwholesome. Asphyxia has even in some rare instances been induced, when an individual has been long exposed to the influence of such an atmosphere. A melancholy proof of this, quoted by Dr. Paris,* occurred at Leighton-Buzzard, in Bedfordshire. "Mr. Sherbrook having frequently had his pinery robbed, the gardener determined to sit up and watch. He accordingly posted himself with a loaded fowling-piece, in the greenhouse, where it is supposed he fell asleep, and in the morning was found dead upon the ground, with all the appearance of suffocation, evidently occasioned by the discharge of *mephitic gas* from the plants during the night."†

* Paris and Fonblanque. Medical Jurisprudence. Vol. ii. p. 49.

† 'Observer' of 16th. and 'Times' of the 17th. October, 1814.

It is generally found in mines mingled with a large mass of air and is then called the *choke damp:* it sinks to the lowest stratum of atmosphere contained in the mine because of its great specific gravity, and hence it is very difficult to remove it from the galleries in which the workmen are employed. It issues in some volcanic regions, in great quantities from fissures in the rocks, and is found in caverns, as at Pyrmont in Westphalia, and at the remarkable Grotto del Cane at Naples, where, to gratify the morbid curiosity of travellers, dogs are immersed in the gas collected in the lower stratum of the air contained in the grotto, until Asphyxia is induced.

This gas cannot be breathed in a pure state, as it occasions an immediate spasmodic action of the glottis, which cannot be overcome by the strongest efforts. Sir Humphrey Davy* having prepared some very pure carbonic acid gas attempted to inspire it, but it was in vain that he made repeated efforts to draw it into the windpipe. It occasioned such painful irritation of the glottis and upper parts of the throat, as to occasion a complete closure of the opening into the larynx. When, however, the gas was diluted with about double its volume of common air, he

* Researches concerning Nitrous Oxide, &c. p. 472.

was enabled to breathe it for nearly a minute, when it produced a slight degree of giddiness, and an inclination to sleep. Pilatre de Rozier* had made a similar experiment on the effects of undiluted gas by descending into a brewer's vat, containing a great quantity of carbonic acid evolved from the fermenting liquor beneath. Every attempt to breathe was accompanied with an instant sense of suffocation, which was relieved by raising his head above the level of the gas and breathing the common air. But it is evident that he must have also inspired some diluted gas, as he was affected with giddiness—his face was purple, his muscular power much enfeebled, he could not distinguish objects, and with difficulty understood what was said to him.

When the diluted gas is inhaled, it has a pernicious influence on the nervous system, and the fatal effects ensue after a shorter interval than when hydrogen or nitrogen only are inspired. Its influence is apparently of the most sedative character, and death ensues attended with little or no suffering. The younger Berthollet committed suicide by shutting himself up in a close apartment in which carbonic acid gas had accumulated from a choffer of charcoal. He sat down calmly

* Journal de Physique. Tome xxxviii. p 418.

at the commencement of his fatal experiment to record the sensations with which he was visited, and they appear to have been just such as would have been produced by a narcotic poison. Then an illegible word occurred: and it is supposed that at this moment the fatal effects suddenly supervened—that his hand fell powerless, and he ceased to exist.

The experiments of Bichat and Nysten* had led to the erroneous supposition that carbonic acid gas is not more deleterious in its effects when inspired, than nitrogen or any of the negative gases. †M. Collard de Martigny, however, has proved that it has a remarkable sedative influence. If carbonic acid gas be substituted, in the same relative proportion, for nitrogen, in the atmospheric air, animals cannot breathe it for more than a minute or two, without exhibiting symptoms of the effects of a narcotic poison. Animals even speedily die in such a mixture of common air and carbonic acid gas as will support combustion, and men have been taken exanimate from wells in which lights continued to burn. Asphyxia, from the simple deprivation of air or the substitution of hydrogen or azote, does not occur so soon in the various gradations of the

* Recherches de Physiologie et de Chimie Pathologiques.

† Archives Gen. de Médicine. Juin, 1827. T. iii. p. 91.

animal series as when carbonic acid gas is inspired. The sedative effects may be produced by enclosing the body in an atmosphere of carbonic acid gas, whilst atmospheric air only is inspired into the lungs—head-ache, imperfect vision, vertigo, tinnitus aurium, exhaustion, and a vague terror supervene, and death has thus been produced in animals.

"Professor Rolando, of Turin, having found that the land-tortoise sustained very little injury when the great air-tube of one lung was tied, he contrived to make it breathe carbonic acid gas with one lung, while atmospheric air was inhaled by the other; and he remarked that death took place in a few hours."*

The symptoms produced by the inhalation of carbonic acid gas differ considerably, according to the source whence it arises, and as it is more or less diluted with atmospheric air or other gases produced at the same moment with itself.

One of the most interesting cases of the effects of the gases produced in the slow combustion of charcoal, is related by Dr. Babington.† The waiter of a tavern and a little boy thirteen years of age went to bed, and not having risen between six and seven o'clock the following

* Christison on Poisons, p. 596.

