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With the Author's Compts.

A TREATISE

ON

VITAL CAUSES.

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BY

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DEDICATION

TO

SIR BENJAMIN BRODIE, BART.

(BY PERMISSION.)

SIR,

I HAVE ventured to forward to you the first and only copy, which has left the printer's hands, of a work I am on the point of publishing.

It will be a gratification to me if, after inspecting it, you will permit me to dedicate it to you.

I have no hope of its being considered deserving of that distinction as a matter of intrinsic merit; but if there has been sufficient industry displayed in the researches which have led to the publication, and if the attempt alone is such as to meet your approval, irrespectively of whatever amount of failure may attend my effort in consequence of insufficient ability for the task, still such a modified approbation will more than compensate me for whatever pains I may have bestowed, and my ambition will be gratified, if I may be allowed to give expression to the respectful homage which every member of the medical profession feels for one to whom all are deeply indebted.

The particulars of the investigations, on which the publication is founded, have been already communicated to the Royal Society. They were only published in abstract ; but I have felt entire confidence in the truth and importance of the facts which I then introduced, and I have anatomical preparations which amply verify them.

I have been content to wait for their final acceptance until other inquirers should have confirmed the views which I propounded, or until I might be enabled to submit them in a more detailed manner to the public at large.

My wish now is to dedicate the work to you personally, as the head of the medical profession.

I remain, Sir,

Your obedient Servant,

JAMES NEWTON HEALE.

WINCHESTER, *May 15th*, 1859.

CONTENTS.

A POPULAR TREATISE

ON

VITAL CAUSES.

CHAPTER I.

RELATING TO MECHANISM IN GENERAL.

In every sort of mechanical contrivance consisting of a number of dissimilar parts, each of which conduces in its own special way to the conjoint action of the whole, three distinct sets of events arise, namely, the peculiar action of each separate part, next the harmonious relation which these bear to each other and to the whole, and, lastly, the aggregate performance and attributes of the machine itself. So distinct are they, that in the construction of a watch there are those who make the works, then those who adjust them to each other, and, lastly, those who regulate the performance of the whole machine. Also in every landscape there are certain properties, such as the laws of perspective, which belong to the whole, in contradistinction to those peculiarities which relate to each individual portion of which the whole is compounded. So also, in every contrivance adapted for the accomplishment of a special purpose, a number of special circumstances arise, in proportion to the complexity and perfection of the machine, and these are totally distinct from the properties of the isolated parts, and resolve themselves into laws belonging to the whole, and possess only a secondary application to the individual parts.

But in proportion as the mind penetrates into the causes of things, and becomes acquainted with the mysteries of construction, fresh contingencies and attributes continually present themselves to the understanding now capable of distinguishing and reasoning upon them.

The animal body is a wonderfully-constructed whole. The study of its individual organs is in itself a very interesting one; but it is a most serious error to narrow the observation to the structure and function of isolated portions alone, (an error, however, which is almost universal,) instead of studying the attributes of the whole, and the proportionate relation with which each separate part conduces to the accomplishment of the aggregate design.

To investigate the laws of adaptation in their application to the animal body would be to study the highest combinations, as far as man can judge, that perfect skill could adjust; and to form even a cursory estimate of them would be far beyond the grasp of any human intellect, unless prepared, step by step, to comprehend some of the simpler, by first witnessing the necessary circumstances that attend even those ruder adaptations, which man can himself construct. Let any one contemplate the most primitive instrument on which man may exercise his ingenuity—a spade, for instance. The whole must be adjusted to the strength which will be available for its use, and each of the parts of which it is formed must be in some proportion to the remainder. In its application to the purposes it was designed to accomplish, deviations from what is suitable are soon recognised as impediments to its use, and, by experience, the user draws primitive laws or conclusions which help him to correct what is erroneous until excellence is attained, and then its various parts merge into a perfect whole. In order to gain these general ideas, so as gradually to initiate the mind into the more perfect combinations prevailing in the animal structure, it is useful to follow up the gradations by which the contrivances of man at length attain a certain amount of excellence in the adaptation of dissimilar and complex parts to simple, definite, and harmonious objects. It is instructive to contemplate a steam-engine at work, and, while noticing the smoothness and precision of its motions, to allow the imagination for a while sufficient play to recognise the adaptation of the whole machine, and the object which it is its nature to accomplish, and to which all its parts conduce each in its appointed way.

This fixed intention may be said to give an individuality, an identity, and almost a personality to the whole. This design, —or, as it may also be justly called, this "volition,"—derived from its constructor, in proportion to the accuracy with which its plan has been conceived and executed, will continue to pervade all its properties as long as the machine exists, and even when its parts are scattered to remote distances, each individual joint will retain undeniable traces of the original intention and purpose for which it was constructed.

These are hieroglyphics establishing its affinity with the human understanding, the key to which will never be lost as long as the human intellect itself remains.

The steam-engine possesses its individuality, which man has imparted to it by successive acts of volition—first on the rough ore, afterwards on the malleated metal. When seen in the execution of its appointed task, power, precision, and perseverance seem personified. When the untaught savage witnesses its performance he is impressed with respect, accompanied, perhaps, with some degree of awe; and when, at word of command, and by the movement of what appears to him a very insignificant part of its structure, it suddenly stops, and its multifarious spindles cease to revolve, while the texture which it was engaged in weaving ceases to grow beneath his eyes, the stillness which succeeds, creates in him even a greater astonishment than its former activity, which feeling is allied to consternation at the apparent death of the busy and gigantic being, and he exclaims, "It is the work of the Great Spirit!" When it recommences its employment without perturbation or haste his satisfaction is evident, and perhaps it would not take much now to persuade him, that it would be very expedient to conciliate the monster by doing him reverence.

A steam-engine with its pair of lungs—that is to say, with two cylinders—each adapted to hold a cubic foot of steam of the temperature of 275°, and breathing in and out in both lungs one hundred times in a minute by making fifty revolutions of the crank, possesses altogether a power equal to that of about twenty-six horses. About the proportion of six of these will be occupied in overcoming the fatigue of breathing, or the resistance the steam itself occasions in its escape, after having exercised its direct force, and in overcoming the friction in its own members. If it has got the rheumatism, or any other impediment in any of its joints, this proportion will be increased. The remaining power, equal to that of about twenty horses, can be applied to other purposes; thus, if the machine be supplied with locomotive organs, it can take a tour of pleasure or advantage—it can go about and honestly earn its own living—it can collect its fuel that serves for its food, and, if necessary, it can cut it into lengths—in other words, masticate it; and, having placed it within its stomach, digest it and renew its strength thereby. If the machine be floated on the water it may be said to be in its own element. As the water passing over the gills of a fish supplies it with air, so the water, passing over the bronchial tubes or boiler tubes of the engine, furnishes it with steam to maintain all the functions belonging to it, and with the strength which all its various functions require.

For every breath this engine of the supposed description takes while using all its power, three cubic inches of water—that is, about a wine-glassful—must be converted into steam of the requisite heat and force; and, as it takes into each lung or cylinder one hundred such breaths in a minute when working, it follows that six hundred cubic inches of water must, every minute, be converted into steam of the requisite pressure; and, as pressure and temperature mutually correspond, it may be stated that the heat of this steam engine's breath is 275°, that is, 63° above the heat of ordinary boiling water, to say nothing of the heat which has been called "latent," and which, by a narrow philosophy, has been imagined to go to sleep just at the moment when it was displaying the greatest activity; five parts of the heat being supposed by this theory quietly to go into repose, while the sixth does all the work.

Every fresh cubic foot of steam, entering each cylinder of such an engine, will push the piston on one foot to make room to admit it, thrusting the piston backwards and forwards alternately, as the successive cubic feet of steam enter; and this has been assumed, in the supposed case, to happen one hundred times in every minute, and, as there are two such cylinders, it follows that two hundred such fillings will take place each minute. Now, one cubic inch of water, when expanded into steam and under the weight of only one atmosphere, will about occupy the space of one cubic foot. One cubic foot contains 1728 cubic inches; so that water, by being converted into steam of ordinary temperature, is made to occupy rather more than 1700 times as much space as it did before.

In the case of the steam-engine above supposed, as steam of thirty pounds pressure on the square inch is used, a pressure equal to three atmospheres has to be produced, because the ordinary atmosphere weighs fifteen pounds on every square inch, but two others are required to overcome the additional thirty pounds, which is the resistance that the steam has to encounter beyond that of the atmosphere; therefore the quantity of steam, which would occupy a cubic foot under the pressure of the atmosphere alone, will only occupy one-third of that space, when it has to sustain a pressure three times as great. It will, consequently, take three cubic inches of water to fill one cubic foot with steam of the elastic force of thirty pounds per square inch over and above that of the atmosphere.

The power and force which such a machine exercises can, therefore, be measured with exactness by the quantity of water converted into steam in a given time; and the quantity of vital force which any animal body exercises may, in like manner, be measured by the consumption of atmospheric air which it effects in any allotted period. Every function which the steam engine performs, whether it be only oiling its own joints, or whether it be producing some complex and ingenious work, depends entirely on the quantity and force of the steam it consumes—from this alone its force is derived; and the quantity of steam it gets rid of is the exact measure of its combined performances. If, like the human body, the steam-engine were required to be kept constantly at work in order to prevent its dissolution; in other words, if there were no possibility of rekindling the fires when once they were extinguished, and no possibility of keeping a reservoir of steam while the engine was at perfect rest, it would be necessary, when the fires were slackened during night, that the engine should work sufficiently to keep the different parts in motion, and thus to provide that a sufficient quantity of water should continue to flow around the tubes, so as to prevent their being damaged by the fire.

This modified action of the engine, just acting sufficiently to keep its own structure in order, allowing, by its tardy motion, the oil with which it is fed to percolate and renovate its most concealed joints, and all strain being removed, enabling those parts whose functions depend on elasticity to recover their original forms, and thus become prepared for the next day's labour, may be compared to the condition of the human body during *sleep*.

When the hour of rest arrives, the sensorium—

that is, the engineer in charge—ceases to watch the spindles or to direct the rudder, and he also consigns himself to repose, ready, however, to start up at the first tinkle of the bell, or the first warning of the contrivances, which have been adapted for the purpose of giving him timely notice whenever his vigilance may be required.

These appliances may be called the "nervous system" of the steam-engine, and are of two kinds, one of which (like the governors, that regulate the speed) causes distant parts to act mutually in unison with each other, adjusting the supply of materials, of speed, of oil, &c., to each other, and it does this without the direct intervention of the sensorium, or thinking agent, resembling in this the automatic nerves of the animal body; while the other division of the nervous system appeals, by certain startling effects, to the attention of the engineer, who is called upon to regulate what may be amiss, which he is also enabled to do through their unseen agency; and this represents the volitional nerves in their obedience to the thinking quality, conveying information, while they execute commands.

Now, the nervous system in the steam-engine and in the human body is not the motive force; it regulates it, but it is a great mistake to imagine that it is the agent which *creates* the force. Vital energy, nervous energy, *vis nervosa*, &c., are the effects, and not the causes of the bodily functions. The body lives, because certain changes take place within it, the action of the air upon the blood in the lungs being the primary agent, and the changes which this undergoes being the measure of all subsequent operations. True, volition first constructed and afterwards regulates the whole machine; but this volition, whether present or past, is not the physical motive force: *that* is supplied by the steam in the steam-engine, and the breath in the animal.

The volition of man constructed the steam-engine, and the will of God made man. The first constructor adapted all the parts, and brought the machine to perfection; he placed therein the engineer, as the regulating mind of the whole structure—the occupant of the state cabin, the sensorium.

This engineer, so far from having made the engine, or being able to make it, is not even fully acquainted with some of its recondite parts. He has a sufficient knowledge, however, to enable him to take proper care of the machine, which has been confided to his charge, and to use it according to his directions. He may be aware that he is intrusted with it, not so much for the sake of the machine, or of the work or profit which he may accomplish through it, as for the purpose of training himself for higher employment, and testing his intrinsic worth; yet the machine performs its own functions obedient to its own nature, and limited in its power by the intentions of its maker, and the engineer can only direct its performances, by adhering strictly to all its natural attributes. If the engineer absents himself, is negligent, or is incapacitated, by any cause, from superintending the processes performed by his charge, it is in the condition of an insane person—its fearful powers may be exerted to its own destruction, or to the great damage of its neighbours. The water which supplies its breath, or the fuel with which it is fed, may be deficient or bad in quality, and disorders of weakness may arise, beyond the control of the engineer; the tubes may get red-hot from the imperfect supply of water, and an explosion or sudden death may ensue; or, whilst the tubes are in that heated state, the obstruction to the supply of water may be removed, and a quantity of steam suddenly generated may cause the engine to work with frantic energy for some time, to the great danger of wearing out or breaking some of its machinery, which vehement action the engineer may be unable to check or to control; and this state may be compared to "delirium."

It is possible, if the machinery be in other respects in a sound condition, that it may struggle through the paroxysm, and the heated tubes may become gradually cooled by the increased quantity of water supplied, and the engine, though shaken and worn, may yet be restored to utility, and even to health.

Now, this connection between the engine and its controller has many points of similitude to that of mind with matter. In his very nature the engineer is distinct from, and even contradictory to, the machine, from which he derives his power and influence; and certainly, though the vast machine implicitly obeys his control, and submits its mighty force to his will with all possible docility, yet it is beyond its nature to understand the attributes of its master, as matter can never unravel the mysteries of mind. The finite mind of man, however, has obtained a certain insight into the properties of matter, and has learnt thereby to turn their attributes to useful purposes, as the engineer may be conversant with the engine which he manages, and may even learn to correct any temporary derangements to which it may be liable; and reason, experience, and revelation convince him that mind in its highest perfection is supreme over all matter.

