fess our ignorance than attempt to be wise upon the basis of conceit. All that we do know is, that bodies of every kind are reducible to a few elementary principles, which appear to be unchangeable, and are certainly invisible; and that from different combinations and modifications of these proceeds every concrete and visible form: hence, air itself, and water; hence mineral, vegetable, and animal substances. Air, therefore, and water, or either separately, may contain the rudimental materials of all the rest. We behold metallic stones, and of large magnitude, fall from the air, and we suppose them to be formed there: we behold plants suspended in the atmosphere, and still, year after year, thriving and blooming, and diffusing odours: we behold insects apparently sustained from the same source; and worms, fishes, and occasionally man himself, supported from the one or the other, or from both. These are facts, and as facts alone we must receive them, for we have at present no means of reasoning upon them. There are innumerable mysteries in matter as well as in mind; and we are not yet acquainted with the nature of those elementary principles from which every compound proceeds, and to which every thing is reducible. We are equally ignorant of their shapes, their weight, or their measure.

LECTURE XIII.

ON THE CIRCULATION OF THE BLOOD, RESPIRATION, AND ANIMALIZATION.

The progress of science is slow, and often imperceptible; and though in a few instances it has been quickened by an accidental discovery or an accidental idea, that has given a new turn, or a new elasticity to the chain of our reasoning, still have we been compelled in every instance to follow up the chain, link after link, and series after series, and have never leaped forward through an intermediate space without endangering our security, or being obliged to retrace our career by a painful and laborious reinvestigation.

It required a period of three thousand six hundred years to render the doctrine of a vacuum probable, and of five thousand six hundred to establish it upon a solid foundation. For its probability we are indebted to Epicurus, for its certainty to Sir Isaac Newton. The present theory of the solar system was commenced by Pythagoras and his disciples five centuries before Christ, and only completed by Copernicus fifteen centuries after Christ. Archimedes was the first who invented the celebrated problem for squaring the parabola, which was upwards of two hundred years before the Christian era; yet an exact problem for squaring the circle is a desideratum in the present day. The simple knowledge of the magnet was familiar to the Romans, Greeks, and some of the oriental nations while in their infancy; it has been employed by the mariner for nearly six centuries in Europe, and for a much longer period by the Chinese, in their own seas; yet at this moment we are acquainted with only a very few of its laws, and have never been able to appropriate it to any other purpose than that of the compass.

The circulation of the blood in the animal system is our subject of study for the present lecture, and it is a subject which has laboured under the same difficulties, and has required as long a period of time as almost any of the preceding sciences, for its complete illustration and establishment. Hippocrates guessed at it; Aristotle believed it; Servetus, who was burnt as a heretic in 1553, taught it; and Harvey, a century afterward, demonstrated it.

I shall not here enter into the various steps by which this wonderful discovery was at length effected; the difficulty can be only fairly appreciated by those who are acquainted with the infinitely minute tubes into which the distributive arteries branch out, and from which the collective veins arise; but every one is interested in the important fact itself, for it has done more

towards establishing the healing art upon a rational basis, and subjecting the different diseases of mankind to a successful mode of practice, than any other discovery that has emblazoned the annals of medicine.

In our last lecture we traced the action of the digestive organs: we beheld the food first comminuted by means of jaws, teeth, or peculiar muscles or membranes; next converted into a pulpy mass, and afterward into a milky liquid; and in this state drunk up by the mouths of innumerable minute vessels, that progressively unite into one common trunk, and convey it to the heart as the chief organ of the system, for the use and benefit of the whole.

But the new-formed fluid, even at the time it has reached the heart, has by no means undergone a sufficient elaboration to become genuine blood, or to support the living action of the different organs. It has yet to be operated upon by the air, and must for this purpose be sent to the lungs, and again returned to the heart, before it is fitted to be thrown into the general circulation.

