Respiration

by

George Scott

In order that the nutritive fluids of animals may be properly elaborated and prepared for the nutrition of the various tissues in which they circulate, it is necessary that they first undergo certain changes with the atmospheric air. + This equally applies to aquatic as to terrestrial animals, for, atmospheric air being dissolved in the water in sufficient quantity to allow the blood of the former to be properly aerated, it is merely the mechanism of the respiratory organs which is changed, and not the interchange of the materials which is the essential part of the process.

In considering the subject of Respiration, it is first necessary to ~~state~~ the conditions which are necessary in order that it may be carried on in the simplest way, and thus endeavour to prove what is the essential part of the process divested of all that complex machinery which serve as accessory parts in the higher animals. And to do this, it will be proper to take a comparative view of the mechanism of the respiratory organs in general, beginning at the lowest class of animal life and gradually ascending in the scale, until we arrive at last at the highest orders of Mammals who possess completely developed lungs.

At first sight, it would be difficult to discover any analogy between the changes which we know to take place in the fluids of the Infusoria through the medium of their slender integument, and that complex process carried on in the higher animals, which we denominate the function of Respiration. We are tempted to say that the Infusoria cannot be truly said to respire, as we are unable, by the strictest scrutiny, to discover any organs in them at all analogous to the lungs or gills of higher animals. But, by tracing the arrangement of the breathing organs from the simplest to the most complex types, we shall see that the respiratory surface in all of them is nothing but modified integument, and that the different forms which the breathing organs assume are merely mechanical adaptations to pack in, as it were, as much respiratory surface as is required for the proper aeration of the fluids of the various animals. Thus, we shall see that the respiratory function of the higher animals although more active and vigorous, is yet, in all essential points, the same as ~~that~~ which is carried on through the slender integument of the infusorial animalcules.

In the Polygastria, the lowest

division of the infusorial class, the cilia which exist, in greater or less number, according to the species, on the surface of their bodies, are in continual move-ment, and roll the little animal quickly through the water and thus continually renew the surrounding oxygenated medium upon the surface of their integu-ment. In the higher division of this class, we already see a considerable modification and further develop-ment of the mechanism of the breathing organ. The external surface of the bodies of the Rotifera is smooth and not provided with cilia, but the wheel-like organs which surmount the anterior part of the animal serve to change the oxygenated fluid which bathes their surface. As far as this, the mechanism of the Respiration in the Rotifera is quite analogous to that in the Polygastria. But there is an additional means subservient to the respiratory func-tion. We observe upon the neck an opening which admits the water into the interior of the body, thus exposing the vascular surfaces of the viscera to the influence of the surrounding oxygenated medium. In many species, this opening in the neck is prolonged upon one or two tubes built with vibratile cilia, which serve to produce a continual current to and from the abdominal cavity. We here observe the first indication of the respiratory organs beginning to assume that complexity which we shall see them doing in the higher animals, by the folding in, as it were, of the external integument to increase the amount of respiratory surface.

In those Polyps, such as the Actinia, which have their digestive tube suspended in the interior of the body by mesenteric folds, the surface of the abdominal cavity is beset with cilia, which keep up a constant current of the water admitted into that cavity by the perforations at the extremity of the tentacula. In the highest family of Polyps, the Bryozoa of Owen, the water cannot find entrance into the abdominal cavity, and therefore Respiration cannot be carried on in the same way as in the Actinia. The Tentacula, however, are beset with vibratile cilia, which serve to keep up a constant renewal of the oxygenised medium upon their surface, thus exposing the nutrient fluids in their interior to the influence of the surrounding water.

In the Acalepha, the mechanism of Respiration presents the same simplicity as in the polygastric animalcules, for the only organ to which we can ascribe the purpose of carrying on the respiratory process is the slender integument on the under surface of the margin of the disc, where the nutritive vessels are ramified in a very minute state of subdivision.

The three families which compose the class of the Echino-dermata, viz: the Stelleridæ, the Echinidæ, and the Holothuridæ present great differences in the mechanism of their respiratory organs. Thus, the first class, the Stelleridæ, admit the water into the interior of the body, this bathes the vascular surfaces of the viscera (which are every-where provided with vibratile cilia, and by means of them the necessary currents in the oxygenated fluid are kept up. In the next family of this class, the Echinidæ, besides the respiration which goes on in the peritoneal cavity of the body into which the water is freely admitted through the interspaces of the teeth, there are additional organs both external and internal, which subserve this process. The former consist of branched processes attached to the oral extremities of the interambulacral areæ, these float in the sea-water on the outside of the body, and thus expose the fluids in their interior to the full action of the oxygenated medium. The internal organs of respiration are the vesicles at the bases of the tub-

-ular feet. These are covered with a very abundant vas-
-cular network of vessels, and the water is admitted into their interior by a terminal pore at the free extremity of the sucker, the proper renewal of the fluid being provided for by the contractions of the vesicles which, at the same time as they extend the suctorial feet, force out the water at the terminal pore. The exter-
-nal breathing organs above mentioned are the first special organs of the kind which we have yet met with: the internal cannot be so called as they sub-
-serve the function of locomotion as well as that of the respiration. In the third and highest family of the Echinodermata, the respiratory organ shews a much higher degree of development and importance than we have hitherto seen it assume. In these animals, it consists of two arborescent tubes opening by a common duct into the cloaca at the anal end of the animal. Here we have the first appearance of a special vessel to convey the nutrient fluid to the respiratory organ. The fluid is conveyed from the intestinal vein running along the attached edge of the intestine, to the respiratory trees by a vascular plexus, which ramifies in a very minute state of subdivision over these organs.