But man, judging according to the measure of his intellect, as demonstrated by Locke, can only arrive at the conclusion of the existence of matter from the fact of its occupying definite space, and of space from its being occupied by matter. He can neither connect the two events by ratiocination nor explain their coincidence, much less can he develope their attributes. The *properties*, as they are vaguely called, of mind and matter, and of space, become merged and intermixed beyond man's power to disentangle.

Even in the steam-engine, which the finite being—finite as to his present existence—has invented, and all whose parts he has fabricated, he finds that all its force results from matter, which he incloses in a certain space, namely, the steam in the cylinder, and that all the force which his machine possesses, is derived from the strong propensity of this steam, so inclosed in one space, to occupy some other space, and *that* three times as large as that, by which he has become acquainted with its existence.

This propensity or attribute to enlarge itself he calls "elasticity;" but he recognises in that property, "elasticity," something more than the mere matter, simply occupying space, to which he has given the name of steam, because, while in the confined space (which proves its materiality), and not allowed to expand itself, its property of elasticity is inoperative; the steam is in the chamber, but there is no evidence of the elasticity, which is to move the machinery; neither is it the same principle which gives the idea of strength, since a mass of iron not only occupies space, but gives him this idea of strength or force in the strictest sense. He has thus a practical exposition before his eyes, in his own work, of something beyond mere matter, but which bears some analogy to mind, inasmuch as it acts upon matter, and imparts to it its attributes. He also contemplates himself in his own material form, and his reflections thereon prove to him the operation of causes, very distinct from matter, but which matter serves to demonstrate, and temporarily to subserve.

As man may be allowed, and is enjoined, by an instinctive perception of what is right, to study the structure and uses of the steam-engine which he directs, though the property of elasticity of steam, from which it derives its power, may, as an abstract principle, be inexplicable to him; so may and ought he to study the functions and structure of his body, though the nature of the mind itself, by which it is directed, may be beyond his comprehension. There are also many other attributes, besides that of elasticity of steam, such as temperature, moisture, and the laws by which these are governed, which he recognises as quite distinct from the material qualities of steam, if ponderability and the occupation of space be accepted as the definition of materiality; and even these last may be considered qualities of matter, rather than essentially matter itself.

CHAPTER II.

RELATING TO INORGANIC OPERATIONS.

In studying the external qualities and properties only of any human contrivance, however excellent in materials or workmanship it may be, if passive symmetry or durability is its only characteristic, nothing more is presented by it to the mind, than a mere diagram or representation of some particular action or sentiment, which its outline, or some such association, may possibly suggest.

As far as its capacity extends merely to excite particular thoughts, sentiments, or imaginations in the mind of the beholder, certain words scrawled upon paper may produce precisely the same results. For though this contrivance may have eyes, feet, hands, mouth, and other members of very excellent shape, yet, unless these organs can perform the work their construction seems to promise, the *entity*, which in reality belongs to the machine, is only the same in kind, with that which the rude stones or rocks in its vicinity, and from which, in point of fact, it may have been originally chiselled, still possess. But could all the parts of this symmetrical arrangement be disturbed from their state of passive stillness, and all the joints of which they are formed begin to revolve around and about each other, so as to execute some precise operation, the whole of these motions and performances would then deserve to be classified under a *term of nomenclature*, which would mark the distinction between the *instrument* and the *work* it accomplished. The difference which exists between an automaton and a mere statue would thereby be discriminated.

No such generic term is to be found in the English language.

A machine is in a passive, unmoving state ; something occurs to put it in motion ; and, having undergone certain changes or evolutions within itself more or less complicated, its constituent parts return to their original relative positions, and the whole is capable of repeating its former gyrations, or resumes its former attitude, according as outward circumstances may direct. What word is there that embraces all these consecutive phases ?

The machine itself possesses an *entity* of its own, which it still retains, whether in motion or not ; but the rhythmical or psychical operations, which may appertain to it, constitute an essence altogether distinct and external to itself.

The latter state bears the same relation to the verb "to do" which the former does to the verb "to be."

Three coincidences are implied in it: first, the exciting agent; secondly, the operating cause; and thirdly, the active effects, for which a generic term is now required.

In the case of the steam-engine the exciting agent is the man who turns on the steam; the operative cause is the steam itself, acting by its own elasticity; and the whole performance is the aggregate of the phenomena which take place in the interval of *time*, comprised between the moment when the disturbance commences, and that in which it is completed and the instrument resumes its former posture and condition.

The essential characteristic of the whole chain of events is motion or change. The act of transition of particular ingredients from one state or condition to another, such as when the starch contained in grain is transformed into sugar, sugar into alcohol, alcohol into vinegar is, in those cases, and in some others, called "*fermentation*," and the opposite set of changes, whereby materials of the same sort, originally derived from the earth, the air, and the rain, ascend through other gradations until they at last become "*grain*," is called "*vegetable growth*," a term sometimes used synonymously with " vegetable life."

These special names are given to special transitions, but no generic name is applied to that peculiarity which marks the distinction between *entity*, or materiality, on the one hand, and the active attributes which may become superadded to it on the other.

The word "force" may be used to signify both the exciting and the operating *causes;* but the third set of events—the mutual offspring of "force" and "matter"—is only unsatisfactorily represented by such terms as the following:—"Motion," "momentum," "fermentation," "decomposition," "life," "growth," "heat," "light," "electricity," "sound," &c., which are sometimes called "imponderable matter." Now, *matter* and *entity* have a special reference to "space," while these "imponderables" have a corresponding relation to "time." Each is a division or constituent of a different infinity—infinity of *space* and infinity of *time.*

Tracing out the relation which *heat* bears to *matter* will mark the distinction here insisted on; heat being cited as an example of one development or quality, which may be superadded to matter, but which is not itself matter.

The earth, in its aggregate, represents "matter," and, in an hypothetically passive or unmoving state, may be used as an example of ponderable substance, disjoined from imponderable additaments.

From its centre to its circumference the relative position of its particles remains practically the same, setting aside certain slow developments which corroborate the reasoning here employed rather than the reverse, and therefore none of the contingencies which would result from any commotion among them are developed; and were the same passive condition of things to be extended from its circumference in a straight line towards the sun, or other centres of attraction, the same undisturbed equilibrium would prevail on the earth's *surface* which exists within its depths.

But the diurnal rotation of the earth on its axis causes an alteration in that balanced uniformity of opposing forces, and a perturbation is thereby produced, in precise proportion to the *velocity* with which the different portions of its surface change their relative positions with regard to the sun in particular, and thence the commotion induced by the exchange of particles, on which the sun's attraction is immediately exercised, is greater near the equator than the poles.

Relative *change* cannot occur without engendering that quality external to "entity," the essence which connects it with "*time*."

Heat is one of the effects by which this may be manifested; and thence the comparative heat of various parts of the earth's surface may be calculated, *cæteris paribus*, from the weight of the whole body in motion and the velocity with which any particular spot on its surface changes its relative position, in reference to the attractive forces which would tend to draw it to an equilibrium; and equally so, other qualities which may be called into operation by the same causes, may likewise be inferred from the *weight* and *velocity* brought into mutual opposition.

An explanation seems here required to account for the different temperature, which affects the same spot on the earth's surface at different seasons of the year.

The velocity of any part of its surface must always be the same in relation to its own central axis, and the inclination of its axis to its own orbit is likewise the same at all times, viz., $23\frac{1}{2}^{\circ}$; but the circles of traction, which its diurnal revolution causes it to make in relation to the sun, vary according as the earth occupies different situations in its own orbit. Those circles of traction will be greater in any particular spot in either hemisphere, according as its relative pole may be nearer or more distant to. the sun in comparison with its opposite.

In proportion as those circles of traction are large, it is evident that the velocity of traction must be great also, since each of them is made exactly during the period of twenty-four hours.

This comparative velocity of traction is sufficient to account for the difference of temperature, which each place exhibits at different seasons of the year.

The same chain of reasoning applies to all other methods by which heat can be engendered.

Heat developed in water under the pressure of one atmosphere can never exceed 212°; because, beyond that point, the expansive force rends asunder the cohesion of particle to particle, in the same manner that a proportionate note of music can be obtained from a string tightened up to its capacity of resistance, but not beyond it.

The power of producing a note of a certain pitch is exactly measured by the capacity of resistance to being rent asunder, which the particles of which the string is made may possess; and the dynamical condition, in water or any other material through which heat can be elicited, terminates at that point where the disruption of the particles, of which it is formed, takes place. The expansive force being after that dispersed over a much larger area than before, the resistance, which is the essential ingredient in the continuance of the joint contingencies, now no longer antagonises the active force, and therefore a loss of force, or what amounts to the same thing, a loss of time, ensues.

When water, resisted by the weight of only one atmosphere, expands into steam, it occupies seventeen hundred times its former bulk; the particles become twelve times their former distance apart from centre to centre, since they then occupy a space which is the cube of twelve times as great as before. The *increase* of heat, which brought them up to the point of transition, may, therefore, well appear to have been six times as great as that which now occurs in the same duration of time, when, by the persistence of the same expansive force, its effects are distributed over a much larger space than before, when the particles were in close contiguity, and a bond of union capable of being stretched held them together.

The steam is, then, susceptible of no further expansion, so long as any water remains unchanged into steam; but should the expansive tendency be still further increased by one-half in rapidity, compared with that which was sufficient to convert a given quantity of water into steam, (*i.e.*, should half as much more velocity be imparted to the particles, and this can be done by supplying only two-thirds the quantity of water which a given expansive force is capable of converting into steam in a given time,) then the effect would be to rend asunder the water itself into its constituent gases, instead of changing it into steam, because the dynamical force holding these together is exactly half as much again as that which induces the particles of water to adhere together as such. Therefore water under the influence of one atmosphere, when it is expanded so as to occupy seventeen hundred times its former space, is "steam;" and the same water, when expanded to two thousand five hundred times its own area, is then oxygen and hydrogen. But by adding external pressure, so as to resist the too distant spreading of the particles, the water may be made susceptible of any proportionately increased heat beyond that of 212°. Thus, by doubling the resistance which the ordinary atmosphere affords, heat, with all its qualities up to 250°, can be communicated to the water, and, by trebling it, heat of 275° can be manifested, and so on in progression.* And by increasing simultaneously both the expansive force and the resistance, any equivalent degree of heat could doubtless be arrived at; and there can scarcely be a question but that, if a vessel sufficiently strong to offer adequate resistance could be constructed, water itself might be made to dissolve a solid metal by means of heat applied through its intermedium.

As soon as the expansive principle, in opposition to the sides of the vessel, should have induced an elastic tension in the particles of the water, equal to that by which the particles of metal had hitherto maintained their cohesion, these latter would be as free to move as those of the water; in other words, they would melt.

But the cohesion of particles of metal to each other can be overcome, without the intervention of the water and the very strong outer case above supposed. By surrounding the metal with coal, and by inducing in the latter the requisite vehemence of tension among its constituents, and by bringing the particles of metal into sufficiently close contiguity with the coal, so that they shall be included in the area where the commotion takes place, the particles of metal may be made to participate in the effects, and their cohesive property will then be antagonised and overcome by the expansive impulse vicariously communicated to them; and becoming, in consequence, free to obey the laws of gravitation, unrestrained by their former tendency to adhere together in mass, the solid shape, which they before held, will be exchanged into one of fluidity.

But in accomplishing this end by means of coal, the operation is greatly promoted when an intervening fluid, called a flux, is used to act as the combining agent between the two. A more intimate bond of junction is thus formed between them, whereby the commotions among the particles of one are more readily distributed to the other. When such is the case, the parallel to a state of solution, before supposed, becomes more precise.

When the active cohesion of the particles of metal among themselves becomes so reduced by a counteracting cause, that they become free to alter their relative position with facility under the control of gravitation, they are said to be in a state of fusion.

It is not necessary here to inquire whether the active state of transition among the particles of coal is derived from primary expansion among the particles, or from secondary combinations of these, involving equal rapidity of commotion, or, as it may be called, for the sake of convenience, "*extra-materialism,*" (to signify the action which may be added to materiality). It is sufficient to know, that the chemical composition of coal furnishes the requisite conditions for engendering the rapid changes of form and arrangement, which the extra-material quality, thus *superadded,* implies; and the participation of the coal and metal, in one conjoint operation, imparts to them for the time a single "entity," which the flux still more intimately ratifies between them.

The metal may also be made liquid by another process, without the intervention of the active commotions which the constituents of coal are capable of engendering. By supplying such a constituent as shall be capable of joining the metal in *entity*, and balancing with an embrace of its own the cohesion which its particles had for each other, this feat may be accomplished.

An acid radicle is an example of such a counteracting power. It is necessary that the effective force of the dissolving agent should be directly opposed to that of the cohesive attraction, which it is destined to counterpoise. When several of such opposite causes concur in the production of particular new formations, geometrical principles in accordance with them must naturally become evolved, when the freshly-formed particles begin to re-aggregate together, in consequence of the force which held them in a liquid condition being withdrawn, either from a lowering of the temperature, or from the removal of a portion of the fluid which enabled them to resist the attraction of particle to particle.

When such a tendency to solidification begins to be developed, crystalline forms, with their various axes and cleavages, illustrate the interlacing effects, which the forces, called into operation during their chemical construction, still exercise in certain definite directions, after the ingredient, which before counteracted their inclination to cohere together, is removed.