† Medico-Chirurgical Trans. Vol. i. p. 83.

morning, a person went to the chamber, and found the waiter insensible and apparently at the point of death; the poor lad lying lifeless on the floor, and a chafing dish containing some extinguished charcoal at the foot of the bedstead. An attempt was made to restore the boy by insufflation of the lungs and the use of galvanism; but no signs of life having, after some time, transpired, he was reluctantly abandoned to the insensibility which oppressed him. The waiter was removed into a larger and more airy apartment—his breathing was stertorous, the countenance flushed, the lips livid, the pulse full and strong, and about ninety in the minute, and ten ounces of blood were therefore abstracted from his arm by his attendant. After some time, (when Dr. Babington first saw him,) the pulse had become weak and quick, and the respiration very imperfect; though the heat of the upper part of the body remained. The power of voluntary motion was suspended, and slight convulsive twitchings of the muscles, which at first prevailed, altogether ceased. Sensibility was extinct, the countenance pale, the eyelids closed, the eyes prominent and rolling, the tongue swollen and projected from the mouth, and the jaw locked upon it, whilst a copious discharge of saliva issued from the corners of the mouth. The window of the room, in which there was no fire, was left open, and the external temperature was about 50° Fahr. On passing a galvanic shock through the chest, the patient drew his breath deeply. The muscles of the abdomen were seen to react though feebly, while those of the face were slightly convulsed, and the eyelids raised. The respiratory motions became more powerful at each successive application of the galvanic current, and the arterial pulse was gradually developed. After a certain interval, a bladder of oxygen gas was respired by the patient. As the heat of the body was not diminished, water was dashed on the chest and face, and the respiratory muscles were evidently stimulated by this application. The inhalation of oxygen was repeated, and the galvanic shocks were applied alternately to the head and chest every half hour for some time, until it seemed that the excitement produced by them was followed by a corresponding depression, and they were therefore discontinued. Ammonia was rubbed on the temples and chest, and its vapour inhaled; which latter application rendered him uneasy and excited coughing. These and other means were continued until a warm perspiration broke forth, and his condition rapidly improved. In the afternoon the pulse had risen to 120 and was strong, but, as the stertor had diminished, a bleeding which had been proposed was postponed. In the night, however, the bandage came away from the arm, and he lost nearly a pound of blood, and it appeared probable, for some time, that he would not be able to survive the effects of this hæmorrhage; but during the night he recovered, and on the following day was able to speak, though very imperfectly. For two days, the left side of the face appeared paralysed, and his mind was considerably disordered. He recollected nothing from the time that he lay down—when he remembered having seen the charcoal burning brightly—till the second or third day after the accident. Bourdon* relates the case of a female who being in despair, alike from disappointment and jealousy, attempted to destroy her own life and that of her daughter, by shutting herself up in a small closet with her little girl, and exposing herself to the fumes arising from a choffer of burning charcoal. Their bodies were found prostrate on the floor, and means were successfully employed for the recovery of the mother, but the child was quite dead.

Dr. Schenck† relates a case of Asphyxia, differing in some of its features from those which

* Principes de Physiologie Medicale. Partie ii, p. 560.

† Horn's Archiv, für Mediz. Erfahrung.

have generally been observed. A married couple were found suffocated by the smoke of a forge. The temperature of the surface, which Orfila and Jaeger state to be higher than the natural warmth in asphyxiated persons, was not in these bodies increased, but resembled that of other corpses at the same period after death. There was no remarkable flexibility of the limbs—considered by Portal, Larrey, and Orfila to be characteristic; nor any unusual tendency to putrefaction, which is not consistent with the observations of Jaeger and Renard. Moreover, Larrey and Renard describe the face in such cases to be bloated, and Orfila says it is tumid and livid, but, in this instance it was pale and collapsed. In both bodies, the right side of the heart contained some blood; the left was empty; whereas, in three asphyxiated persons, Renard found the right heart empty, flaccid, and collapsed. Like other observers, *" Dr. Schenck found a blackish sooty mark at the nostrils, large patches of a brownish violet colour on the surface of the body, white foam at the mouth, great brightness of the eyes, immobility of the lower jaw, great fulness of the cerebral vessels, the lungs collapsed but gorged with dark blood, the

* Lancet, Vol. i. 1829-30, p. 164.

pericardium containing reddish serum, the arteries empty, and the veins filled with dark coloured blood. Dr. Schenck concludes his paper by saying, 'I was struck by the extreme tranquillity expressed in the features and the whole posture, from which even the attempts at vomiting, of which there were distinct signs, had not roused them; they appeared to be buried in the most placid sleep, and seemingly had not made the least attempt at saving themselves. This great tranquillity in the countenance might, perhaps, be useful in ascertaining whether death be produced by Asphyxia.' "