The different subdivisions of

the class Annellata, in the Articulate group of the Animal Kingdom, present various forms of respiratory apparatus. Thus, in the most simply organized of these, such as the leech and earth-worm, the respiratory function is carried on by small sacculi arranged in a linear series along the sides of the body and communicating by small openings with the exterior. These are not special respiratory organs, as they are also the reservoirs of a kind of mucus secreted by peculiar or looped glands which pour their secretion through the medium of these sacculi on the external surface of the body. These sacculi alone would not be sufficient to carry on the process of respiration in these animals, and hence the skin serves to aid this process in a marked degree, as it doubtless does in all animals, more or less. In the higher families of this group, the respiratory organs are more complex in structure. In the Annellata tubicola, the process is carried on by cephalic branchiæ or tufts in the form of long and sometimes tortuous filaments, radiating from the head generally in two fasciculi. In the last family, Annellata errantia, respiration is carried on by lateral branchiæ, extended from the sides of a certain number of the segments of the body.

cirrhopoda

The class Cirripedia is divided into two primary groups. In the first, the pedunculated or Lepadoid group, of which the common barnacle is a type, respiration is carried on by means of slender, conical branchiæ attached to the base of the maxillary foot and to that of some of the cirrigerous feet. In the balanoid or sessile group again, the branchiæ assume the form of two or more broad, transversely plicated, vascular membranes attached to the inner side of the mantle.

The Crustacea are all suited for aquatic respiration, and hence their breathing organs assume the form of branchiæ. These are, in the lowest tribes of this class, appendages of the locomotive members, but in the higher forms, such as the lobster and crab tribes, the gills are contained in a sort of branchial chamber closed in above by the carapace and laterally by the apodemata. The water is admitted into this cavity by an opening in the posterior part of it, and after bathing the surface of the branchiæ, escapes by an opening in the front. Land-crabs are, by no means, an exception to the general rule, that all Crustacea are suited for aquatic respiration, as it is by a peculiar modification of this respiratory cavity that it is enabled to retain water in its interior, and thus always keep the branchiae bathed with this fluid. The fluid in the branchial chamber is renewed at the will of the animal, the aperture being situated in front of the base of one pair of claws, and so arranged as to be opened and shut by the move-ment of these members.

And now we come to consider a most remarkable modification of the breathing apparatus. Hitherto, in all the classes of animals whose respiratory organs we have examined, we have always seen the nutrient fluid min-utely distributed, in a fine capillary net work, over the respiratory surface, and in this way exposed to the influence of the oxygenated medium. Now, however, in the Insecta, the method is reversed, and instead of the nutrient fluid being distributed over a reservoir of air or water, we have the air distributed in a minute capillary net-work over the reservoirs of blood. This is doubtless a beautiful provision of Nature for lessening the specific gravity of the insect, and thus furnishing it with the necessary degree of lightness for flight; and this mode of locomotion is further assisted by the presence of a greater or less number of air-

-sacs within the body. The respiratory organs in this class consist in the folding in of the external integument in the form of tracheæ or tubes kept patent by an elastic cartilaginous filament dis-posed in a continuous spiral coil, and situated between the external cellular and internal epithelial lining of the tubes. These tracheæ commence by openings arranged along the sides of the body and called Stigmata. After entering the body the tubes divide and subdivide once or twice, and then end in a large longitudinal tube running along parallel with the margin of the body on each side. These two longitudinal tubes are connected together by transverse branches, and form an exceedingly minute net-work of air-vessels, which thus convey the oxygenated medium to the blood in all parts of the body. Some of the tubes dilate into large air-receptacles or reservoirs of which we spoke before, and which, like the air-cells of birds, are no doubt subservient to the function of flight, being in direct relation with the powers of the animal in that respect. The wings of Insects no doubt subserve, more or less, the respiratory function, at all events, in the early state, when they are abun-dantly traversed by a capillary net-work of vessels.

According to Owen, these wings are the homologues of the tergal branchiæ of the vermiform Articulata, raised to a higher function, in correlation with a generally transmuted state of the rest of the organization, which is advanced to the utmost perfection of which the Articulate type of structure is susceptible. V?

In the lower families of the Arachnida, such as the mites, respiration is carried on by means of tracheæ such as we have seen in insects, only that their orifices are on the under surface of the body and not at the sides. In some of the higher tribes, however, such as some spiders, the breathing apparatus assumes a higher degree of development, as, in addition to the tracheæ, we observe orifices in the abdomen opening into what are called pulmonary sacs, into which the air enters. The surface of these vesicles is increased by a number of broad, and close-set lamellæ, which project into its interior. In the most highly-developed Arachnida, such as the scorpion, the tracheæ have entirely disappeared, and we have respiration carried on merely by these pulmonary vesicles which, like the others above mentioned, open also on the abdomen, and their surface is in like manner increased by a number of broad and close-set lamellæ projecting into their interior.