The new particles then become free to obey the attractive influence of their fellows, and the aggregate form, which they construct, coincides with the nature of the cohesive properties, which influenced the chemical affinities of their constituent parts; and it is not improbable that algebraical analyses of their structures may, at some future time, be made from mathematical deductions derived from the forms which they assume under the influence of such intersecting causes.

Whenever two or more opposite tendencies are brought into antagonism, it must happen that a stage of transition intervenes, during which the equilibrium between the uncombined materials must be in a state of disturbance previously to their equipoise being restored. While that interval lasts a different state or condition must have influence among the particles, from what happens when the balance among them has been re-adjusted, and when they resume their posture of rest.

To this set of phases a name may justly be given. If the word "heat" does not embrace the ultimate fact, at the least it may be assumed as comprising many of the proximate ones.

Heat is the most common evidence of the alacrity which particles display during their assumption of a new entity; and when their transition is completed, and a new substance is formed, the heat which marked the transition is no longer discoverable.

The new substance then totally differs from both, or all of the constituents from which it was formed.

During its construction a new extra-material essence has become evolved, and, in the particular instances above quoted, heat, or, in other words, a power of distributing the same tendencies, which itself exhibits, to other materials brought within the same area, or " space," marks the tumult then engendered, and is the name given to several of the most prominent phenomena which then manifest themselves.

But, when once the new substance has been fashioned, it thenceforth has no further power of eliciting that " extra-material " quality, until the new entity which has been constructed is again disquieted, and a fresh one is in process of construction.

Certainly it would be difficult to convince an entirely uninstructed person that the new substance ever possessed anything in common with either of its predecessors, in respect of materiality or resemblance; still more that it was identical with both. What identity could he recognise, by outward observation, between a crystal of green vitriol and the iron and sulphuric acid from which it was constructed?

When the motive impulse has exceeded the limits, within which any particular material can resist its effects without its own destruction, it is no longer appreciable by the same means or scale of measurement as before, and it is said to have become dormant, or " latent," until it is again made evident by the opposite cause to that of expansion being substituted. The velocity of impulse *then* recoiling in the opposite direction, a concentration or condensation of the whole bulk proves that the particles are again drawn together with an energy as active as that by which they were before rent asunder.

The conclusions dependent upon these facts are sufficiently obvious to a moderate exertion of the reasoning faculty, and therefore it will not be necessary to analyse more minutely how heat becomes evolved in the changes converse to those produced by expansion, technically called its conversion from " latent " into " sensible " *caloric*.

The corollaries to these propositions will also furnish the explanation of what is called " specific heat."

" *Elasticity*," with its collateral quality, " *vibration*," signifies a very similar development of active phenomena. To take an instance. A spring is bent by means of a string, which draws its two extremities out of a straight line. Whatever active qualities the spring now possesses, in addition to its own passive materiality, are also shared by the string. A circuit of mutual relation is established between them; the tension is equal throughout, however dissimilar the materials may be; an equilibrium soon becomes established among all the particles constituting the circuit, and this would endure to all eternity, unless some event should occur to disarrange it.

Whatever results might afterwards be manifested on the instrument would be wholly due, and in precise proportion, to the degree and extent to which this equilibrium between the spring and the cord was altered; and the alacrity, which the transitions would manifest during the efforts of the particles to regain their former relative states, would be the exact measure of the effects produced. As a consequence of this, the displaced particles would be drawn towards their original positions with an impetuosity proportioned to the degree in which they were disturbed, and by the time that some of them reached their original positions they would have accumulated a velocity which would carry them beyond that spot, and tend to displace them nearly as far in the opposite direction; and were it not for external impediments, which it is not here necessary to expatiate upon, the persistence of the disturbing events might be prolonged indefinitely. The mutual interchange, however, of opposing movements, crossing and recrossing each other, which would naturally result from the actions and reactions instituted in the elastic machine just instanced, would create, by their successive incidents, an "extra-material" property in it, which would be easily susceptible of a mensuration by "time."

Qualities would thus be called into play, quite dis-distinct from those which the passive instrument possesses.

All such "extra-material" events of every sort bear the same relation to "time," which matter itself does to "space;" and, like as the measure of the entity of matter is the proportion which multitudes of equal and similar atoms bear inversely to the size of the "space" in which they are inclosed, so also the "extra-materialism" induced in those atoms will be proportionate to the number of equal and allied events included in the limited duration of "time" in which they occur.

Matter has only a feeble entity when not concentrated in bulk; and extra-materiality has but a faint development when the events in which it consists are spread out in time, and are tardy in their effects.

Therefore the extra-material quality neither consists in the operative nor resisting causes, nor yet in the equilibrium established between the two; but it distinguishes the state of transition which prevails when the equilibrium is altered, and active efforts are developed, whose tendency is to counteract the disturbance, and to draw the particles back to their mutual state of rest.

The extra-materialism consists, therefore, in the *contest* between reciprocating forces.

The word "oscillation" may perhaps imply as good a summary of the principle of extra-materialism as any other word as yet in use; but it is desirable that a new term should be invented to signify strictly and exclusively the active qualities which materials assume in their transitions from one state of "entity" to another.

Such a word could have an algebraical significance assigned to it, through which, by means of a multiple, after the manner adopted in the atomic theory, the comparative energy by which different entities combine in the formation of known substances could be accurately indicated; since it requires no argument to prove that the active results, engendered by the combinations of known materials, must have a ratio of comparison among themselves, as definite as that which is numerically displayed among the various atoms of which the entities themselves are composed.

And as it is possible to assign a numerical comparison among the molecules, whereby their ratio of combination as to quantity may be prefigured, in like manner the active forces which are called into play during their transitions must have a similar correspondence among themselves; and the ideas intended to be expressed by such words as "elective affinity" could doubtless, in a similar manner, be reduced to a scale as definite as that belonging to the atomic weights. Before attempting to invent a word which shall comprise "extra-material commotions," it is requisite that the reasoning upon which the necessity is founded should be acknowledged: until such is the case that question must be diffidently postponed.

But, without presumption, two conclusions may be adopted as the result of the foregoing propositions:—

First, that entity and active change are distinct in their ultimate nature; and, secondly, that however complex the entity may be, and consisting of how many soever dissimilar constituents, yet, when these all combine to produce any particular set of changes, the various materials employed in conjunction then constitute one "entity."

As the strung bow is *one* instrument, and all the events, associated in its product or function, form one "extra-material" essence, however dissimilar the constituent phases may be among themselves, even so the elasticity derived from the strung bow is the single product of many coincidences, and would have no existence if one of its contributing facts were obliterated.

CHAPTER III.

THE SIGNIFICATION OF THE WORD "LIFE."

EACH particular animal body, at any given time, consists of a multitude of dissimilar materials associated together, and circumscribed by an outline, within which is comprised the "entity" of which the whole consists.

This entity does not apply to identity of materials, since these are constantly changing during life, while the entity remains the same; but it refers to an identity of form, arrangement, and composition. It is possible that not only the entity, but the identity of the materials of the body might suddenly be stereotyped and preserved in an unaltered condition for centuries by the whole being frozen; but the preservation of its fixed identity, and the consequent cessation of all change, would annihilate those extra-material oscillations, known in a general sense by the word "Life."

It has been already remarked that for the production of any such rhythmical events as, from their uniformity and mutual relations, deserve to be comprised under this generic term, two other conditions, besides that of entity, are required before this extra-material quality can be evoked, and both of these are included under the word "Force," of which they are considered to be sub-divisions.

In order to "live," an entity, *i. e.*, a body of suitable form and materials, is the first condition implied; but this can exist in a very permanent state without any quality beyond its passive entity being present. An "exciting" cause, which shall inaugurate some changes, and an "operative" cause, which shall prolong them, or induce their repetition, are both necessary contributing agents to the production of those changes, which, becoming superadded to materiality, claim their assigned dimensions in the infinity of "time."

The word "life" implies the three conditions. First, the "exciting" cause, which inaugurates the changes; secondly, the "operative" cause, which induces their continuance; and, thirdly, those generic changes themselves.

The first two are anterior to, and beyond the confines of, unassisted human reason, and the sight and sense, by which they may be recognised and understood, do not belong to man's present corporeal entity; but the last, namely, the psychical commotions and generic changes, which proceed in rhythmical order, and bear definite relations to various contributing materials (both those belonging to the special entity of the body, and those which do not form part of its structure, but are equally essential to it), are susceptible of being generalised under one head, and their results are such as, from the nature of things, possess great uniformity.

For since the entity, amidst all its oscillations, remains the same, or is only altered in form or quality by secondary collateral circumstances, and the exciting and operative causes do not vary, it thence follows conclusively that the changes must consist of repetitions of similar events, or sets of events, very closely corresponding among themselves.

The word "life" does not, with absolute accuracy, apply to all and each of these, because many of the contributing occurrences essential to them could be equally well developed in materials to which there would be no pretence for attributing the faculty of "life;" and materials which previously *did not* constitute any part of the entity, said to live, act quite as conspicuous a part in the production of the phenomena as those which *did* so. Therefore the chain of events, resulting from these mixed coincidences, cannot, with rigid precision, be called "Life," because that is a condition strictly belonging to the entity itself; but the whole of these heterogeneous, though uniform doings, when combined together, concentrate themselves into a focus of events, emphatically claiming for their conjoint operations an allotment in the measurement of time; and for want of a better term, and limiting the word to the narrow meaning thus assigned to it, the whole set of extra-material phenomena may be suggested to the mind by using, for the sake of convenience, and without any pretence of philosophical accuracy or religious precision, the expression "animal life," meaning thereby simply the physical events by which that is invariably accompanied, and which, in their aggregate, comprise the various facts, without any or all of which it would be impossible that "animal life" should exist.

But if, in investigating the events that invariably occur in "living" animals, we aim at comprehending the *final* cause by which they are called into existence, undoubtedly we attempt to grapple with what, in the nature of things, is quite beyond the scope of our powers.

Such an attempt would be an effort of the less to contain the greater—an endeavour of the finite to measure its origin. Presumption, at least, if not impiety, would be implied by such a pretension. The faculty of reason, in its application to earthly matters, seems to have been given for one special purpose, and for which its attributes are suited, viz., to investigate the proximate laws which Infinite Intelligence has impressed upon all nature, to the intent that, by the knowledge thus acquired, its gifts may be employed, measured, and appreciated, and the beneficent purposes of their Maker be extended and diffused by an intelligent use of them.

If the reasoning faculty were not given for this object, then it would be clear that it could not be applicable for any good purposes whatever, and in that case would be the very reverse of a benefit; but if, indeed, that attribute may be employed at all, then to use it thus must be no less a duty than a privilege.

The propriety of such an application of the mental faculty to the events appertaining to the *inorganic* world has not, of late years, been questioned, at least, in civilised countries, and the efforts made to this end have been rewarded with a success proportionate to the zeal displayed in the search, and to the confidence reposed in the uniformity and congruity displayed by the laws by which inorganic matters are governed.

There can be no just reason for excluding *organic* structures from a like scrutiny.

The recognition of paramount laws, undeviating in their operation, maintaining universal supremacy over all created things (whether organic or inorganic), whose docility to them resembles that subjection which the laws themselves owe, and unhesitatingly yield, to the power whence *they* originated, is not the result of scepticism, but, on the contrary, of belief and obedience to the principles and data from which that recognition is drawn. In other words, that recognition implies honesty of purpose, while a fanatical rejection of their evidences proceeds from an opposite tendency.

Life is spread throughout creation in a lavish extent; the vegetable world attests it; the insects, birds, reptiles, and beasts bear witness to the varied and universal presence of its causes. Are these so many contradictions to the known laws governing the universe, or are they developments and harmonious results confirming and elucidating their wonderful excellence?

But in endeavouring to make out the physical contingencies, which invariably occur whenever "life" is present, let it not be an accusation that such an attempt is either presumptuous or conjectural; because, if it be right for man to exercise his reason upon the laws relating to inorganic matter, *à fortiori*, it must be more so to direct his thoughts to those higher combinations, which the *former* were created to subserve; and except that they should be recognised, and their Maker honoured in respect of them, the mandates relating to their construction, and to the uses which their various mechanical perfections were adapted to accomplish, would, as far as created beings in this planet could discriminate, have possessed a fruitless excellence; were it possible, indeed, that that which is fruitless could be excellent.

An inevitable necessity requires that all the manifold perfections of organisation must possess a crowning object, giving significance to their details, and that a *contemplative faculty* must somewhere be found capable of recognising and acknowledging their import.

Were it otherwise, they would owe their existence to an exertion of skill without purpose or result.

The culminating point to which *organisation* is subservient, and in which organisation itself terminates, constitutes the germ, or commencement, of a *new development*, of which the *reasoning faculty* recognises in itself the nativity, but into whose future progress and destiny it finds itself, while involved in the turbid exhalations of its present corporeal existence, unable to penetrate.

The crowning object and the contemplative perception become now, in dim portraiture and in a nascent state, a new production, being itself neither organic nor inorganic, but added on to organisation, and surpassing both—a phosphorescent light issuing out of their *débris*.

But if it were otherwise than right for man to direct his scrutiny to the laws which govern his intellectual nature, and also to those relating to organic and inorganic matter, then it would be evident that he ought not to exercise his reason at all, and the paradox would be proclaimed, that man was so much inferior and more unfortunate than all other created beings, in proportion as he possessed a faculty of reasoning from which they were exempt, if the only employment to which he could subject that attribute, without incurring guilt, would be that of suppressing its own powers.