This is the rule that takes place in all the more perfect animals, as mammals, birds, and most of the amphibials;* and hence these classes are said to have a double circulation. And as the heart itself consists of four cavities, a pair belonging to each of the two circulations, and each pair is divided from the other by a strong membrane, they are also said to have not only a double circulation, but a double heart—a pulmonary and a corporeal heart.

The blood is first received into the heart on the pulmonary side, and is conveyed to the lungs by an artery which is hence called the pulmonary artery, that soon divides into two branches, one for each of the lungs; in which organs they still farther divide into innumerable ramifications, and form a beautiful network of vessels upon the air vesicles of which the substance of the lungs consists; and by this means every particle of blood is exposed in its turn to the full influence of the vital gases of the atmosphere, and becomes thoroughly assimilated to the nature of the animal system it is to support. The invisibly minute arteries now terminate in equally minute veins, which progressively unite till they centre in four common trunks, which carry back the blood, now thoroughly ventilated and of a florid hue, to the left side or corporeal department of the heart.

From this quarter the corporeal circulation commences: the stimulus of the blood itself excites the heart to that alternate contraction which constitutes pulsation, and which is continued through the whole course of the arteries; and by this very contraction the blood is impelled to the remotest part of the body, the arterial vessels continuing to divide and to subdivide, and to branch out in every possible direction, till the eye can no longer follow them, even when aided by the best glasses.

The arterial blood having thus visited every portion of every organ, and supplied it with the food of life, is now returned, faint, exhausted, and of a purple hue, by the veins, as in the pulmonary circulation; it receives, a short space before it reaches the heart, its regular recruit of new matter from the digestive organs, and then empties itself into the right side or pulmonary department of the heart, whence it is again sent to the lungs, as before, for a new supply of vital power.

The circulation of the blood, therefore, depends upon two distinct sets of vessels, arteries and veins; the former of which carry it forward to every part of the system, and the latter of which return it to its central source. Both sets of vessels are generally considered as consisting of three distinct layers or tunics; an external, which in the arteries is peculiarly elastic; a middle, which is muscular in both, but whose existence is doubted by some physiologists; and an internal, which may be regarded as the common covering or cuticle. The projectile power exercised over the arteries is unquestionably the contraction to which the muscular tunic of the heart is excited by

* Cuvier seems to ascribe a double heart to the class of amphibia, without any limitation. See Lawrence's additional note E. chap. xii. of his translation of Blumenbach's System of Comparative Anatomy. Blumenbach himself has remarked, that many of the frogs, lizards, and serpents have a simple heart, consisting of a single auricle and ventricle, like that of fishes.—Sect. 162.

the stimulus of the blood itself; and which contraction would be permanent, but that the heart appears to become exhausted in a considerable degree of its muscular irritability by the exertion that produces the contraction, and hence speedily returns to its prior state of relaxation, exhibiting that alternating succession of systole and diastole which constitutes pulsation.*

In the venal system, however, we meet with even fewer proofs of muscular fibre than in the arterial, and no such force of the heart as to produce pulsation on a pressure of the finger; and hence, to this moment, we are in a greater degree of ignorance as to the projectile power by which this system is actuated. The theories that have been chiefly advanced upon the subject are, first, that of a vis à tergo, or an impetus given to the blood by the arterial contraction, which is supposed by its supporters to be sufficient to operate through the whole length of the venal canals; secondly, that of capillary attraction, the nature of which we explained in a former lecture; and lastly, a theory of a much more complicated kind than either, and which supposes the projectile power to result jointly from the impetus communicated by the heart and arteries, from the pressure of the surrounding organs, and especially from the elasticity of the lungs, and the play of the diaphragm, in conjunction with the natural irritability of the delicate membrane that lines the interior of the veins. It is unnecessary to enter into a consideration of any of these theories; for they all stand self-convicted of incompetency; and the last, which is the most operose of the whole, has been only invented to supply the acknowledged inefficacy of the other two.† Whatever this projectile power consists of, it appears to have some resemblance to that of the vegetable system; and, like many of the vessels in the latter, is assisted by the artifice of numerous valves inserted in different parts of the venal tubes.