In the lower families of Mollusca, the organs of respiration present a very rudimentary type. In the Tunicata, it consists of a branchial sac opening externally by one of the foramina in the outer tunic, internally into the œsophagus. Thus we see that the oxygenated medium and the food enter by the same orifice, and the dilatation and contraction of this sac which serve to draw in and expel the water for respiration, also serve to draw in particles of food for the animal. The internal surface of this pharyngeal sac is beset with vibratile cilia. The renewal of the water in the sac is effected in this wise: the tunic of the animal being composed of two coats, an external elastic and an internal muscular, closely adherent to one another, after the contraction of the latter to expel the water from the sac, the external one, in virtue of its elastic property, returns to its original shape, and draws with it the muscular coat, opening, of course, the pharyngeal cavity to its full extent, when the water again flows in. This pharyngeal cavity serving as a respiratory organ, is the first example we have yet met with of the oxygenated medium entering by the same orifice as the food.

The only organs of respiration observed in the Brachiopoda are the vascular surfaces of the mantle which, being beset with cilia, are constantly exposed to a renewal of the oxygenized currents.+

The Lamellibranchiata breathe essentially in the same manner as the Brachiopoda, i.e. by means of the mantle, only this is complicated by certain internal folds of membrane so as to form branchiæ, and thus expose a greater amount of nutrient fluid to the action of the water. The respiratory currents are occasioned also by the action of the vibratile cilia studding the surface of the mantle and gills.

In the Pteropoda, the branchial vascular network is situated upon the inner surface of the mantle, which is ciliated in the same manner as in the former class.

In the class Gasteropoda are comprized both aquatic and terrestrial species, and their respiratory organs are, of course, modified accordingly. In the lower organized aquatic species, the breathing apparatus consists of external gills projecting from the sides or back of the body. In the terrestrial species, the respiratory organ is in the form of a simple undivided sac on the dorsum of the animal, and opening generally by an orifice on the side of the body. There are some amphibious Gasteropoda which possess both branchiae and pulmonary sacs.

The class Cephalopoda are all fitted for aquatic respiration and the gills are contained in a branchial chamber formed by an extension of the mantle in front of the viscera. The respiratory surface is not provided with vibratile cilia as in other Mollusca. How then, is a constant renewal of fluid kept up upon this surface? The water enters the respiratory cavity by an opening in the mantle outside the base of the funnel. this opening is guarded by two valvular folds of fibrous membrane to prevent the fluid from escaping again at this orifice. it is, therefore, propelled by the whole force of the contraction of the muscular mantle through the cavity of the funnel, the base of which is articulated, in most of the Cephalopods, by lateral joints, with the sides of the anterior aperture of the mantle.

We now come to consider the arrangement of the respiratory organs in the Vertebrata where they attain their highest degree of development.

We meet with two kinds of respiratory apparatus in the Vertebrata, viz: branchiæ or gills, and lungs. These are developed according as the animal is formed for aquatic or terrestrial life, or both, as in the Amphibia, where both gills and lungs are present in the same individual.

In the Cartilaginous or lowest kind of fishes, the breathing organ is formed by the inversion or folding in of the external integument through a greater or less number of fissures situated immediately behind the head. The inverted integument is extended on dense, cellular plates affixed to the branchial arches, and elevated into folds arranged perpendicularly to these arches, communicating anteriorly with the mucous membrane of the mouth. In the more highly organized, osseous fishes, the branchial arches are unattached to the external integument along their edges. On their convex margin are attached the branchial leaflets, and on their concavity they are beset with teeth. From the branchial arches which support the gills being more or less free and unattached at their margin, it is clear that they would be quite exposed on the outside of the animal, were there not some special contrivance to cover them in. In the earlier stages of development indeed, the gills are free and expand on the surface of the body, but at later periods of existence, they are closed in and protected by what are called opercula or gill-covers, which consist of a more or less complicated arrangement of bones supporting the opercular membrane. The water passes in by the mouth of the fish, and is driven by the movements of the branchial arches and hyoid bone over the surface of the gills, and after bathing these, escapes by the external opening of the branchial cavity, kept either patent or closed by the action of the gill-cover. In some fishes, we see the process of respiration aided by the development of pulmonary as well as branchial organs. They are hence called amphibioid. The former are generally in the form of sacs situated behind the kidneys, and presenting internally the same cellular structure as in the lungs of serpents. They open by two, long, membranous tubes on each side of the esophagus. In some of the true osseous fishes, we observe several vascular hollow sacs contained either entirely in the branchial cavity or extending thence underneath the lateral muscles. These, doubtless serve the purpose of pulmonary organs. Some fishes can live for a considerable time on dry land. This they are enabled to do by possessing over and above the gills, the respira-

-tory organs proper, certain accessory cells supported on the upper pharyngeal maxillae, wherein water can be retained for a considerable time, thus serving as reservoirs for this fluid.

Reptiles are either amphibious or terrestrial. In the former case, they possess both branchiae and lungs, in the latter lungs alone. The latter form of breathing apparatus, consists, in the lower orders of reptiles, merely of simple, elongated, hollow bags, sometimes symmetrical on both sides of the body, at other times unsymmet-rical, atrophied more or less, even altogether wanting on one side, as in the Vipers. In the higher orders, the lungs become more complicated by the folding in or inversion of the delicate membrane internally, so as to increase the amount of respiratory surface.