Neither let it be argued that, in seeking to understand or arrange the essential events accompanying "life," or indicating its presence, the sequence is substituted for the cause, nor that it is pretended to state what life is, by simply making a catalogue of the events by which it is accompanied.

It is admitted that the abstract principle of "life," in its cause or ultimate nature, is neither the end nor within the scope of the present inquiry; but it may be allowable, in the absence of a more appropriate selection, to employ the four letters by which that word is spelt, to grasp and include all the physical events, which mark the distinction separating organic from inorganic operations. Any other word would be equally useful, provided that the meaning thus defined were attached to it.

Avoiding, therefore, all metaphysical discussion as to the ultimate nature of that which is commonly understood by the word "life," and employing that expression, in the limited sense now defined, to comprise only the physical events inevitably occurring while any animal lives at all, and using it only to embrace that particular result which all these events in their conjoint action of necessity give rise to, it follows that this extra-material quality, by whatever name it be distinguished, is essentially a transient operation, existing only during the space of time while all the contributing circumstances supply their concurrence; and its condition being that of an active agent, implying "*mutation*," in opposition to that of passive entity, implying permanence or fixedness, it is further demonstrated that this quality must not only be *transient* or mortal, but must also depend for its prolongation upon a continual supply of fresh materials from without, with which it may accomplish those mutations, and therefore an *extrinsic*, as well as *intrinsic* chain of causes must mutually coincide in producing whatever degree of permanence the succession of events may be susceptible of.

The following diagram will explain more fully the meaning desired to be conveyed :—

	Influenced by	Constituting as the result
Animal body	Intrinsic agents Extrinsic agents	Animal life.

	Consisting of	
Intrinsic causes	Decompositions	*a.* Those which occur as readily in the dead body as in the living. *b.* Those which can only occur while the body is in a living state.
	Fresh formations	*a.* Those which are final, *i.e.*, those which must in the next metamorphosis be wholly, or in a great measure, extruded from the body. *b.* Those which are preliminary to some other uses in the body.

Extrinsic causes	*a.* The air which is breathed. *b.* The food which is swallowed. *c.* The influences which relate to the production of fresh individuals.

Collateral causes, which do not at any time enter into actual junction with the materials of the body, such as climate, temperature, &c., are excluded from the list of constituent events contributing to the production of that complex whole, named in these pages "animal life."

For the continuance of those combined operations, by whose repetitions the series of events called "animal life" is kept in existence, it is necessary that the apparatus said to live should, as soon as it has completed each round or cycle of the collective "mutations," periodically vibrate back to a similar condition to that in which it commenced the succession, so as to be again in readiness to accomplish a similar task, and likewise that other materials resembling those upon which, and by the aid of which, it has already wrought its changes, should still be furnished.

Were it possible, by way of hypothesis, that *perpetual motion* might prevail among the particles of which the body is composed, a sequence of evolutions might then occur, vibrating back periodically to the same starting-point from which the vital operations first commenced; and the same materials being all restored to their original condition, in a state of fitness to repeat the same, no fresh materials might be required; but even in that case the necessity for a reciprocative action, corrective of the motive force which first induced the disturbance, must still be apparent, restoring back at definite intervals the constituent portions to their first condition relative to each other, otherwise the operations, whatever they might be, must speedily terminate, because, when one series of events had been completed, unless the apparatus were again in the condition in which that commenced, the next set of occurrences (if any such happened) must be different from the former, and, therefore, the first series must have ceased, and the same fatal catastrophe must sooner or later occur in every such automaton if either the motive or the reciprocative were to preponderate.

In the animal body two such conflicting causes must continually be in operation, counterpoising each other; and to the fact that they do not with perfect precision correspond with each other, are to be attributed the progressive alterations the animal body undergoes, occasioning its successive variations in shape and consistence, and at length the final termination to which those developments, in the natural course of events, inevitably lead.

But those changes, both motive and reciprocative, cannot be brought about by the agency exclusively of the body itself, and of the materials which it can itself supply.

Both the one and the other must be accomplished —at least, in part—by the aid of materials which previously formed no portion of its structure.

While one set of causes is producing certain changes in the materials of which the body is composed, another set is equally actively engaged in reproducing fresh fabrics, precisely similar to those which are being consumed by the operation of the first. A continual destructive process requires to be balanced by an equally persevering constructive one, and in both, commodities, which previously formed no part of the body, must be supplied.

In order to live, it is necessary that portions of the body should continually die. Every vital act compels the consumption of some of the materials of which the body is composed; and independently of that destruction which vitality requires and occasions, the body itself consists of ingredients so chemically constituted, as of their own nature, quite irrespectively of strictly vital causes, inevitably and rapidly insure their own destruction, when exposed to that atmospheric temperature and to other dynamical influences, under which alone it would be possible for the body to exercise any vital functions.

These latter decomposing influences have a disintegrating power, not only in the dead body, which it ultimately restores to the original inorganic elements from which it was first constructed, but produce effects quite as rapid in the living body also, and, indeed, form one of the links in the chain of events by which the body is maintained in a living state.

But the destruction wrought by these combined causes demands to be compensated for by appropriate reconstruction, and by the due removal of the products of destruction. During life the restorative, as well as the destructive, processes are energetic in proportion to the degree of active vitality then prevailing, unless, indeed, the converse be the more correct way of stating the proposition, *i.e.*, that the vital action is the consequence and the measure of the restorative and destructive processes at any given time in operation, and the vital result the evidence of its energy.

After life has ceased, some of the destructive agents are still at work in a less degree; but none of the restorative ones counterbalance their effects.

But these restorative processes, existing only during life, are only in part furnished with materials contributed by the body itself. Additional commodities require to be added to make up for certain ingredients, which cannot be restored from its own *débris;* and to occupy the places of those portions which, having arrived at a particular stage of combination, rendering them inapplicable to further uses within the body, need to be got rid of.

External commodities, previously forming no part of its physical entity, are the sources whence this reinstation is made; and, in order that these shall become available for the purpose, something more than mere passive supply is requisite.

The process by which these are initiated into the living structure, and thenceforth, for a time, become constituent parts of its fabric, constitutes the pith and point of the *secret,* separating organic from inorganic action, and makes all the difference between living and dead matter.

At the same instant that fresh materials are converted into living flesh, a similar change from a condition of living flesh into dead and excrementitious matter is taking place. This latter process is technically called "*secretion.*"

The action, or force, or property, whatever it may be, which induces inorganic substances to co-operate and participate in the performances by which vitality is sustained, is itself due to a conjoined action instituted between the blood contained in the lungs of the living animal, and the air with which it is there brought into contact, but which previously had no participation in its fabric. But this effect, resulting from the approximation of the atmospheric air and the blood, is not simply due to a mutual set of events in conformity with the chemical characters of each, nor is it a vital action of the blood in obedience to its own physiological properties; but it is a conjoint effect, in which the chemical action of the one coincides with the physiological attributes of the other.

But more than this. Each of the vital actions, of every sort and kind, which take place in any part of the body at any identical instant, forms an integral portion of one moiety of an event, common to the whole, in which the coalition of the air in the lungs with the blood contained in them constitutes the other half.

The air could not vitally combine with the blood in the lungs, with which it is brought into contact, unless the correlative vital actions in distant parts, corresponding in force and quantity, were at the same instant completed; neither could these distant vital effects be produced unless, at the same moment, the complementary changes were wrought in the lungs.

Vitality, therefore, may be considered as the conflict of the materials of which the body is composed with those by which it is surrounded, rather than as a process exclusively belonging to its own organised structure.

In brief, the animal body is not capable of maintaining its own "life," by any inherent faculty, exclusively of that engendered and renewed by "mutations" in perpetual operation among its own materials, nor of doing so by the aid of such materials alone, irrespectively and without the co-operation of external materials. The body cannot be kept alive by an inherent vital action, except in as far as that is fed and stimulated by the air which is breathed; and those mutations, which coincide with the vital action, cannot again and again be provided for by the repeated use of the same materials, which the body itself can furnish, without the addition of other fresh commodities derived from external sources.

The phenomenon of life, then, taken in the sense already defined, depends upon the conjoined operation of several contributing causes, of which the fabric in which it is exhibited constitutes one of them. By the withdrawal of any of these the conjoint result would be immediately destroyed; therefore the phenomenon does not wholly or exclusively belong to the structure in which it is displayed, any more than the flame of a lamp could be said to appertain wholly to the instrument, irrespectively of the air by which it is surrounded, and the oil by which it is fed. In both examples a joint operation is established, in which a certain intrinsic fitness, in conjunction with an appropriate external supply, equally participate in producing its effects.

But though such is the case with regard to those events included in the term "animal life," yet one peculiarity attaches to the fabric, wonderfully controlling all its rhythmical performances, and seeming to act like a special command, distinct from those physical laws which control the "vital mutations," distinct also from the intellectual faculty, to engender which is the end and object for which the whole was constructed. The peculiarity alluded to is that inherent faculty possessed by the living body, whereby it maintains unaltered the type and characteristic form derived innately from its ancestors.

How this arises it is at present impossible for man to do more than conjecture, and the means and agents by which the result is brought about are equally obscure. The materials of which the body is formed seem to have no power to modify or influence this invisible "force." The commencement of each individual can be traced back anatomically to a microscopical globule, and it is in this molecule that is compressed the faculty of again developing all the peculiarities which its predecessors have exhibited, and which shall in due time be transmitted to its successors in indefinite multiplication. Let the materials of which the body is formed be again and again wholly renewed from the most opposite and conflicting sources; let them be drawn from the ocean, from the atmosphere, from vegetable or from animal supplies, from all or from any; let the air which is breathed, or the climate which surrounds, be changed, or remain unchanged—it matters not; the "power" which moulds all these conflicting events to one definite result, remaining unaltered, still prevails, man knows not how.

In all other phenomena which man has the power of studying, a certain definite material is requisite for the exhibition of any definite law; but in this instance the law itself seems to prevail, uninfluenced by, and independent of, all subjection to materials.

Should this coercing power, which compels all materials, however heterogeneous, to contribute to one unalterable result, be called "life," and all the changes which take place be considered as the by-play, while the great result proceeds within the cabinet itself, then "life" in that sense must be an *ultimate* law inscrutable to man, because man has no means of studying powers except in their *proximate* effects upon materials; and "life," in the sense above supposed, is not the object of study now aimed at, which has no higher ambition than to discover the definite effects on materials concurrent, if not identical, with "life" itself.

Though this property of blending and subjecting all those heterogeneous and possibly contradictory matters, which the body has at various times to deal with, so that the type and order of all the various parts, in all their minutiæ, shall be maintained unimpaired through a long series of years, cannot be attributed to chemical or philosophical laws, with which man has at present any cognizance, or which furnish him with any data of measurement or comparison, still it is very necessary that the fact should be both acknowledged and appreciated. The results, though not the cause, are very obvious and distinguishable.

Herein is something permanent and unaltered amidst perpetual change, and which perpetual change is essential and inevitable to the maintenance of that same unalterable and permanent phenomenon.

Undoubtedly, if that which is "*permanent*" is "life," then that which is *mutable* is not life; and if the fact that the permanence belongs to the race in a stronger degree than it does to the individual be taken into consideration, it may be allowable to discard this chain of phenomena from the consideration of those specially relating to individual "animal life," in the limited definition ascribed to that term, since the two are evidently not identical, however nearly allied they may be in their *original cause.* The coincidence of like events with respect to vegetables corroborates this view.

But if it is difficult to assign the reason, why this permanence of type should be maintained with such remarkable constancy, it is still more so to ascertain whence it proceeds—rarely, indeed, but still it does happen—that this type itself becomes altered and vitiated, as in some few instances of congenital malformation (to which the alteration in type may be assigned as a cause), and also when the natural structure of the body becomes changed in its character, and cancerous and other *unnatural* growths—resembling, indeed, but still different from, the healthy and proper formations—take the place and are substituted for the latter.

These deviations from normal structure—namely, the perversion of the creative power, from an error of that process, which should regulate the type and maintain the adherence to the primitive shape and character of the various parts of the body—are rare in comparison with those other deviations, proceeding from causes sufficiently obvious, and which are susceptible of being detected, and in many instances remedied, by duly instructed persons.

Some reasoners attribute these unnatural formations to an error of the "vital" principle; but until the nature of the vital principle, as they would explain it, is clearly understood, the reasoning on the subject is not at all advanced by adopting such a phrase. But it may certainly be affirmed that it is not due to that "vital principle," as that term has been defined in these pages, which is confined to the chain of events, or "mutations," of which the action of the air in the lungs, upon the whole circle of the blood throughout the body, is the efficient agent and operative cause.

As those changes, in their mutual dependence and relation to each other, constitute in the aggregate the condition called "animal life," it is manifest that certain other changes, which produce results hostile to the former, cannot be the same as those to which that definition is applied ; therefore the causes, whence those unnatural formations are produced, must be sought for elsewhere than in the causes, by which the healthy and restorative processes are maintained.

Three kinds of existences or immutabilities, drawn from mutable things, have timidly, and it is hoped reverently, been endeavoured to be traced in the previous words of this chapter, each successively blending into, and giving origin to, the next.

First. The immutability of the primitive laws by which *unorganised* matter is controlled—immutable as far as man's finite understanding can comprehend immutability, because the possibility of a season arriving when material creation will be emancipated from their control, points to a region of time to which the mental attributes of man cannot reach, nor afford him any clue.