The most important process which takes place in the circulation of the blood is that of its ventilation in the lungs. It is this process which constitutes the economy of RESPIRATION, and has till of late been involved in more than Cimmerian darkness.

We see the blood conveyed to the lungs of a deep purple hue, faint and exhausted by being drained in a considerable degree of its vital power, or immature and unassimilated to the nature of the system it is about to support, in consequence of its being received fresh from the lacteal trunk. We behold it returned from the lungs spirited with newness of life, perfect in its conformation, more readily disposed to coagulate, and the dead purple hue transformed into a bright scarlet. How has this wonderful change been accomplished? what has it parted with? what has it received? and by what means has so beneficial a barter been produced?

These are questions which have occupied the attention of physiologists in almost all ages; and though we have not yet attained to any thing like demonstration, or even universally acceded to any common theory, the experiments of modern times have established a variety of very important facts which may ultimately lead to such a theory, and clear away the difficulties by which we are still encumbered.

These facts I shall proceed to examine into in language as familiar as I can employ: I must nevertheless presume upon a general acquaintance with the elementary principles and nomenclature of modern chemistry, since a summary survey of zoonomy is not designed to enter into a detail of its

* Physiological experiments have sufficiently proved of late that the same alternation of contraction and dilatation does not take place in the arteries in a free or natural state; for where there is no resistance to the flow of the blood along their canals, there is no variation in their diameter; and that it is only the pressure of the finger or some other substance against the side of an artery that produces its pulse. Study of Med. ii. p. 16. Experimental Inquiry into the Nature, &c. of the Arterial Pulse, by C. H. Parry, M.D. 1816.

† It has lately been pretty clearly established, that by far the most active power in the return of the blood to the heart from the veins, is the comparative vacuum which takes place in the ventricles of the heart when exhausted of blood by the systole or alternating contraction of this organ; in consequence of which, the venous blood is, as it were, sucked up into the right ventricle from the venæ cavæ, or venous system at large. So that the heart, upon this beautiful principle of simplification, becomes alternately a forcing and a suction pump. By its contraction it forces the blood into the arterial system, and by its vacuum it sucks it up from the venous. See Study of Med. ii. p. 19, 2d edit. 1825.

mere alphabet or rudiments, but to apply and harmonize detached facts that relate to it, and to condense the materials that have been collected by others into a narrow but regular compass.

The chief substance which has been ascertained to be introduced from the atmosphere into the air-vesicles of the lungs during the act of respiration, and from these into the blood, is oxygen, of which the atmosphere, when pure, consists of about twenty-eight parts in a hundred, the remaining seventy-two being nitrogen.

That this gaseous fluid enters into the lungs is rendered highly probable from a multiplicity of experiments, which concur in proving that a larger portion of oxygen is received by every act of inspiration than is returned by every correspondent act of expiration; and that it passes from the air-vesicles of the lungs into the blood we have also reason to believe from the change of colour which immediately takes place in the latter, and from other experiments made out of the body, as well as in the body, which abundantly ascertain that oxygen has a power of producing this change, and of converting the deep purple of the blood into a bright scarlet.

It is also supposed very generally, that a considerable portion of caloric or the matter of heat, in its elementary form, is communicated to the blood at the same time and in conjunction with the oxygen; but as this substance has hitherto proved imponderable to every scheme that has been devised to ascertain its weight, this continues at present a point avowedly undetermined. That an increase of sensible heat at all times accompanies an increase of respiration is admitted by every one; but since caloric may be obtained by other means, if obtainable at all, and since a denial of its existence as a distinct substance has of late years been as strenuously urged as it was in former times by the Peripatetic school, and upon experiments inaccessible to those philosophers, we are at present in a state of darkness upon this subject, from which I am much afraid we are not likely to be extricated very soon.