In Birds, we have a very remarkable modification of the respiratory organs, which, as in Insects, are more or less subservient to the function of flight. The lungs of birds differ essentially from those of reptiles in being symmet-rical, equally developed on both sides of the body. They are situated in what corresponds in Mamma-lia to the thoracic cavity, and are attached posteriorly to the vertebrae and ribs. The lungs are made up of a series of membranous tubes running in all directions but all opening superiorly into the wide vesicular cavity formed by the dilated end of the bronchus. All the tubes also communicate more or less with each other, so that the whole lung can be injected fully from any one point. Posteriorly, and on the inner side, the lungs, or the tubes forming them, open by several orifices into the remarkable air-cells of the bird, formed by reflected prolongations of the pleura and peritoneum. These air-cells are to be observed over all the abdominal cavity, being the unfilled up spaces, as it were, of the viscera. In some birds, these cells are much more numerous and form large air-sacs beneath the skin of the head, neck, breast, and belly. These communicate with the lateral cells of the trunk. These air-cells also communicate with some of the bones, which are hollow, unprovided with marrow, and filled with air, thus serving to lessen most materially the specific gravity of the body. The bones most commonly filled with air are, the humerus, cranium, sternum, and femur. Nearly all the bones in the body may, however, present this hollow structure for the reception of air, as e.g. in the genus Buceros, where, in addition to the cranial and maxillary bones, the cervical vertebrae, the pelvis, the caudal vertebrae, and all the bones of the extremities, even to the phalanges and toes, are permeated with air. The Apteryx of New Zealand is the only bird yet known, which has neither air-cells nor any of the bones permeated with air.

The movements of respiration in birds go on in the following manner. A portion of the air-cells is contained along with the lungs in the thoracic cavity, and all these cells communicate with the bronchus by a wide tube. When the thoracic cavity expands by the action of its appropriate muscles, the lungs and that portion of the air-sac contained in the thorax being firmly attached to the sides of the cavity, expand likewise, when, of course, air rushes into the lungs and air-cells. Now, these air-cells receive air from two sources, first, directly from the bronchus by the tube which we mentioned above, connected each of the tubes with it, and secondly, from that portion of the air-cell itself which is out of the thorax, and which is seen to collapse during inspiration. In expiration, the air is expelled from these air-cells in two ways, 1st, into the bronchus, and 2ndly into that portion of the cell external to the thoracic cavity, which was seen during inspiration to collapse. In this manner, a constant renewal of fresh air is kept up both in the lungs and air-sacs.

The lungs in Mammalia differ essentially from any we have yet mentioned, in being lobed and having terminal air-cells. The bronchi strengthened by imperfect, cartilaginous rings divide and subdivide, losing gradually their rings of cartilage, the tubes being formed ultimately of muscle alone, and ending finally in a bunch of air-cells composed of mucous membrane alone, filaments of elastic fibrous tissue surrounding and keeping them together.

Thus we see that we can trace, by almost imperceptible gradations, the simplest form of breathing apparatus, as seen in the tender integument of the lowest Infusory, to the most complex, exemplified in the lung of the most highly developed Mammal. We have endeavoured by tracing, although in an imperfect manner, ~~to prove~~ this gradation, to prove ~~that~~ the process of aeration carried on through the tender integument of a polygastric animalcule, is, in all essential points, the same as that carried on by the lungs of the highest animals, and that in all breathing organs, however complicated, the respiratory surface is merely modified integument, and that hence all the multitudi-

-ous forms of breathing apparatus observed throughout the whole animal Kingdom, are nothing but modi-fications of the cutaneous respiratory surface of the Infusorial animalcules. If we admit this proof, we see that the sole condition is absolutely necessary for the due interchange of materials between the nutrient fluids of animals and the atmospheric air are: that these two media should be separated by an animal membrane permeable by gases. It is not even necessary that the intervening membrane should constitute a part of a living organism; for, numerous experiments have proved, that venous blood can be almost as perfectly arterialized when contained in a bladder or any other animal membrane, and exposed for some time to the influence of the atmos-sphere, as it can in the minute capillaries of the lungs. Of course the process will be slower, and the arterialization will not extend to the centre of the venous blood, that being too far removed from the influence of the surrounding atmosphere to enable it to undergo the usual change. We hence see the reason for the blood in the lungs being distributed in such minute streamlets- that no portion of it may be so far removed from the influence of the atmosphere, as to prevent it undergoing the necessary arterialization. We thus perceive that the respiratory process is not what is called vital, — that is to say, one that can only be carried on in the living animal — but strictly depends upon the working of chymico-physical laws, which can always be brought into action — and which, moreover, will always continue to operate, so long as the necessary conditions for their fulfilment are present. —

We are thus led to consider the nature of those laws, which, by so simple a mechanism, are enabled to produce such wonderful results. — For the life of every animal depends on their proper working — prevent the blood from undergoing its proper aeration — cut off the living organism from this vivifying medium, for only a few short moments — take away the necessary conditions of Respiration alike from the simply constructed Infusorial animalcule, as from Man himself — and you put a stop to the simple mechanism of the one, and the complex machinery of the other — And here arises a consideration which it may perhaps be proper to mention — viz: that the more simple the structure of an animal, the more tenacious it is of life — and the more easily does it sustain without permanent injury to itself a temporary cessation of that respir-