Secondly. The development of fresh laws, to which the former relating to *inorganic* matter were subordinate and ancillary, whence spring the multiform and various, yet constantly reproductive permanence of organised creation, animal and vegetable, inaugurating an immutability correlative with the commands from which itself issued, which in its turn brings into being and engenders from its ruins,

Thirdly. An immutability, brighter far and still more enduring than either, namely, the brightness of the spiritual essence, whose home is beyond the decaying organisation whence it derived its birth.

All investigation into the properties of matter, organic and inorganic, proves that one universal key-note prevails throughout creation, uniting in one song of jubilee the mighty and the minute; that trumpet voice which, from the beginning to the end of time, vibrates throughout the universe—the voice of the Creator—which the rocks and the sea obey, but which man, though he may recognise it with all the force and vividness of which his intellectual nature may be capable, can but feebly shadow forth when he tremulously articulates conjoined epithets, "Power" and "Goodness," and "Majesty" and "Honour"—expressions whose feebleness to grasp proclaims the mightiness of the thought which fills every avenue of his mind.

Except by the gift of his reasoning faculty, man could make no employment of the benefits which creation imparts beyond that of causing them to conduce to the merest animal wants: their beauties, their excellence, and their beneficence would be lost for want of the faculty to discern, acknowledge, and appropriate them. Can any one dread that this impression could suffer diminution by extending the contemplation from inorganic to organic, or, higher still, to mental creation? Is it forbidden to man to pry into that quality with which the Author of creation has crowned his work—that quality, abstracted from materiality, which still bears some resemblance to the crystal source whence it originated—that sea of glass, in the midst of the throne, to which it is again flowing, though turbidly, from its present admixture with attributes whose essential affinity to their divine origin is more remote?

Is the faculty, by which alone anything that is excellent can be discerned in the physical construction of things on earth (as far as such could be discoverable by the eye of any created being on this planet), to be itself the only development of the Creator's power on which it is forbidden to man to cast a glance? Is it due to Him who gave the mental faculty of seeing, that man should be wilfully blind to the most glorious of the achievements which He has given him the power of contemplating, namely, that very power of contemplation?

Can it be, then, an act of impiety to endeavour to learn His will, by studying that spiritual quality which men call "intellect;" which forms the climax of the Creator's best work here upon earth, and the index of the greater glories which are beyond? It cannot be possible that, in scrutinising the proximate laws which relate either to the material creation or to the intellectual developments that spring from it, more can be unfolded than its Author intended should be known, or that man should thus invade the prerogatives of his Maker.

In the present creation it is not difficult to perceive that inorganic laws subserve the purposes of the organic world, which, in its turn, ascends out of and beyond organisation into a region of which human intelligence displays, as it were, the glimmering initiative; and this preter-organic quality stretches away beyond the confines where the mists and clouds, by which its present atmosphere is obscured, intervene, and, in so doing, becomes conscious of an effulgence beyond its own scope, which, but for the veil which now interposes, would scorch up and destroy all that now appertains, organic and inorganic, to the being in which human intelligence now burns with its flickering flame.

Those are regions which man submissively recognises that his Maker has enjoined that he shall not yet explore. His portion is not there while organisation remains.

CHAPTER IV.

ORGANIC OPERATIONS: THEIR ANALOGIES AND CONTRASTS.

It has been shown in the previous chapter that one distinguishing characteristic of "life," whether in the vegetable or the animal world, is constant interchange in the materials of that which is said to live with those external supplies by which it is surrounded.

In proportion as the commotion thus excited is rapid or otherwise, the intensity of the vital principle is greater or less.

A tree may, therefore, be said to live less absolutely than a man, and a man than a bird, in which the organic changes are more rapid, and the results more energetic.

The maintenance of a fixed type or outline of form in certain minute new formations, and the perfect resemblance of these, not only in shape, but also in the actual chemical elements of which they are made, to those which preceded them, constitutes another very noticeable peculiarity essentially belonging to "life," in the rude acceptation of the term, applicable to both vegetables and animals.

Both an analogy and a contrast to these changes and reproductions may be drawn from those events which are known to occur in the different kinds of fermentation.

Grain, sugar, wine, and vinegar are all compounded of similar ultimate elements variously combined, namely, oxygen, hydrogen, and carbon. Some of them likewise possess an identity as to the relative proportionate qualities of each of their ingredients, the difference consisting in the varied manner or pattern in which those elements are interwoven, just as very dissimilar buildings may be constructed of bricks, timber, and plaster, though the materials themselves, as well as their relative proportions, might be found not to differ, when the buildings were pulled down, and each of the constituent parts was arranged on its appropriate heap.

The processes by which each of the commodities named above is taken to pieces and rebuilt—so that of the materials of starch (in the grain) sugar shall be made, sugar shall be converted into wine, and wine into vinegar—are each called "fermentation," constituting a "saccharine," a "vinous," and an "acetous" fermentation, to which may be added a "putrefactive" fermentation, by which last the materials are again restored to the inorganic world—the earth, air, and water from whence they sprang originally.

The highest point from which they descended, namely, grain, was at first in a condition in which "life" may be said to be "latent," because, though the functions of vitality were not at that time in actual operation, the elements of which the grain was composed were in such a state of arrangement that the appropriate stimulus was only required in order to develope all the phenomena which belong to vegetable life.

Therefore grain in its quiescent state may be considered as the connecting link between the processes of fermentation or reduction, on the one hand, and "life," or building up, on the other.

Heat is produced spontaneously in each of the different fermentations, and the rapidity of the changes coincides with the energy of the specific operation, and they therefore become convertible terms: the changes and the specific fermentations, when spoken of in the aggregate, are synonymous.

A very slight change of outward circumstances is sufficient to induce the commencement of any of these fermentations in the descending scale; but man has no power of reversing the events so as to change vinegar into wine, and wine into sugar.

A feeble durability, alternating with an active commotion, prevails in the intervals between these successive fermentations; but that word itself applies to the active, and not to the quiescent state of the particles.

In each of them there is a strong tendency, when once the requisite action has been begun in any portion, however small, that the impulse under which it acts should be rapidly communicated to the remainder, and that the process should go on in accelerated velocity, until the changes should have involved all the materials capable of exhibiting them; and the commotion once excited can usually be only brought to a conclusion, by the absence of any fresh commodities, on which the same events can be exhibited.

Could fresh materials be gradually introduced, and the products of former changes be as gradually removed, no doubt the operation might be prolonged indefinitely, and some of the lowest forms of vegetable life may possibly be compared to such a condition.

But the ordinary processes of vegetable life, when once established, differ from fermentation in this—that the tendency is not to produce a fresh and different substance in a lower state of combination, but constantly to reproduce new formations, corresponding in form, in materials, and in properties with those which the changes have already destroyed, or are destroying.

These new formations, which it is the function of vegetable life to create, have an innate tendency to increase in numbers by a process of multiplication, since each vegetable molecule in which these changes are wrought bursts, and sets free from its interior numerous other small bodies similar to itself, but in a less developed state, each of which in its turn repeats the same process, and the constant repetition of these events constitutes the one permanent operation which the life of plants exhibits.

The nutritive fluid, derived from the earth, enters the spongioles of the roots, influenced by laws which the inorganic matters also acknowledge; it ascends in the form of sap, supplying appropriate nourishment to the molecules in which the changes occur, and thereby assists in the formation of fresh molecules, which float upwards as the sap advances; while the residue, consisting in a great measure of the shells or outer cases of defunct molecules, becomes deposited in the form of lignin, or woody matter; and in this residue the property of life may be said to have ceased, since no further change takes place in its constituents, except that of compression, perhaps for centuries.

The changes in the sap constitute the leading peculiarity from which all subsequent events, incidental to what is called the "life" of the plant, are derived, as from a necessary antecedent. While these continue the plant may be transplanted, and will grow according as outward circumstances are favourable to those changes or otherwise.

All durability, which may belong to any portion of the plant, can only be obtained in proportion as these changes are made to cease.

If the lignin is to be used as timber for permanent purposes, a termination of the changes in the sap must be secured, before the wood itself can safely be exposed to decomposing tendencies, otherwise the proneness to change, which exists in the sap, will extend to the contiguous lignin, and, in the absence of the supply which the ascent of the sap should provide, will induce its decay: the plant, in its attempts to live, will feed on its own lignin.

Events similar to these, namely, the production of globular bodies floating in the natural juices (or blood) of the living fabric, which, arriving at a certain maturity, burst and set free from their interior other similar globules, likewise occur in animals; but to these is superadded the specific influence which constitutes the difference between the "life" of animals and that of vegetables.

This specific event is derived through the agency of the breathing apparatus, in connection with a circle of blood, which is an essential accessory to the respiratory function.

In vegetables, the bursting of the cells floating in the sap not only sets free fresh cells, which are destined to burst in their turn, but the outer cases of the cells remain, and, cohering together, form tubes, or channels, through which the sap containing fresh molecules, continuing to ascend, is conveyed to distant parts, and thus the residue of the cells construct a scaffolding or skeleton of the tree. The natural result, therefore, of these changes is to increase indefinitely the bulk and dimensions of the tree; and this increase of size is only terminated by some cause which shall bring the changes themselves to a conclusion.

In animals, however, the case is, in some points, similar, and in others it is different. The materials by which their structure is repaired are, in a similar manner, taken up by the organs, which represent the spongioles of the roots of the plants, namely, by the lacteal and lymphatic absorbents, and are conducted by the tube which answers to the stem of the plant, namely, by the thoracic duct, to the blood itself, and by it they are conveyed to all parts of the body where the nutritious supply may be required.

During its transit through these channels, the vegetable functions (or rather, those functions in animals which resemble those of vegetables) may have been very accurately performed ; nay, long after the death of the animal in which they occur, they may be seen still perseveringly repeating the same process in a very energetic manner ; yet the materials so supplied, however perfect they may be, can only be worked up and interwoven into the fabric of the body, by the means of a particular impulse, which is derived from the process of breathing. The vital shuttle, which interlaces these into animal flesh, requires to be impelled by an influence operating throughout the whole vital circle, which particular impulse the air is capable of generating in the act of breathing; and the effect which results from this is operative, not only in the lungs, but also, at the same time, in the distant parts, wherever the vital tissue is being spun, or any strictly vital act is being performed.

Any person who should observe the hammers, in the interior of a piano, striking the wires, would admit that the musical note was not only due to the action of the hammers, but also that the fingers of the player, by striking the ivory keys, had an equally potential influence in creating the sound, although it might be very evident that neither the ivory keys nor the fingers of the player actually touched the wires where the note was elicited. He would readily admit that the *motion* of the finger on the ivory key, and the *action* of the hammer on the wire, were both occupied in the production of the result.

In like manner, the action of the atmospheric air in the lungs, when brought into contact with the blood in the pulmonary capillaries, not only produces a *local* effect on that fluid analogous to the action of the finger on the ivory key of the piano, but likewise excites in the systemic capillaries a corresponding set of events, although these latter capillaries may be placed at a considerable distance from those, with which the air is brought into direct contact.

Certain intermediate rods connect the ivory key, in the piano, with the hammers which strike the wire, and certain intermediate tubes, called arteries and veins, connect the pulmonary capillaries, where the air exercises its force, with the systemic capillaries, where the process of creating renewed animal flesh resides ; and the blood which these arteries and veins contain is the only direct means by which the fluids belonging to the opposite sets of capillaries communicate with each other.

Moreover, in case the hammer in the interior of the piano should at any time, owing to some accident, happen to be so put out of order as that it could not strike the wire, it would then probably be found that the ivory key also would be in such a condition that it could not obey the finger: not only would the hammer fail to strike the wire, but the key itself would be immovable to the touch of the finger.

In a similar manner, should it so occur that the distant systemic capillaries might, at any given time, be unable to perform the part of the vital task implied in the creation of renewed animal flesh, which the process of breathing ought to call into exercise, then, although the atmospheric air might be brought into contact with the pulmonary capillaries, no vital combination between that air and the blood would take place, because the equivalent effects, which ought to happen at the same time in the distant systemic capillaries, were not executed.

The combination of the air with the blood in the lungs can only occur in precise proportion to the amount of action in the systemic capillaries; and this systemic action, in its turn, can only happen in exact proportion to the amount of vital combination which actually takes place between the atmospheric air and the blood contained in the pulmonary capillaries.

These converse operations mutually counterpoise and regulate each other, and this they do by the blood, which establishes two channels of communication, by means of blood-vessels, between the capillaries, where each operation takes place; one of which channels is through the left side of the heart, and the other is through the right side; the one going, the other returning.

The amount of systemic vital function which occurs will, therefore, exactly tally with the amount of vital combination between the air and the blood, which takes place in the lungs, and the amount of combination which is there made to happen will neither exceed nor fall short of that which the systemic capillaries discharge.

The action of the systemic capillaries and that of the pulmonic ones constitute one undivided operation, and coincide the one with the other, as much as the action of the ivory key, in obedience to the finger, coincides with the motion of the hammer on the wire of the piano in the production of one result, evidenced in the latter case by the musical note. They form each a moiety of one joint performance, to which the other is an essential contingency, and the operation of one cannot be dissevered from that of the other.

These facts do not depend for their confirmation upon deductive reasoning alone, but have been established very conclusively by a series of careful experiments, to which that distinguished anatomist, Mr. S. Lane, most kindly lent his valuable assistance and persevering co-operation.