I have already observed that nitrogen, or azote, as it is also called, is the other gaseous fluid that constitutes the respirable air of the atmosphere. And from a variety of well-conducted experiments by Mr., now Sir Humphry, Davy, it appears also that a certain quantity of this gas is imbibed by the lungs in the same manner they imbibe oxygen, and that, like oxygen, it is also communicated from the lungs to the blood while circulating through its substance; for in the experiments adverted to he found that, as in the case of the oxygen, a smaller quantity was always returned by every successive act of expiration than had been inhaled by every previous act of inspiration.*

The only gas that seems to have been thrown out from the lungs in the course of these experiments is carbonic acid; a very minute proportion of which appears also to be almost always contained in the atmospheric air, though altogether a foreign material, probably eliminated from the decomposition of animal and vegetable bodies, that is perpetually taking place, and certainly unnecessary to healthful respiration.

The general result of these experiments was as follows: the natural inspirations were about twenty-six or twenty-seven in a minute; thirteen cubic inches of air were in every instance taken in, and about twelve and three-quarters thrown out by the expiration that succeeded.

The atmospheric or inspired air contained in the thirteen cubic inches,—nine and a half of nitrogen, three and four-tenths of oxygen, and one-tenth of an inch of carbonic acid. The twelve inches and three-quarters of returned air contained nine and three-tenths of nitrogen, two and two-tenths of oxygen, and one and two-tenths of carbonic acid.

This inhalation, however, varies in persons of different-sized chests from 26 to 32 cubic inches, at a temperature of 55°; but these by the heat of the lungs, and saturated with moisture, become forty or forty-one cubic inches.

Taking, therefore, 40 cubic inches as the quantity of air equally inhaled and exhaled about 20 times in a minute, it will follow that a full-grown per-

* Priestley had before shown that nitrogen is absorbed. See Phil. Trans. 1790, p. 106.

son respires 48,000 cubic inches in an hour, or 1,152,000 cubic inches in the course of a day; a quantity equal to about 79 hogsheads.

A similar train of experiments has more lately been pursued by Messrs. Allen and Pepys, and will be found fully detailed in the Transactions of the Royal Society for 1808. They confirm the preceding proportions, excepting in the retention of nitrogen; this substance having been found by Messrs. Allen and Pepys to have been returned in every respiration, in the precise proportion in which it was received. It is highly probable, however, that the diet of these two sets of ingenious experimenters had not previously consisted of the same proportion of animal and vegetable materials; and that the blood in the former instance was less charged with nitrogen than in the latter; which would at once account for the difference.

Upon Sir Humphry Davy's experiments, however, the quantity of nitrogen received by the lungs is very inconsiderable, not amounting to more than two-tenths of a cubic inch in an inspiration. And omitting the consideration of this gas, as also that of caloric, on account of the unsettled state of the question, respiration, from this view of the subject, consists merely in the act of receiving oxygen, and throwing out carbonic acid gas; the lungs imbibing and communicating to the system not less than 32.4 cubic inches of the former, and parting with not less than 26.5 of the latter, every minute. So that, taking the gravity of carbonic acid gas, as calculated by Lavoisier, eleven ounces of solid carbon or charcoal are emitted from the lungs every twenty-four hours.*