-atory process, which we find so essential to the life of every being e.g. We all know, that if we cut off the supply of air from a human being by immersion in water, constriction of the ~~Larynx~~ trachea - or any other cause - for the space of three or at most of four minutes, life will become extinct - and nothing that medical skill can apply, will suffice to restore that individual to life. - While on the other hand, if we remove any of those Infusoria of which we spoke above, from the water in which they live - they will become dried up, and to all appear-ance dead, but on restoring them to the medium whence they were taken - on presenting them to the same conditions from which they were rem-oved - they will quickly resume their wonted activity - and fully prove that the cessation of the respiratory process in them has no other effect, than of suspending for a time the vital functions - and this after a lapse not of minutes or hours - or even days - but after they have remained to all appearance dead and disorganized for the space of months and years. -

The tendency which all gases shew to diffuse themselves equally through space, and the remarkable rapidity with which this is done — as all those can testify who may have happened to be in a room where a small amount of chlorine or any other strongly pungent gas had made its escape, and the fact that the intervention of a moist animal membrane, does not prevent gases from mutually intermixing, explains the cause of those changes which take place between the atmospheric air, and the venous blood contained in the bladder.

We shall afterwards see when we come to speak of the changes which take place in the blood during the process of arterialization, that the free gas in the venous blood and the oxygen of the Atmospheric air — obedient to the law of Diffusion of gases mutually permeate the moist membrane of the air-cells, and while oxygen is being added to the blood, carbonic acid is being at the same time exhaled from that liquid to supply the place of the oxygen just removed from the atmosphere.

The question may here be asked, is it strictly a mechanical cause which regulates the intermixture of these two gases? that is to say, does it depend upon the purely physical law of diffusion of gases only? or is it aided by certain vital attractions inherent in the venous blood itself, whereby it is enabled to in-

-hale oxygen from the air? Now, the question would be solved, if it could be proved that the law of diffusion, is sufficient of itself to effect all the changes necessary in the blood. We have already seen that all the changes which take place in the venous blood when exposed to the influence of the atmosphere in the capillaries of the lungs of a living animal, also are effected when the blood is exposed to its influence through the medium of an animal membrane, quite independent of a living being. Now, as it may be fairly supposed that no vital attractions can continue to exist in the blood after this is removed from the body, we may safely conclude that vital attractions are not essential to the proper performance of the respiratory functions. - To add an additional proof, Spallanzani in his experiments on snails, found that they absorbed oxygen, and eliminated carbonic acid not only in a live state, but also when dead, although in smaller quantity under the latter circumstances. "This observation", he says, "proves two things, 1st that the lungs and heart are the causes of a part of the absorption, and 2dly that the body of the animal produces the remainder: if the latter produces this absorption after the death of the animal, there is no reason why it should not do the same, when the animal is alive." We thus arrive at an easy explanation of the circumstance of oxygen being absorbed and carbonic acid being given out in less quantity in dead than in living animals. For, in the latter case, both the lungs and the skin absorb oxygen, but, when the animals are dead, it is clear that the lungs can no more perform their function, as, the movements of respiration having ceased, the renewal of air cannot be kept up in the breathing cavity, and it is only the body or skin which can perform the respiratory function. It is also evident that, in this case, no vital attractions can exist either in the blood or tissues, for nothing vital can remain in an organism after it is dead, and when it is in a decomposing state, as these snails no doubt were. This would go to prove that the cutaneous respiration, carried on more or less in all animals, is not dependent upon any vital attractions existing in the blood and fluids, but strictly depends upon chymico-physical laws, and which, ~~moreover~~, will always go on wherever fluid containing free gases is exposed to the influence of other gases

Why not – the effect of stimulation increase vital force through the medium of an animal membrane.

We have endeavoured to prove above that the respiration carried on by special organs for that purpose is essentially the same as that carried on by the integument of animals. If we have then succeeded in proving that the cutaneous respiration in snails is not vital, we must, therefore, be considered to have proved that the pulmonary respiration is, in like manner, independent of any vital attractions existing in the blood. Again, in another place, the same observer proved by experiment that the absorption of oxygen by the bodies and shells of the snails was much greater when those animals were confined in pure oxygen than when confined in atmospheric air. This clearly proves that the absorption of gases during the respiratory process depends merely upon a physical law, something concerned in keeping up the balance between the gases on the exterior and interior of the respiratory surface, for, if this absorption of gases in respiration were dependent, as some suppose, on a peculiar vital force existing in the blood, why should the absorption of oxygen be greater when animals are confined in pure oxygen than when confined in atmospheric air? There cannot exist a greater vital force in the one case than in the other. All this would lead us to conclude that the changes the blood undergoes in the ~~lungs~~ process of aeration, can be carried on by the agency of chymico-physical laws, independently of any vital attractions on the part of the blood.