But it has been shown, by experiment, that the supply of materials may continue to be manufactured by the lymphatic and lacteal absorbents, and be by them conveyed into the blood itself, even after life has actually ceased; and that the same occurs during life is equally beyond controversy. It is manifest, therefore, that those changes which occur during the transit of the fluid through those ducts, though usually concurrent with vitality, are not identical with it, but are, on the contrary, independent of those causes, which strictly appertain to "animal life," since they can occur when that is absent. Their action bears a resemblance to the processes which belong to vegetables, rather than to those which relate exclusively to animals. The lacteal and lymphatic fluids, then, continuing to be supplied in obedience to causes, which are only incidentally allied to vital requirements, must be liable to redundancy as well as deficiency, according as the supplies may vary. That such is the case is sufficiently proved by the process continuing to go on after vitality itself has ceased, furnishing at once an example of superfluity; and it is very clear that should it so happen, at any particular time, that all the materials furnished should not be immediately worked up into the fabric of the body itself, there would then be a considerable risk of such an excess.

To meet this contingency, certain filtrating organs, called glands, are provided, by which these redundant matters, together with certain other products, (the residue of the natural changes which are no longer serviceable,) are extruded from the circulation, which they would otherwise have a tendency to block up and impede.

Plants, indeed, draw their nourishment from the earth in which their roots ramify ; but animals, being for the most part locomotive, require that they should carry the soil, from whence they derive their supplies, within their own circumference, and it is therefore necessary that their commissariat should be both compendious and capable of being frequently renewed. The concentrated form in which the food is placed within their bowels accomplishes this end.

In order still more to economise the bulk of portable nutriment, the lymphatic vessels are employed in gathering up, from the redundant material dispersed over the body at large, such commodities, even though they may have already been employed in the fabric itself, as may still be suitable for the services demanded of them. But these lymphatics have a further use, namely, to keep up a supply of nutriment in a more advanced condition of culinary preparation, than the more crude fluid, recently derived from the external world, could supply. Experience shows that an adequate supply of healthy lymphatic fluid is even more important than fresh contributions, drawn immediately from the food itself.

When, from insufficient vital action, occasioning an insufficient consumption of the material, furnished for the demands of vitality, or other causes, a redundancy of nutriment is found in the circulating fluid, the fact is usually proved, and the remedy provided, by the diminution of the appetite. The regulating agency, which it is the function of the nerves to supply, comes into operation in such cases.

The laws which appertain to them will be discussed in the appropriate chapter.

Vegetables, therefore, form a bond of connection between inorganic matter and animals, and accomplish the preliminary changes which enable the latter to dispense with the inconvenience to locomotion, which the bulk requisite for their nutritious supply would occasion them, unless that had first undergone concentration by the previous preparation, which the processes of vegetation are capable of accomplishing.

Animals, in like manner, establish the connection which exists between present created things, and that higher development which has its commencement in the perceptive and reasoning qualities of man. Even the thoughts which spring out of man's organisation may remain a permanent reality, long after every vestige of that organisation shall have been utterly annihilated. Still more may it be that the mental creation whence those thoughts were distilled—like deciduous products, which it was enabled to shed, while the faculty itself remained unimpaired and undiminished—may be destined hereafter to hold its own continuance, independently of the organic elements out of which it ascended.

Breathing, then, and, as a necessary part of that function, a circle of blood whose properties are governed by the air breathed, constitutes the essential characteristic which distinguishes the life of animals from that of vegetables. The instant an animal breathes it begins to live, and when it ceases to breathe it ceases to live.

Accessory circumstances, such as muscular irritability, the spontaneous passage of fluids through the ducts, the continued peristaltic motions of the intestines after death, and the like, must be considered as results of life, or adjuncts to it, and quite distinct from that property itself, or from the motive causes which govern its operations. And as many of these remain in activity for some time after life has ceased, of which the heat of the body is an example, so also many functions—such as those of the nerves, for instance, volition, sensation, the elimination of effete or superfluous materials, commonly called "secretion"—though some of them actually cease, in many cases, before "life" itself has departed, may, it is presumed, be very fairly looked upon as the products and evidences of vitality, rather than as themselves forming an integral part of that property.

Until an animal has itself breathed, it has no separate or individual existence. Previously to this, while in the fœtal state, its fabric has been wholly governed, and its functions performed, through a vital influence which belongs to its parent, by whose breathing its various parts have been brought into a certain physical condition, *ready* to receive life. It has had no *independent* vascular circle, but that segment of a circle which it possesses has been completed into a circle by a segment, which has supplied its pulmonary force vicariously by passing through the lungs of the mother.

Hitherto its growth has been parasitical; and though, in some tribes of animals, the structure of their progeny attains a very high degree of perfection previously to breathing, while in others, as in the monotremata and eggs of birds, their organisation, at the period when they first enjoy an independent existence, is very imperfect—in the latter, indeed, it can hardly be said to have commenced—still the animal existence and the separate vital identity in all begin only at the moment when their circulation is first influenced by the air which they themselves inhale.

In the case of birds' eggs, the air, permeating the shell, excites the first vascular loop of blood in the allantois, and regulates all its subsequent developments, aided, of course, by external warmth. This air communicates the first impulse by which life is imparted to the prepared ingredients, and maintains its flame as long as the fabric thus commenced endures in its new existence.

In some animals, then, breathing and separate life commence when the physical frame hardly possesses a trace of development; in others the corporeal fabric is only imperfectly formed when breathing and separate life first occur; while, in the highest, separate and independent vitality is postponed, until all the organs with which the animal is to be endowed have been completed, and the creation of the animal has, so to speak, been brought to perfection.

In this latter case, the beautiful mechanism (which has been slowly collecting, and so minutely becoming gradually fitted for a future purpose, to which its fœtal condition bears no analogy) has constituted a part of the physical structure of its mother, as strictly so as any other part of her frame, and is destined to be detached from her only by a process of natural amputation.

It is true, a certain stage of physical development, or capacity for separate existence, may be attained before that independent condition actually commences. The mother may die from sudden accident, and the offspring being brought, some time afterwards, into the air, may still be susceptible to its influences, and begin to live. Its existence being in the mean time in abeyance, its actual life can no more be said truly to have commenced, than the seed, which has been inclosed for centuries in the folds of a mummy, can be said to have begun to grow when first placed there, or than a railroad engine, remaining in its station shed, can be said to have been absorbing latent motion all the while. The heart of the fœtus may or may not, (it matters not to the argument,) have been feebly beating while in that state of suspended (or rather, unbegun) animation, because the blood in the placenta may have been sufficiently arterialised by the mother's previous breathing to enable it to do so, and may thus have sustained a motive impulse, as regards the heart's pulsation, analogous to the peristaltic movements before mentioned; but this would only be a participation in the same conditions (animal heat included) which the dead body of the parent might still exhibit.

But it may possibly be contended that the action of the heart of the fœtus, being otherwise than synchronous with that of the mother, proves a separate existence; and it is granted that, if the pulsation of the heart were to be taken as synonymous with "life," such an objection would be very valid; but if the action of the heart be considered as one of many results which the breathing excites and governs, it is not at all difficult to account for the fact, that while a certain pulsation may result, in the larger and more developed heart of the mother, in obedience to a particular vital influence, the smaller, more irritable, and more recently constructed heart of the fœtus may be thrown into much more rapid action by the same vital force being communicated to it. The organs are different, but the facts do not prove that the vital force, by which they are thrown into action, may not be the same.

These conclusions are drawn from investigations and experiments which have been already published, but which it is not considered necessary to repeat in these pages.

During the suspended state of being, which forms the interval of transition between maternal and independent existence, the physical structure is, as it were, ready to receive its vitality. The armature is applied; but, in order to complete the circle, the appropriate stimulus, which should connect the opposite poles, and excite the vitality throughout the circuit, is wanting, until the air, acting upon the venous blood in the lungs, supplies that deficiency, and calls that force into existence.

All the responsibilities of existence, up to this period, have been exclusively those of the mother. With good reason, the Grecian mothers contemplated beautiful statues during their pregnancy, in order that the formation of their infants might partake of their excellence of outline: with much greater reason do Christian mothers contemplate and cultivate in their minds gentleness, benevolence, cheerfulness, and goodness, that the physical structures of their descendants may each become a suitable habitation for a soul possessing those qualities. For, as the influence of human passions leaves its impress upon the countenance, whereby a physiognomist can read the secret character, so also do sentiments indulged in by the pregnant woman mould the physical and mental attributes of her progeny, at least so far as those qualities depend upon configuration. Throughout creation fitness and congruity prevail. The ploughman mercifully has a mind and body given him suitable to his duties, and this independently of education; the disposition and intelligence of a greyhound are such as are well adapted to his shape and physical powers; and the corporeal frame of man, fashioned in unison with the passions of the mother, in whose life it originally partook, receives a soul adapted for the temporary abode which has been modelled for its reception. The new-born child of man, thus grown and detached from its predecessor, now comes into the world, furnished with all its organs, perfect in their outline, though imperfect in their maturity.

These functions, which it now begins to execute, it will continue to perform as long as it lives at all.

I. It breathes. II. It takes food. III. It uses its muscles. IV. It grows. V. It exercises its sensorium, and the nervous centres employ the controlling functions which belong to them. VI. Its senses assume their sway. VII. In due time it produces a successor. And VIII. Finally, it dies.

All these performances result from processes which commence with the first air that enters the lungs, and which the structure has previously been prepared and fashioned to accomplish; and, when once commenced, they continue to act, though subject to vicissitudes, until the moment when the last breath is drawn.

CHAPTER V.

ON THE FUNCTION OF BREATHING IN ITS RELATION TO THE CIRCULATION.

Breathing, then, is a function in which every part of the body participates, and which plays its part in every vital performance that each organ executes.

In insects the air itself is carried, by means of pipes, to the localities where each individual function is discharged, and each portion of the body performs its own independent breathing at the same spot where a demand is made for the vital stimulus which the air can engender.

In other animals, on the contrary, the blood itself is carried, by means of pipes, called veins and arteries, to a central locality, where it can be exposed to the air. In those animals, therefore, the ostensible acts of breathing are performed in a separate chamber or compartment of the body, set apart for that purpose, and the blood is, as it were, elongated, or made continuous, from the localities where the general functions of the body are performed, to the place provided for its exposure to the air.

By this prolongation of the blood from the localities where the general functions are performed, to that place where the atmospheric influence is communicated to it, an uninterrupted continuity of the blood, both coming and returning, is maintained between them; and thus those opposite sites, though placed at a distance from each other, are brought into intimate communication, and the same blood, coming from one, and returning to the other, is common to both. The same end is thereby accomplished, as if the air itself were carried to the organs where the general functions are performed.

Several advantages are gained by the fact that the air is received into a central chamber of the body, in animals in general, instead of being, as in insects, dispersed over the various structures of the body.

First. The bulk of the body is much diminished, in proportion to the space it would otherwise have to occupy.

Secondly. In consequence of the veins, which assemble the blood from all the various organs of the body, emptying their contents, in some animals, into a large blood-vessel, and in others into a cavity which answers the same purpose, called an auricle, the whole of the blood becomes thoroughly mingled and blended together.

Thirdly. By being spread out in the breathing organs, and dispersed over a wide surface, minutely reticulated by myriads of small capillary tubes, into which the whole quantity is equally subdivided, the blood is thereby subjected to one universal influence of the air, acting equally and impartially on every portion of it; a rapidity, as well as uniformity of effects, is thus secured.

Fourthly. By the blood, which has undergone this influence, being again collected equally and indiscriminately from all parts of the breathing organs, and being again assembled into a large blood-vessel or receptacle, where it is a second time intimately blended and mixed together, the whole quantity, which is then dispersed to the same organs, from which that blood which went to the breathing organs was derived, is rendered of one uniform character and quality, and all the various organs of the body become supplied with a fluid exactly corresponding in all particulars.

Fifthly. By the changes which the blood undergoes in the lungs, a vital orgasm of one uniform and universal character is called into operation, and is made to pervade the whole body, uniting every part in one consistent and equable series of effects, and causing an unanimity to prevail throughout all the various organs, which would, perhaps, be more aptly expressed by the French word "*ensemble*" than by any English term.

Blood of precisely the same character is supplied to all and each of the organs, and a single and equal vital orgasm is communicated to them all; therefore, unless they all act in precise unison, the deviations must be due to secondary or extrinsic causes. (It may be incidentally remarked that the nerves, by the influence which they exercise, are the principal operative agents of the deviating causes.)

The lungs are merely the administrative agents for all the other parts of the body, by which this function of breathing, which belongs to all of them collectively, is performed.

The lungs are inclosed in the cavity, or compartment of the body, set apart for their use, and are themselves carefully folded up within it, in a double layer of a delicate tissue, called the *pleura*, which resembles the silver paper with which one incloses any valuable apparatus.

The two surfaces of this membrane do not adhere to each other, except in cases of disease, and then the efficiency of the lung itself, which they surround, is impaired. The outer surface of the lung is separated or insulated from the surrounding parts by these two layers of the pleura.

One of these layers lines the inside of the thorax, adhering to it like paper to the walls of a room, and the other layer incloses the lung itself, to which it closely adheres.

The two surfaces of the pleura—namely, of that which covers the lungs, and of that which lines the chest, which look towards each other—are very smooth and polished, and they are quite distinct as regards their surfaces, though they are continuous by their edges, where the contraction, called the root of the lung (or which might more reasonably be called the stem of it), creates a fold, at which place that portion of the pleura inclosing the lung terminates, and that which lines the chest commences, and the two there merge in each other.

Each of the lungs resembles a leaf, of which the petiole represents what is called the root of the lung; and this petiole consists principally of the larger air-pipe, or tube, by which the breath is conveyed to the interior of the organ, accompanied by the blood-vessels, going and returning, which especially are concerned in the function it discharges. This air-pipe, called the bronchial tube, is a continuation of the windpipe, and divides again and again into lesser tubes, and each of these at length terminates in an incalculable number of minute globular cavities, called air-cells. These are divided into groups or clusters, in each of which a minute air-tube terminates; and several of these groups cohering together in a little congeries, constitute a lobule, which is partially separated from other contiguous lobules by a fold of the cellular tissue, by which the whole is surrounded; and the whole of these lobules, assembled together, form lobes, of which the right lung has three, and the left only two.