The whole of the theory and some of the supposed facts here advanced, however, have of late been very considerably disputed by Mr. Ellis, in his Inquiry into the Changes induced on Atmospheric Air by the Germination of Seeds. He concurs with Messrs. Allen and Pepys, in ascertaining that precisely the same quantity of nitrogen is expired as is inspired; but he objects to their conclusion, that the whole of any constituent element of respired air introduced into the air-vesicles, and not returned by the alternate expiration, is *necessarily* conveyed into the blood-vessels, believing that much of this may remain unascertained, in consequence of an increased, but not sensibly increased, expansion of the chest. He admits that carbonic vapour is thrown forth in the quantity usually alleged, with every act of expiration; but he offers evidence to prove that it is the carbon only that is discharged from the animal system, in connexion with the exhaling vapour; contending that the carbon thus existing is separated from the vapour by its union *with the whole of the oxygen* introduced by the previous act of inspiration, by which alone it is converted into carbonic acid gas: for he found the same decomposition of atmospheric air produced by introducing a small bladder, moistened, and filled with any substance, or perfectly empty, and introduced into an inverted glass containing a certain proportion of atmospheric air, standing upon quicksilver. He denies, therefore, that the air-vessels are in any degree porous to gases of any kind, excepting caloric; and, consequently, denies that the blood is converted from a deep modena hue into a bright scarlet by its union with oxygen; believing, or seeming to believe, that this result is entirely produced by the action of the caloric separated in the air-vesicles upon the union of the carbon of the vapour exhaled from their surfaces, with the oxygen introduced by inspiration. So that, according to this theory, respiration is nothing more than an introduction of caloric into the system, and the conversion of a portion of oxygen (the whole received by the act of inspiration) into an equal bulk of carbonic acid by the carbon exhaled from the living organized body. Air, therefore, examined after respiration, is found to differ from the same air before it is breathed, in having lost a portion of oxygen, gained an equal volume of carbonic acid, and in being loaded with pure watery vapour, the vapour thrown off from the lungs; and he has offered an additional proof that the oxygen of the carbonic acid is that introduced in the act of inspiration, by showing, as in the case of breath-

* Phil. Trans. 1808, part ii. 249.

ing hydrogen gas, that no carbonic acid is returned, and apparently none produced.

In opposition to the hypothesis of Dr. Priestley, he seems to show, and plausibly to establish, that all terrestrial plants, whether growing in absolute darkness, in the shade, or exposed to the direct rays of the sun, are constantly removing a quantity of oxygen from the atmosphere, and substituting an exactly equal volume of carbonic acid; that they produce this change by emitting from their leaves, flowers, fruits, stems, and roots, and by a process like animal exhalation, carbonaceous matter, which combines with the oxygen of the surrounding air; and that such a function is essentially necessary to their vital existence. In doing this, however, the carbonaceous matter is given forth more freely from the green parts than from any other, especially when exposed to the direct rays of the sun, by means of its affinity for the calorific rays; in consequence of which the oxygen of the carbon is set at liberty, and escapes from the cellular texture of the green parts through the external pores; an action, however, which is not necessary to life, for a plant does not die when this has ceased, while it is equally found to occur in a dead as in a living plant. It was probably this occasional escape of oxygen that induced Priestley to regard it as an invariable and constant process, affording a compensation for the animal carbon thrown into the air, and thus taking from and giving to the animal world what seemed to be mutually demanded.

Mr. Ellis also affirms that all the various colours of vegetables depend on the varied proportion of alkaline and acid matter mixed with the juices of the coloured parts of plants: that green and yellow, for example, are always produced by an excess of alkali in the colourable juices of the leaf or flower; and all the shades of red, by a predominance of acid; while a neutral mixture produces a white. And hence there is most green in the summer season, when the oxygen is parted with most freely, as drawn away by the rays of light; while in autumn, when there is less separation, the other colours of yellow and red are most frequent.

Mr. Ellis has also quoted a variety of experiments on different kinds of fishes, muscles, marine testacea, snails, leeches, zoophytes, and tadpoles, in which it was found that the water wherein these animals had been placed had lost a part of its oxygen, and received an addition of carbonic acid, while its nitrogen had remained unaffected.*

This hypothesis, however, requires confirmation, and is at present open to many objections. If caloric can permeate animal membranes, as Mr. Ellis admits it to do, and unite by chemical affinity with the blood in the blood-vessels, so also may oxygen in certain cases of combination. Mr. Porrett has shown that the Voltaic fluid, when operating upon water, is capable of carrying even water itself through a piece of bladder, and of raising it into a heap against the force of gravitation; and hence other affinities may not only introduce the oxygen of the respired air, or a part of it, into the blood of the blood-vessels in the lungs, through the tissue of the air-cells, but at the same time carry off the superabundant carbon in the form of carbonic acid, instead of its being thrown out in that of carbonic vapour. Nor have we any proof that carbon will dissolve in water, and produce such vapour; and hence such an idea is gratuitous.†