The constant interchange of the gaseous fluid in the lungs is being continually provided for by means of the movements of inspiration and expiration, which alternately draw in and expel air from the thorax. These movements are purely excito motory, being caused by that peculiar feeling in the chest which the French call "le besoin de respirer." This sensation, which is felt if the chest remains at rest a few moments after expiration has been performed, and which soon amounts to intense agony if not relieved by a rush of air into the thorax, depends, according to Dr. Alison, upon venous blood moving through the lungs and acting upon the sensitive nerves of those parts which then convey their impression to the Medulla Oblongata — the part of the brain, which seems more particularly to preside over the function of respiration; there certain changes taking place, the impression is transmitted along the nerves distributed to the

muscles of inspiration — which then contracting en-
-large the capacity of the thorax, and produce a vacuum,
which is immediately filled up by a rush of air from
the surrounding atmosphere. After the respiratory
act has been performed, the relaxation of the mus-
-cles employed in the enlargement of the thorax, and
the elasticity of the walls of the chest itself, allow this
to resume its former capacity, and consequently a
quantity of air is expelled from the lungs.

The cavity of the thorax is
capable of great change of dimension from the state
of deepest inspiration to that of deepest expiration.
Sir Humphrey Davy calculates that his lungs in
the state of forced inspiration contained about
254 cubic inches; while in a state of forced expiration,
they contained only 41 cubic inches. The enlargement
of the thorax takes place in three directions; in the
vertical, by the contraction of the diaphragm, and
the elevation of the upper part of the chest; in the
transverse and antero posterior directions, by the
elevation of the ribs. In the ordinary state of the
respiratory movements, the enlargement of the chest
for inspiration, is effected principally by the descent
of the diaphragm, without much aid from the
movement of the ribs, or elevation of the upper part

of the thorax, while the resiliency and elasticity of the walls of the chest, and the relaxation of the muscles employed in inspiration, are sufficient to produce the act of expiration. But, however, when the frequency or activity of the respiratory movements are increased beyond their usual intensity, from exercise, disease, or any other cause, then not only is the act of inspiration, aided by all the muscles, which can enlarge the chest in all directions, but the act of expiration is also assisted by all those muscles which, by pushing up the abdominal viscera and pulling down the ribs, cause a diminution in the size of that cavity.

The movements of respiration take place in a healthy person on an average about 18 times per minute, once for every four pulsations of the heart, but they are variously modified, both to suit the wants of the economy, and according to the state of mind of the individual at the time. The quantity of air drawn into the lungs during an ordinary inspiration, and the quantity expelled during an ordinary expiration, varies so greatly in different individuals, and is so modified in the same person according as the body is in a state of rest or activity, that it is a matter not to be wondered at that physiologists should have obtained such dissimilar results. To give an idea of the difficulty of obtaining any accurate data, with regard to the quantity of air exhaled at each expiration, we may quote the statement of Vierordt, who found that the quantity varied in his own person, as much as in the proportion of 1 to 4.75.

Herbst concluded from his experiments that a healthy ~~person~~ adult of average size, should, in an ordinary inspiration, inhale from 24 to 30 cubic inches, and Valentin gives as the result of his experiments, that the quantity of air expired in ordinary up to somewhat quickened respiration - ranges between 14 & 95 cubic inches. Bourgery concludes that the volume of air required in an ordinary respiration, augments gradually with the age, being least in youth in consequence of the extreme vascularity of the lungs, increasing from that to adult life by reason of the diminution of the closeness of the capillary network in the lungs, and still further augmented in old age, on account of the diminution of the extent of the respiratory membrane, which begins to take place after the lungs have attained their full development.

We now come to consider

the changes which the atmospheric air undergoes during the process of respiration. The most obvious change in the respired air, is an increase of its temperature, and, as a necessary consequent, an increase also in its bulk, and amount of watery vapour exhaled from the fluid secretions of the inner surface of the air-passages. According to Valentin, the average temperature of the expired air is 99°.5 F., when breathing in an atmosphere of ordinary temperature. This does not, however, vary greatly, even in very great differences in the temperature of the inspired air; e.g. the same experimenter found that in breathing air of a temperature varying from 51° to 107° F., a difference only of 3°.937 F. was observed in the temperature of the expired air. He calculates also, that the inspired air at a temperature of 60° F., is increased about 7 per cent by volume when returned again to the atmosphere, on account of the increased temperature it acquires by contact with the lungs.

The quantity of watery vapour which escapes from the body along with the expired air, Valentin and Brunner estimate at 7.819.222 grains in 24 hours,
the maximum being 13156.323 do.
and the minimum 4.511.374 do.
The quantity they found to vary in the same

and the more abundantly the animals have fed. Cold also tends to increase the amount of carbonic acid exhaled, and this is easily explained by the fact that the atmosphere being more dense than in a warmer temperature, a greater amount of oxygen gains access to the lungs in a given time, and the respiratory process is consequently more active. Moderate exercise, not carried so far as to produce fatigue, greatly promotes the exhalation of this gas. Heat by rarefying the atmosphere, tends to diminish the amount of carbonic acid exhaled, as do also fasting, violent exercise, alcoholic liquors, and mental emotions both of a joyful and depressing nature.