If each lung could be spread out, it would be found that an upper and an under surface could be distinguished throughout its structure, just as in a leaf. In the upper surface the air-cells, or parenchyma, of the lung could be seen, and in the under surface, that which answers to the venation of the leaf, and which consists of the air-tubes, accompanied by the blood-vessels, conveying the blood to and from the air-cells.

The blood which is called "venous" is conveyed to these air-cells by blood-vessels, called pulmonary "*arteries*," and that which is called "arterial" is conducted away from those air-cells by vessels which are denominated pulmonary "*veins*." The solecism arises from calling the heart in mammalia "the centre of the double circulation," which is another error of words equally glaring. There is, in point of fact, no double circulation in mammalia. The blood, returning from the various parts of the body towards the lungs, is assisted on its course by two contrivances for its propulsion. The second of these is the more muscular of the two, and is called the right *ventricle*, while the other is called the right *auricle*, and the two together are denominated the *right side* of the heart; and the arterialised fluid which returns from the lungs has another similar, but more powerful apparatus, which is called the *left side* of the heart, to propel it onwards towards the various parts of the body to which it has to be distributed.

In passing through the respective auricles and ventricles the two streams are kept wholly asunder, and they do not form any junction in the heart, so as to complete a circle.

The continuity of the circle is only formed where the terminations of the venous current join with the commencements of the arterial in the lungs, and the terminations of the arterial communicate with the beginnings of the venous blood in the various structures of the body.

Except by means of these two sets of capillaries, the arterial and venous streams do not form any junction, so as to constitute a circle. By the junctions, however, which these two sets of capillaries establish between the arterial and venous blood at each extremity of both, a perfect circle is formed, which has no claims to be called a " double circulation."

The term " double circulation " is usually described as consisting of a lesser circulation through the lungs, and of a greater circulation through the body in general, but neither of these separately forms a junction so as to complete a circle ; but when both are taken conjointly, then a complete circle is formed. Therefore they together form only a " *single* " circulation.

Moreover, it could be easily demonstrated that, as regards the quantity of blood sent to both, that which is called the lesser circulation exceeds in quantity the other, since precisely the same blood which leaves the lesser is transmitted without any addition to the other ; but that which is sent to the lesser consists of that which has afterwards to suffice for the greater, and it also receives that additional quantity which is requisite to supply the consumption made by the function which the lesser discharges. Therefore it is quite erroneous to speak of mammalia and birds as possessing a " double circulation," consisting of a greater and lesser circulation.

When the junction of the two kinds of blood is formed in the capillaries of the lungs, and likewise in those of the system at large, the whole then forms a "*single*" circulation.

These two opposite junctions can only be effected by means of the vital force, which the breathing can call into exercise.

The two sets of capillaries, placed between the extremities of the blood-vessels, containing the arterial and venous kinds of blood, interpose a resistance to the intermingling of the two fluids, and this resistance can only be surmounted by the aid of the vital force derived from the breathing; therefore the degree and energy with which the obstacles are overcome are the measure of the intensity of vital force then called into exercise, and the degree of vital force which the breathing at any time engenders is the gauge of the resistance which these capillaries offer.

In mammalia and birds the blood is *brought up* to these two sets of capillaries by a wave of pulsation, communicated to it by the heart's action: its transmission *through them* is due to the *vital* action which the breathing excites.

The muscular action of the heart is, therefore, auxiliary to the vital force derived from the breathing. But the action of the heart is forcible or otherwise in proportion to the energy of the vital orgasm brought to bear upon it; and this vital orgasm is precisely in accordance with the vital force which pervades the remainder of the body, and is derived from the same source, namely, from the breathing. Unless, therefore, the heart has sustained damage, and its efficiency has become thereby impaired, the vital actions throughout the body and the cardiac pulsations are duly apportioned to each other. Sometimes, however, it happens, from some such cause as that above named, that the cardiac action exceeds or falls short of the vital requirements, and then the mechanical function does not correspond with the vital action, to which it is secondary, and should be subordinate.

In some animals the muscular contrivance for pushing on the blood is placed only on that side of the circle in which the fluid is travelling, from the system in general, towards the breathing organs, in them called "gills;" while in others it is placed on that side in which the fluid is leaving them, and proceeding towards the general purposes of the body, and not on the venous side, while in mammalia and birds it is so placed as to aid both the arterial and venous streams.

In reptiles the blood is received into two auricles (one for each kind), and is by them emptied into a single ventricle, so that the two sorts of blood become mixed there ; and then the ventricle distributes its contents in two directions, one towards the lungs, and the other towards the general uses of the body. This example forms some approximation to a double circulation, while that to which that term has been applied affords no such resemblance.

The reason of the admixture of the two kinds of blood in reptiles is sufficiently obvious. The force of vitality, which any animal exhibits, is in direct proportion to the complete severance and marked contrast, which the qualities of the two sorts, arterial and venous, display.

The fluids are kept asunder and prevented from intermingling by the two sets of capillary network, one of which intervenes between each extremity of both, namely, by the capillaries in the lungs, which resist the passage of the venous to the arterial side, and those in the system generally, which restrain the arterial from mingling with the venous.

In proportion to the resistance to the vital impulse which these interpose, so must the intensity of contrast prevail in the respective kinds of blood, and in proportion to that intensity of contrast must the vital energy, which results from it in relation to the action of the air upon it, be measured.

Therefore, in those cases (reptiles) where the provision for the partial admixture of the two kinds of fluid is made, it is clear that the attainment of any considerable intensity of vital force in them is provided against; and accordingly it is found in the crocodile, which at certain seasons exhibits a vital energy greater than at other periods, that a contrivance is adjusted, whereby occasionally the two kinds of blood are temporarily, though perfectly separated the one from the other, and the double circulation is converted into a single one.* That is

* For these facts the author is indebted to Professor Owen.

to say, while the necessity for a high intensity of vital action remains, the blood circulating in the body forms no junction between its venous and arterial divisions, except in the capillaries of the lungs and of the system, and therefore only a single circle is then made, and consequently a greater vital intensity can be attained; while, on the contrary, as soon as the animal sinks in the water, and resumes its torpid condition, a junction between the venous and arterial fluids is immediately formed in the ventricle, and the single circulation, by being thus divided, is converted into a double one, which is the natural condition of the animal, reducing it at once to its ordinary vital state.

It is reasonable to infer that at all times the degree of admixture which the two kinds of blood receive in the single ventricle is only just so much as shall prevent the generation of any inordinate vital force, inconsistent with the requirements and well-being of the animal; and a grooved condition of the ventricle of these animals, which can easily be distinguished, seems well adapted to accomplish that partial separation.

In mammalia, the two kinds of blood are propelled towards their appropriate capillaries, the venous by the right side of the heart, and the arterial by the left. The right and left ventricles each propel a wave, not *through* their respective capillaries, because that would require a force at least one hundred times as great as the heart ever exercises with any single pulsation, but it sends it *towards* them, causing a dilatation and congestion in those smaller blood-vessels, which lead to the capillaries; and the force and impulse become diffused and lost in proportion to the increased numbers and diminished size of these, whose elasticity saves them from injury.

The reason why the two sides of the heart, which thus send their contents in two different directions, are placed in close proximity to each other, instead of being actually separate and remote the one from the other, is manifestly in order that the impulse of both should be perfectly synchronous, and that the degree of vascular turgescence in the smaller tubes leading to each set of capillaries should exactly correspond. No argument is required to prove that the whole quantity of blood, which must pass through the two sets of capillaries at any given pulsation, must bear an exact proportion to each other, otherwise an excess or diminution of that fluid on the one side or the other must result.

The venous blood propelled by the right ventricle reaches the root of the lung, and the blood-vessel in which it is contained runs close to the bronchial tube. As this latter continues to be subdivided into lesser and lesser tubes, multiplying in number as they diminish in size, the artery containing the venous blood, which continues in close approximation with the air-tube, is divided in an exactly similar manner; and, as this air-tube diminishes in size, a similarly diminished blood-vessel, containing the venous fluid, still continues in juxtaposition with it, until at last, when the bronchial tube terminates in the little congeries of air-cells which surround its orifice, the venous blood-vessel, now reduced to a very minute size, is split up into its final subdivision, the ultimate filaments of which go to each air-cell, and there form a network, of which the threads are of microscopical dimensions.

Whether this meshwork, in which the venous blood-vessel, called pulmonary artery, finally terminates, contains venous blood, or whether it forms the commencement of the arterial, or whether it occupies a transitional post, is not necessary to determine.

The blood which the pulmonary artery has conducted to this spot is called "venous," because it is that which the veins have conveyed from the various parts of the body towards the right side of the heart, and thence, by vessels called "arteries," towards the lungs. It is of a darker colour than the arterial blood, which runs in the opposite direction, and it contains the fresh contributions of lymph and chyle, which are poured into its stream not long before it reaches the right auricle.

In its passage towards the air-cells, the vessels in which it is contained, after leaving the right ventricle, receive no addition, and give off no contribution to any collateral part: they merely undergo division and subdivision, not even again uniting with each other, and the whole bent and object of their course are simply to be split up into minute subdivisions, so that every filament may ultimately be distributed to its appropriate air-cell. The area of surface which they are thus made to occupy is very great.

The blood which returns from these air-cells is now called "arterial," and is of a florid colour; and the capillaries in which it is contained consist, in the first instance, of two distinct portions, *one* of which returns the blood direct from the air-cells, and forms at once the commencement of the pulmonary veins, and the *other*, after leaving the air-cells, forms a most elaborate and closely-packed network (or plexus) in the membrane of the bronchial tube, having done which, it then joins the former set, and the two become united.

The epithelium, which it is the office of that membrane to produce, is evidently supplied from that division alone by which the plexus is formed. There are no other blood-vessels in the situation where this takes place, and the arrangement of the plexus is clearly adapted for no other purpose than that of causing that epithelial growth, and the physiological results associated with it. (The arteries, commonly called "bronchial," derived from the aorta, have quite a different destination, and do not in any degree conduce to that function, as is commonly supposed.)

Those blood-vessels which begin to be formed by the arborescent junction of the small twigs, derived *directly* from the air-cells, soon, by uniting together, form larger ones, which may first be distinguished on the outer surface, and in the groove-like spaces which the under surfaces of contiguous lobules form between themselves, and they collect their branches indiscriminately from each of the adjacent lobules. The other set of capillaries, having formed the plexus in the bronchial membrane, sends off, at frequent intervals, little perforating branches, which pass from the interior to the exterior of the bronchial tube, and there form little twig-like collections, which soon terminate in the larger veins, which are beginning to be formed by the collection of the former set; but they do not form this junction until these have attained a considerable size, so as generally to be capable of being seen without being magnified.

Larger veins now begin to be formed by the junction of numerous smaller ones, and two of them join each of the larger bronchial tubes, and are placed near (one on each side) the vessel which conveys the venous blood towards the air-cells.

It has been shown that the bronchial tubes, down to their very final termination, have been each accompanied by a blood-vessel conveying "venous" blood to the air-cell; but, owing to the distant situation of those smaller capillary vessels which collect the arterialised fluid, the smaller bronchial tubes are not accompanied by any corresponding pulmonary *veins*, because these latter are then to be found elsewhere, being placed on the part of the lobule most remote from the air-cells; and it is only when both the bronchial tube and the pulmonary veins are of considerable dimensions that they are found in company with each other. But the larger bronchial tubes are accompanied by one pulmonary artery, which carries venous blood in the direction towards the air-cell, and by two pulmonary veins, which convey the arterialised fluid from the air-cell in the direction towards the root of the lung. The smaller bronchial tubes, however, are only accompanied by the branch of pulmonary artery, which faithfully adheres to it to the last. The blood-vessels, therefore, which return the arterialised fluid from the air-cells towards the root of the lungs, comprise in their origin two distinct sets of capillaries (both, however, derived, in the first instance, from the air-cells); namely, those which come direct from the air-cells, and those which go to the construction of the bronchial plexus, after leaving the air-cells.

The fluid which these two sets of capillaries contribute to the common stock of arterial blood must, in its nature, be somewhat different, since from one of them the bronchial epithelium has been constructed, but not from the other.

Another peculiarity which these returning arterial blood-vessels (called veins) exhibit, and which did not attach to their opposites, consists in the fact that they continue to make junctions and intercommunications among themselves; so that, should any obstacle interfere with the passage of the arterialised fluid through any of them, it would still have no difficulty in proceeding on its course towards the left auricle, because the numerous channels of intercommunication between the different branches would allow it to flow with equal facility through the adjacent vessels.

Such was not the case with those which conveyed the venous blood *to* the air-cells. In them each branch went to its appointed lobule, and each filament to its individual air-cell, undergoing merely a succession of subdivisions, without any kind of junction or collateral communication; therefore, if an impediment were to occur in any of them, there would be no possibility of the blood reaching the air-cell, or congeries of air-cells, which it was the duty of the obstructed vessel to convey to them. In the case, on the contrary, of the arterialised fluid, the filaments are collected promiscuously from contiguous lobules, and very free interchanges of the contents of the veins, formed by those filaments, take place subsequently. Therefore, when the two larger veins come into relation with a particular bronchial tube, and its accompanying artery, it by no means follows that they convey exactly the same fluid, only in an arterialised condition, which that particular artery has supplied to the portion of lung in connection with that identical bronchial tube. On the contrary, those veins will have collected their arterialised fluid from many other portions of the lung, besides that to which that individual artery and bronchial tube belong, and that part of the lung also will have returned its arterial fluid by channels which run in connection with many other tubes and arteries besides its own.