Of the general operation, however, there is no doubt, whatever be the manner in which it is performed: and by such operation the new blood becomes assimilated to the nature of the system it has to nourish; and the old or exhausted blood both relieved from a material that may be said to suffocate it, and reinspirited for fresh action. In this state of perfection, produced from the matter of food introduced into the stomach, and elaborated by the gases of the atmosphere, received chiefly by the act of respiration, but perhaps partly also by the absorbing pores of the skin, the blood on its analysis is found to consist of the following nine parts, independently of its aerial

* Inquiry into the Changes induced on Atmospheric Air by the Germination of Seeds, &c. 8vo. 1807. As also, Farther Inquiries into the Changes, &c. 8vo. 1811.

Study of Med. edit. ii. vol. i. p. 474. Thomson's Annals of Philos. No. xliii. p. 75 76.

materials:—first, a peculiar aroma, or odour, of which every one must be sensible who has been present at a slaughter-house on cutting up the fresh bodies of oxen; secondly, fibrine, or fibrous matter; thirdly, uncoagulable matter, but no gelatin, which is a subsequent secretion; fourthly, albumen; fifthly, red-colouring matter; sixthly, iron; seventhly, sulphur; eighthly, soda; and, lastly, water. The proportion of these parts vary almost infinitely, according to the age, temperament, and manner of living; each of these having a character that essentially belongs to it, with particular shades that are often difficult to be laid hold of.

Of these component parts, the most extraordinary are the red-colouring matter, the iron, and the sulphur; nor are we by any means acquainted with the mode by which they obtain an existence in the blood. I have already had occasion to observe, that albumen and fibrine are substances formed by the action of the living principle out of the common materials of the food, and that it is probable the lime found in the bones and other parts is produced in the same manner. Whether the iron and sulphur that are traced in the blood have a similar origin, or exist in the different articles of our diet, and are merely separated from the other materials with which they are combined, is a physical problem that yet remains to be solved. It should be observed, however, that the sulphur does not exist in a free state even in the blood itself, but is only a component part of its albumen. Considering the universality of these substances in the blood, and the uniformity of their proportion in similar ages, temperaments, and habits, whatever be the soil on which we reside; that those who live in a country in which these minerals are scarcely to be traced have not less, while those who live in a country that overflows with them have not more; it is perhaps most rational to conclude, that they are generated in the laboratory of the animal system itself, by the all-controlling influence of the living principle.

The exact proportion of sulphur contained in the system has been less accurately ascertained than that of the iron, which last in an adult, the weight of whose blood may be estimated at 28lbs.,* ought usually to amount to seventy scruples, or about three ounces: and hence the blood of about forty men contains iron enough to make a good ploughshare, and might easily have its iron extracted from it, be reduced to a metallic state, and manufactured into such an instrument.

Iron is seldom found except in the red particles of the blood;† and it has hence been supposed by the French chemists to be the colouring material itself. The process of respiration, according to the theory of Lavoisier and Fourcroy, is a direct process of combustion, in which the animal system finds the carbon, and the atmosphere the oxygen and caloric; and in consequence of the sensible heat which is set at liberty during the combustion, the iron of the blood is converted into a red oxide, and hence necessarily becomes a pigment.

But it is impossible to ascribe the red colour to this principle: for, first, we are by no means certain that the air communicates any such substance as caloric to the blood; and, secondly, let the sensible heat of the blood arise from whatever quarter it may, it can never be sufficiently augmented by the most violent degree, either of local or general inflammation, to convert the iron of the blood into a red oxide, which, indeed, is never produced without rapid combustion, flame, and intense heat. And hence, Sir Humphry Davy conjectures the carbon itself of the blood to be the real colouring material, and to be separated from the oxygen, with which it is necessarily united to constitute

* Blumenbach states the proportion in an adult and healthy man to be as 1 to 5 of the entire weight of the body. By experiments on the water-newt (lacerta *palustris*), he found the proportion in this animal to be only as 2½ to 36.