As regards the changes that take place in the nitrogen during respiration, much doubt exists - some asserting that an absorption of this gas goes on in the lungs, others, that no change is effected in its quantity, that the amount inspired equals the amount expired - and a third party affirming that there is an exhalation of azote. Spallanzani, in his "Mémoires sur la Respiration", details many experiments on snails to endeavour to elucidate this point, - the most numerous of which tend

The elaborate experiments of Allen & Pepys are scarcely alluded to - the more accurate Exps of Dulong not noticed nor those of Despretz while the less accurate investigations of Lavoisier & Seguin, & of Spallanzani are received as full evidence

to show, that nitrogen is absorbed during respiration, and that even to the extent of one fourth of the oxygen consumed, but the rest of his experiments go to prove the contrary, - that azote is exhaled, and that in as great quantity as was the absorption in the other cases. He mentions the very singular occurrence of the latter phenomenon under two circumstances: in one instance, the snails had just made an abundant repast, - in the other, they were in a dying state. He deduces this ingenious theory as an ex-planation of this. "Azote," he says, "being one of the principles introduced into animals by the food, the snails after a considerable repast, may have taken in such a quantity of this, that they get rid of the superfluity by exhalation from the lungs.
Again, when life is nearly extinct, this little animal being about to be decomposed, it is probable that the nitrogen begins already to escape, for it is well known that complete decomposition produces a great amount of this gas. - Allen, Pepys, and Dalton affirm that during natural respiration, no change whatever occurs in the nitrogen, Berthollet that an exhalation of this gas takes place, while Dr. Edwards from numerous experiments performed on sparrows, frogs, lizards, and newly born dogs, detailed in his

work entitled "De l'Influence des Agens Physiques sur la Vie", found that in spring and summer, exhalation of nitrogen takes place, but that sometimes the amount of this gas is not changed, while in summer and winter, there is an absorption of this ~~gas~~ nitrogen; — but there are many exceptions to this rule — Now, from all these apparently conflicting statements, it would be difficult to deduce any theory not open to grave objection, — to choose one opinion, whether that of absorption or exhalation and to lay aside the rest, would be manifestly absurd, as they are all based upon equally incontrovertible evidence. We are thus forced to admit the truth of them all, and this is what Dr. Edwards arrives at, in considering the result of his experiments. He considers the subject in this light, — that there are continually going on an absorption and exhalation of nitrogen in the lungs at the same time, and it is according as the one or other is carried on with the greatest activity, that the amount of nitrogen is either diminished, or increased, or remains the same in the respired air. Thus, if the absorption of nitrogen exceeds its exhalation, it is clear that there will be a diminished quantity in the expired air, and vice versâ. Again, if the exhalation and absorption exactly counter-balance each other, the amount of nitrogen remains the same. And therefore, it is according as external circumstances or peculiarities of the individual, modify the action of these two processes, that the amount of nitrogen is increased or diminished, or remains the same in the expired air.

I must now say a few words regarding the differences in the chymical constitution of venous and arterial blood. In its passage through the lungs, the venous blood from the right side of the heart, changes from a dark purple to a bright scarlet hue, and along with the change of colour, there undergoes all the changes necessary to fit it for the nutrition of the tissues. It here receives the name of arterial blood, and a knowledge of the essential differences in the chymical constitution that exist between venous and arterial blood, is necessary before anything can be said of the chymical changes taking place in that fluid during respiration. —

The most marked difference between venous and arterial blood is that of colour. This difference varies in the different classes of Vertebrata, being greatest in birds and mammals - and least in reptiles and fishes. It is also subject to variation in the same animal, under different conditions of the body and surrounding media: thus in animals inhabiting hot countries, or exposed to artificial high temperatures, when the process of respiration is carried on slowly, the arterial blood may present a darker colour than usual, and approach more the venous hue. Again, in hybernating animals, when the process of respiration is hardly perceptible, during this state of torpor, the arterial blood approaches still nearer in colour that of the venous. On the other hand, in a state of high febrile excitement of the circulation, when both the energies of the heart's action, and of the respiratory movements is greatly increased, the venous blood may be nearly of as bright a colour as the arterial. - The difference of colour between the arterial and venous blood seems to vary in extent, according to the energy of the respiratory process. The temperature of the arterial blood, according to Dr. John Davy, is greater by 1° or 2° than that of venous blood. The specific gravity of the latter is also calculated by Dr. Davy to be rather greater than that of the former, as 1050 to 1053. Some of the analysts who have published the result of their experiments, have discovered more water and less solid material in ärterial than in venous blood — others have observed the contrary, while a third party could make out no difference in this respect. The greatest number of analyses made to elucidate this point, are in favour of the first opinion. As much difference of opinion exists regarding the respective amount of fibrine and blood-corpuscles in the two kinds of blood, but the greater amount of analyses tend to shew that fibrine abounds most in arterial blood, while the blood-corpuscles are more abundant in venous.