The smoke* of burning coal or wood is very

* The following interesting cases related in the Medical Gazette, are particularly worthy of the reader's attention; as also one related by Mr. Ewen, of Long Sutton, Lincolnshire, in the Medical Gazette, Vol. ix. p. 935.—" *Guy's Hospital. Cases of Asphyxia.* On Saturday the 16th instant, four individuals were received into the accident ward, and placed under the care of Mr. Morgan. They had, on Friday evening, shut themselves up in the forecastle of a vessel (which they had navigated to London), and, contrary to the regulations of the master, had made a fire. About six or seven o'clock the same evening some of the crew accidentally placed a covering over the flue, and thus stopped the escape of the smoke from the fire, which was made with a kind of coal containing much sulphur, and brought from Hull. Between six and seven in the morning of Saturday, one of the crew opening the hatches, observed three of the inmates lying on the floor senseless, and frothing at the mouth, the fourth in his crib in a similar condition. The air in the place was most offensive. After the unfortunate persons were brought on deck, one of them, æt. 21, showed symptoms of recovery, and when brought to the hospital seemed only giddy like a tipsy man. He shortly completely recovered. Another, æt. 40, after breathing

deleterious, and curious examples of its effects are on record, which may be consulted by the reader at his leisure. One of the most remarkable is that related by Mr. Braid.*

oxygen gas, and having brandy and ammonia exhibited, scarcely showed any symptom towards restoration, and died in a few hours. A third, æt. 17, soon began to rally (the same means being employed), and after a few hours was perfectly enabled to answer any questions: he declared that he felt no pain, sense of oppression or weight, in either head or chest. The fourth, æt. 15, died at 4 A. M. on Sunday, having exhibited no symptom of rallying; he breathed oxygen gas, and had ammonia and brandy administered by the stomach pump; blood was taken from the jugular vein, and he was cupped on the temples. Friction was freely used, warm blankets applied, and fomentations of hot vinegar. Galvanism was proposed, but not had recourse to. The appearance of the individuals was as follows: lips purple, countenance livid, surface of body cold, hands and nails purple; respiration very quick and short, pulse very small, quick, and feeble; pupils inobedient to light; total insensibility.—The man æt. 40, was inspected about four hours after his decease. The membranes of the brain had an appearance of congestion, and a large quantity of fluid was accumulated under the tunica arachnoides. The sinuses were gorged with blood. The lungs were in a state of great congestion; the same appearance in the cavities of the right side of the heart. It was remarked that this corpse, in appearance, was similar to that of an executed culprit. The lad, æt. 15, was inspected about thirty-three hours after death. Under the pia mater was observed one small ecchymosed spot; in the substance of the brain more bloody points than usual: a small quantity of fluid under the arachnoid tunic; sinuses full of coagulated blood. The lungs showed no congestion. The small veins on heart and pericardium gorged with blood. Heart in a similar state to the man's æt. 40.—As the coal contained much sulphur, and always burnt with a bluish tinge, it is probable that a large quantity of sulphurous acid gas was contained in the mephitic vapour."—Medical Gazette, Vol. i. p. 94.

* Edin. Medical and Surgical Journal. Vol. xiii. p. 353. See also Ibid, Vol. xxxii. p. 345, and Edin. New Phil. Journal, Vol. 5, p. 110.

The treatment of Asphyxia from the respiration of carbonic acid gas consists in the exposure of the whole surface to an atmosphere of moderate temperature; in having immediate recourse to insufflation of the lungs with the double-valved bellows to remove the noxious gases and to re-excite respiration: or this may be accomplished by stimulating the diaphragm to contract by piercing it with acupuncture needles, and passing the galvanic current through it. Oxygen gas should, if possible, be injected into the lungs, or, when partial recovery has taken place, respired, as in the interesting case related by Dr. Babington.*

During the use of these means, the chest and shoulders should be elevated, and cold affusion over the head and chest occasionally practised—the water being dashed smartly upon the face, neck, or chest. If the temperature be reduced, as is sometimes, though rarely, the case, the cold affusion should be employed with greater caution, and cases may occur in which, on account of the great loss of heat, it may be desirable entirely to abstain from this remedy. The application of ammonia and other stimulants to the nostrils and temples; and the friction of the chest with

* Medico-Chirurgical Transactions, Vol. i.

stimulating liniments should be assiduously employed. Bleeding may sometimes be requisite, and as the after treatment requires much professional sagacity, it is desirable that the records of cases of this nature should be collected as carefully as possible.

When Asphyxia has been induced by the inhalation of those gaseous combinations emitted from burning wood, charcoal, or coal, it has been strongly urged that the body should be exposed to cold, and in Russia* where, from the method of heating the habitations, these accidents not unfrequently occur, the common treatment adopted, (as it is said with the most auspicious results,) is friction of the whole surface with snow.

* Paris and Fonblanque. Medical Jurisprudence, Vol. ii. p. 88.

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