† Mr. Brande denies that iron exists more in the red particles of the blood than in the other principles: according to his experiments, it exists but in a very inconsiderable quantity in any of them; but he has traced it in the chyle, in the serum, and in the fibrine, or washed crassament. Phil. Trans. 1812, p. 112. Vauquelin has traced it as a constituent in egg-shells and oyster-shells. Thomson's Annals of Philos. No. 1, p. 66. But Berzelius has proved Brande to be mistaken, and that iron exists largely in the blood, and is the cause of the red colour. See his Anim. Chemistry.

carbonic acid gas, by the matter of light, which he supposes to be introduced into the system in the act of respiration, instead of the matter of caloric; in consequence of which it immediately becomes a pigment. But the difficulties which attend this theory are almost, if not altogether, as numerous as those which attend the theory of combustion, and it is unnecessary to pursue the subject any farther.

In the Philosophical Transactions, and in several of the best established foreign Memoirs, we meet with a few very curious instances of spontaneous inflammation, or active combustion, having occurred in the human body. The accident has usually been detected by the penetrating smell of burning and sooty films, which have diffused themselves to a considerable distance; and the sufferers have in every instance been discovered dead, with the body more or less completely burnt up, and containing in the burnt parts nothing more than an oily, sooty, extremely fetid, and crumbly matter. In one or two instances there has appeared, when the light was totally excluded, a faint lambent flame bickering over the limbs; but the general combustion was so feeble, that the chairs and other furniture of the room within the reach of the burning body have in no instance been found more than scorched, and in most instances altogether uninjured.

It is by no means easy to explain these extraordinary facts; but they have been too frequent, and are too well authenticated in different countries, to justify our disbelief. In every instance but one the subjects have been females, somewhat advanced in life, and apparently much addicted to spirituous liquors. I shall hence only observe, in few words, that the animal body in itself consists of a variety of combustible materials; and that the process of respiration (though not completely established to be such) has a very near alliance to that of combustion itself: that the usual heat of the blood, taking that of man as our standard, is 98° of Fahrenheit, and under an inflammatory temperament may be 103° or 104°; and hence, though by no means sufficiently exalted for open or manifest combustion, may be more than sufficiently so for a slow or smothered combustion; since the combustion of a dung-hill seldom exceeds 81°, and is not often found higher in fermenting haystacks, when they first burst forth into flame. The use of ardent spirits may possibly, in the cases before us, have predisposed the system to so extraordinary an accident; though we all know that this is not a common result of such a habit, mischievous as it is in other respects. The lambent flame emitted from the body is probably phosphorescent, and hence little likely to set fire to the surrounding furniture. It is not certain whether this flame originates spontaneously, or is only spontaneously continued, after having been produced by a lighted substance coming too nearly in contact with a body thus surcharged with inflammable materials.

Such, then, are the circulatory and respiratory systems in the most perfect animals; as mammals, birds, and amphibials. It should be observed, however, that in birds the hollow bones themselves, and a variety of air-cells that are connected with them, constitute, as we have already had occasion to notice,* a part of the general respiratory organ, and endow them with that levity of form which so peculiarly characterizes them, and which is so skilfully adapted to their intention. It should be remarked, also, that in most amphibious animals, and especially in the turtle, whose interior structure is the most perfect of the entire class, the two ventricles, or larger cavities of the heart, communicate something after the manner in which they do in the human fœtus. The lungs of this class are for the most part unusually large; and they have a power of extracting oxygen from water as well as from air; whence their capability of existing in both elements. The oxygen, however, obtained from the water is not by a decomposition of the water into its elementary parts, but only by a separation of such air as is loosely combined with it; for if water be deprived of air or oxygen, the animal soon expires. We have already observed that some amphibials appear to possess only a single heart, and even that of a very simple structure.

* Series I. Lecture xi. p. 118.