Michaelis, Marcet, and Macaire found more carbon, and less oxygen in venous, and less carbon and more oxygen in arterial blood. But, by far the most important consideration connected with the differences in venous and arterial blood, is that concerning the relative amount of free gases existing in the two kinds of blood. — That free gasses do exist in this fluid is now universally acknowledged, having been placed beyond dispute by many experiments made by different observers. on the blood itself, and on animals confined in other gases than atmospheric air. Spallanzani, in his "Mémoires sur la Respiration" mentions having confined snails both in atmospheric air and pure nitrogen, and at the end of 12 hours found, that those snails which had been confined in nitrogen gas, had exhaled more carbonic acid than those confined in atmospheric air, fully proving that the carbonic acid must have previously existed in a free state in the blood. Enschut by subjecting blood to the temperature of boiling water, obtained carbonic acid gas, both from arterial and venous blood, and a greater quantity from the latter than from the former. Bertink and Magnus procured carbonic acid gas from human venous blood by agitating it with hydrogen. The latter experimenter also obtained oxygen and nitrogen from both kinds of blood of certain domesticated animals by means of an air-pump. He also observed that the relative quantity of oxygen to carbonic acid gas is greater in arterial than in venous blood. In the latter, the oxygen was as $\frac{1}{4}$th and often $\frac{1}{8}$th, while in the former, it was at least as $\frac{1}{3}$d or $\frac{1}{2}$ to the carbonic acid. He gives the follow-

-ing table as the results of his different experiments on both kinds of blood by means of the air pump.

	Arterial Blood. Cubic centimetres	Venous Blood. Cubic Centimetres
Carbonic Acid Gas	39.5 or 62.3%	47.5 or 71.6%
Oxygen	14.7 " 23.2%	10.1 " 15.3%
Nitrogen	9.2 " 14.5%	8.7 " 13.1%

Thus we see that, while carbonic acid is obtained in less quantity - oxygen and nitrogen are obtained in greater quantity from arterial, than from venous blood. All the experiments made to elucidate this subject seem to prove that the three gases, Carbonic Acid, Oxygen and Nitrogen exist in a free state in the blood.—

Having thus far considered the differences between the inspired and expired air, and between the arterial and venous blood, it now remains to consider the rationale of those changes in the blood and atmospheric air, during respiration, whereby oxygen is absorbed and carbonic acid given off. From the fact cited above, that the blood after arterialization, contains more free oxygen and less free carbonic acid, than before that process; it is reasonable to suppose that a portion at least of the oxygen absorbed during respiration does not enter into chymical combination +

with the constituents of the blood, - but is held in solution by that liquid, until, at all events, it is circulating in the system, and that the greater part of the carbonic acid which has disappeared from the blood, reappears as the carbonic acid present in the expired air, without the necessity of that gas being formed by the chymical combination of a portion of the absorbed oxygen, with the carbon of the blood, in short that the carbonic acid gas exhaled exists previously in a free state in the blood. And this we have seen fully proved by the experiments of Spallanzani cited above. He found that, on confining four snails in common air and four in nitrogen gas, more carbonic acid was produced by the latter than by the former; - now, it is evident that the carbonic acid produced by those breathing nitrogen alone, must have existed previously in the blood, - since it could not have been formed by the combination of oxygen with the carbon of the blood, for no oxygen was present. All these facts would lead us to conclude that the greater part if not all of the carbonic acid exhaled in the expired air, existed previously in a free state in the blood.

Now, what becomes of the oxygen absorbed into the blood? La Grange and Hassenfratz assert, that it is retained in solution in the blood, until this arrives at the systemic capillaries, where it combines with carbon forming carbonic acid, and that the latter gas is returned in solution in the blood, to the lungs where it is excreted. Gmelin, Tiedemann, and Mitscherlich, suppose that the oxygen absorbed at the lungs, partly unites with carbon and hydrogen, to form carbonic acid and water, which are there exhaled, and partly with organic substances in the blood, to form acetic and lactic acids: that these acids decompose some of the carbonates of soda, brought to the lungs in the venous blood and that the carbonic acid thus set free is also exhaled. The arterial blood in its course through the tissues, more especially those of the kidneys and skin, loses part of its acetic and lactic acids; and the soda with which they are combined, being set free, unites with the carbonic acid formed during the process of nutrition, and these carbonates are again decomposed in the lungs, in the manner described. Dumas believes that the absorbed oxygen combines with certain matters in the blood, to form lactic acid, this combines with soda, to form lactate of soda, and this latter salt, by a real com-

-bustion, is converted into carbonate of soda, which is decomposed in its turn in the lungs, by a fresh portion of lactic acid. Liebig supposes that carbon-ate of the protoxide of iron exists in the red cor-puscles of venous blood, and that in its passage through the lungs, a large portion of the absorbed oxygen unites with it, forms hydrated peroxide of iron, and sets the carbonic acid free. Mulder maintains that the absorbed oxygen combines with the proteine compounds, forming oxy-proteine, which, being conveyed by the arterial blood to the capillaries, is decomposed during the nutritive processes, and carbonic acid is formed and held in solution in the blood. But, by far the most in-genious and plausible theory which has yet been put forward is that of Dr. G. O. Rees, published in the Lond: Ed: & Dubl: Phil: Mag: for July 1848 — Having found by analysis that corpuscles of venous blood contains fatty matter in combination with phos-phorus, which does not exist in arterial blood — or, at most, is found in it in very small quantity — He supposes that the oxygen of the inspired air unites with the phosphorus and fatty matter, and a combustion of it takes place, of which the pro-ducts are water and carbonic acid, from the union of the oxygen with the phosphorus. The carbonic acid and water are exhaled, and appear in the expired air; phosphoric acid attracts the soda of the liquor sanguinis, from its combination with albumen and lactic acid, and thus forms a tribasic phosphate of soda, a salt which possesses in a marked degree the property of giving a bright colour to hæmatosine.

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