In short, a most perfect mixture and interchange of the arterial fluid are very elaborately provided for, so that every part of the arterialised fluid, which reaches the root of the lung, is derived in equitable proportion from the whole of the lung, and not from any distinct portion of it.

Thus far certain blood has been traced to the air-cells; from these it is collected by two distinct kinds of capillaries, which afterwards join and form veins, to convey the arterialised blood; and these veins have been seen to come into contiguity with the larger bronchial tubes, and to be by them conducted towards the root of the lung. It remains to be seen from what source the tissue, or framework of the lungs themselves, derives its maintenance.

In all other organs of the body the blood-vessels of supply continue to divide, and become smaller and smaller as they contribute their various branches to the parts of the body to which they belong; but it has been already shown that the vessels, called pulmonary arteries, which undergo this diminution in their passage towards the air-cells, do not give off any such filaments of distribution to the adjacent structures of the lungs; and it is reasonable that they should not do so for another cause, namely, that they convey only "venous" blood, since all the other organs derive their support from arterial sources; therefore it may be safely asserted that these do not perform the office of repairing the lungs themselves. But likewise it is found that the arterial blood-vessels (called pulmonary veins) which commence at the air-cells in continuation of the former, are occupied in greedily collecting the smaller vessels, and that these join in the construction of larger ones, instead of being engaged in giving off vessels of supply, and that no vessels of local distribution are derived from them. Whence, then, come the means by which the skeleton (so to speak) of the lungs themselves is furnished with blood?

It has in former treatises been demonstrated, by anatomical evidence, that these organs renew their tissue by blood adapted for that special purpose, precisely as occurs in all other parts of the body, and that they derive it from the same source, namely, from the common stock, which the aorta distributes impartially to the whole body.

The vessels by which this supply is conveyed to the lungs are called "bronchial arteries," and they have corresponding veins and intermediate capillaries. The name of these arteries is unfortunate, as it tends to perpetuate an error as to their distribution. It is commonly asserted that these vessels join (anastomose) with the pulmonary set of capillaries; and it has even been advanced by some that they have no corresponding veins. Both these statements are erroneous. The bronchial arteries, capillaries, and veins are as distinct from the pulmonary as are any other systemic vessels in the whole body: they make no sort of junction in the lungs with the pulmonary vessels, but are entirely insulated and secluded from them. The only vascular bond of connection between the bronchial (so called) capillaries, and the pulmonary capillaries, is precisely that, and no more, which the blood itself passing through the large vessels, and through the two sides of the heart, establishes between all the systemic capillaries and the pulmonic ones.

Each individual systemic organ is brought into direct relation with the pulmonic capillaries, where the vital force is generated for the benefit of the whole body, by means of blood which establishes the continuity between them, and each individual organ has its own direct and peculiar circle of continuity with the pulmonary capillaries; and from each of these particular circles all other systemic organs, except the organ specially concerned, are excluded, although a great portion of each of these circles is common to the whole, namely, that part of it which passes through the large blood-vessels, the two sides of the heart, and the pulmonary capillaries. These belong indiscriminately to the whole; but each individual set of capillaries enjoys its own direct communication with the pulmonary capillaries, without the intervention of any other systemic capillaries. Precisely to this extent the bronchial capillaries possess a special connexion with the pulmonary capillaries, and are included in an uninterrupted vascular circle with them; but the continuity of this vascular circle is maintained by means of the blood, which passes through the large vessels, and through the two sides of the heart.

The bronchial capillaries derive their vital force from the pulmonary capillaries; but this vital force is communicated to them precisely as to all other systemic organs, namely, by the circle of blood which is established by that conveyed through the larger blood-vessels, and through the two sides of the heart. The circumstance that the bronchial capillaries and the pulmonary capillaries are in near contiguity with each other in the lungs, does not entitle them to hold direct communication with each other in that locality. The blood itself is the appointed bond of connection between the pulmonary and systemic capillaries in all parts of the body; and the systemic capillaries in the lungs must adhere to that method of communication appointed for such vessels, albeit it is rather more circuitous than a direct anastomosis would be, if that were physiologically possible.

The exclusive function which the bronchial vessels perform is that of repairing the cellular tissue, or framework of the lungs. This corresponds with what also occurs in every other part of the body, and is exclusively a systemic function, and derives the vital force for its accomplishment, precisely as all other systemic functions gain their vital orgasm, namely, from the pulmonary capillaries.

These arteries (so-called bronchial) do not go to the bronchial membrane in particular, except in so far as they supply its framework, in common with that of the remainder of the lung, with the vital supplies which are essential to its repairs; but they are found to be minutely distributed over every part of the lung, being principally conveyed by the tissue, which serves to divide the whole into lobules and sub-lobules. These, therefore, belong to the same kind of blood-vessels, and the same kind of blood which all other parts of the body require for their individual functions, and are distinct in their origins, their terminations, and their functions, from those which particularly appertain to the breathing function ; to the consideration of which this chapter is specially devoted, as far as the mechanical provisions necessary for its performance may entitle it to be treated as a local operation.

To resume. The arterialised fluid, which has been brought to the root of the lung, having been collected into four large veins (two for each lung), is by them emptied into the left auricle of the heart.

The blood has now been traced, at first in a venous state, when it leaves the right ventricle, going to the air-cells; returning thence in an arterial condition, it has arrived at the left auricle. During this progress it has undergone very elaborate subdivisions, and has subsequently been collected again into one common receptacle, viz., the right auricle; and it has been subjected to its subdivisions in order to accomplish one special performance, namely, to generate, by the assistance of the air, a particular vital power, which shall excite and control all the other functions of the body.

The venous blood has been changed into arterial during this process: the direct object has not been this conversion only, but the creation of the vital force, of which that change is the evidence. The degree to which this change has been carried is likewise the measure of the intensity of the vitality which has been called into activity.

No other collateral or inconsistent function has been allowed to interfere in this one all-important and distinct duty, since even the repairs of the tissue of the lungs themselves are deputed to other vessels.

It has been stated, that in the original capillaries, from which the arterialised fluid has, in the first instance, been collected, a marked distinction has prevailed, namely, that one portion of these capillaries has furnished the growth of the bronchial epithelium, and the other has not discharged any such function. It is manifest that these must be different in some quality; their contents, however, are speedily mixed together. A question arises—Is that part which has secreted the epithelium more or less "arterial" than that which has not done so? One or the other it certainly must be. It is very evident that such a provision has not been made without some adequate purpose and result.

The formation of bronchial epithelium, however, cannot possibly be a process antagonistic to that of breathing, since it is furnished by a portion of that very blood on which the respiratory function is more immediately exercised. But since it is produced at the very time, and by the very capillary vessels themselves, on which the action of the air in that process is most energetically displayed, it becomes an almost inevitable conclusion that it must itself be an essential part of the function. Another very potent probability follows, that that other portion of the blood—namely, that which passes directly from the air-cells to the pulmonary veins, without any participation in the bronchial plexus—must have done so in order to dilute and modify, as occasion may require, the undue intensity of the vital force which the other may be in the act of creating, and, by this means, to adjust the intensity of the vital energy to the general requirements of the body, and to provide for the oscillations which its vicissitudes might occasion. When the vital actions of the body at large are energetic, a corresponding intensity of vital action must be excited in the lungs, and a corresponding increase of the bronchial epithelium must result, provided this be admitted to be the natural product of the local respiratory changes. When this temporary orgasm subsides, it must be necessary that the venous congestion, or turgescence, which the previous vehemence of function has produced in the vessels leading to the air-cells, should have some means of outlet, without, on the one hand, being delayed in the lungs injuriously, or, on the other, being forced to pass entirely through the plexus, where the greatest intensity of vital force is being generated, and thus prolong an unnecessarily energetic vital action throughout the frame.

A mode of escape and a means of dilution are doubtless, therefore, furnished by the blood which returns through those vessels, which do not form the bronchial plexus. But it may be asked, Why should the vessels, which do *not* pass through the plexus, be those which dilute the intensity of the fluid, rather than those which do so, since it may be urged that the formation of the epithelium might have the tendency to reduce the arterialisation of the blood to a state more resembling venous, rather than to exalt the opposite propensity of converting venous into arterial blood? In reply to such an objection it must be remarked that, in the first place, it is almost impossible to imagine that two processes should be going on in the same fluid at one time, one of which should be making it more arterial, and the other more venous; that both should be successful, and that the success of both should be in proportion to the degree in which they both accomplished results so diametrically opposed; and secondly, it seems difficult to suppose that any active changes can occur locally, from which distant powerful effects are elicited, without some ostensible local product, beyond that of a mere change of the colour of the fluid, being caused by them, which shall be both the evidence of the actual local operations, and the means whereby such effects are produced. The formation of the bronchial epithelium supplies the requisites both in the rational and physiological chains of causation. Though it would be a most violent hypothesis to suppose that the two opposite actions should occur simultaneously in identically the same fluid, it requires no such extravagant stretch of the imagination, to admit that the blood may be divided into two sorts, of which one shall be exposed to a more vigorous set of vital combinations than the other; and that the preponderance of transmission through the one or the other may depend upon the demand which the various actions, then in operation in distant parts, may determine. The analogy before mentioned in the case of the crocodile, which adapts its condition to varying circumstances, according to the degree of admixture which its blood in different states, as to its arterialisation, is permitted to undergo, tends greatly to corroborate this view.

Having, then, considered the various circumstances which befall the circulating fluid in its journey from the right ventricle through the air-cells, and back to the left auricle, it remains to be seen by what means the junction between the two is made on the opposite side of the circle.

This consideration will involve all that transpires in every other part of the body; in other words, it embraces all the performances which the animal body executes, in addition to the act of breathing, and it comprises all the results which are derived from that very act of breathing, as far as that function is operative elsewhere than in the lungs.

But it will be convenient first to take a summary survey of some of the mechanical appliances called into requisition in the act of breathing, before laying aside the consideration of that moiety of the function which more particularly relates to the duties, which the lungs themselves have to discharge.

When the dimensions of the chest are enlarged in the act of "drawing a breath," each individual air-cell becomes expanded proportionately to the increased space, and as this proceeds they each become filled with a larger quantity of air than they could contain before: this air is thus drawn into the air-cells through the bronchial tubes. When a sufficient quantity of air is inhaled, which is regulated in exact proportion to the degree of functional activity which the body is then exercising, a slight resistance is given to the return of the breath by a partial closure of the nostrils and mouth. If the exertion of the body, mental or muscular, is great at any time, an almost total closure of these outlets is made; and then the bronchial membrane likewise undergoes a turgescence in its vascular plexus, and retards still more the escape of the air from the air-cells. The ribs then collapsing and pressing downwards, while the abdominal muscles compress the diaphragm upwards, the space within the chest becomes diminished, and the air which it contains is compressed, and made to pass through the bronchial tubes; each individual air-cell having represented a diminutive air reservoir. The air is thus brought into very close apposition with the blood contained in the bronchial plexuses. The epithelium which these continue to produce serves as the intermediate agent between the air and the minute blood-vessels, of which the plexuses are made, protecting the latter, while they transmit the materials of barter which the air and the blood interchange. But, as this interchange is a vital operation, and not merely a chemical one, a vital fabric is necessarily produced by it. The local product is the creation of fresh epithelium, and the correlative distant one is the sum of all the various functions at that time discharged by the whole body. The whole blood throughout the frame participates in the effects which are wrought upon that moiety, or division of it, exposed to the direct action of the air in the lungs, and whose effects balance and compensate for all the results elsewhere produced. Carbonic acid is given off, together with watery vapour and some volatile gases. Could all these be collected, they would afford data of measurement by which the whole vital effects throughout the body could be estimated. The air, thus brought into close contact with the blood, engenders the vital force which the various vital functions throughout the body may at that time require, and this is instantaneously telegraphed throughout the whole frame. The fact of hard breathing whenever any active vital function, mental or bodily, is being performed, is thus explained. Any quantity of additional air which may be voluntarily inhaled, beyond that which is required by the functional activity of the body in general at any particular time, will only enter the chest, and pass out again unchanged. The muscular exertion which did this would create some additional consumption of air, but that would be all.

CHAPTER VI.

ON THE CHANGES WHICH THE BLOOD UNDERGOES.

THE influences and changes to which the blood brought by the pulmonary arteries is subjected, while circulating in the lungs (as far as the consideration can be limited to what takes place in those organs individually), may all be comprised in the following particulars :—

First, the transmission of "venous" blood from the right ventricle to the air-cells.

Secondly, the application of atmospheric air to the minute capillaries, in which it is there spread out, and its conversion, through that agency, into "arterial" blood.

Thirdly, its subsequent return through the pulmonary veins to the left side of the heart.

The local products of the changes to which it has been exposed are carbonic acid, watery vapour, and successive crops of bronchial epithelium.

But in order that these results, which may be called "local," as far as the lungs themselves are concerned, should be accomplished, it is essential that certain other effects, which are spread out over the whole frame, should be produced simultaneously, otherwise the former will not do their part.

It would be as futile to place an arrow across the string of a broken bow, in order that it should be shot to its mark, as it would be to expect that the air in the lungs should produce its effects upon the blood contained in the pulmonary capillaries, if those of the system at large, by which the various functions of the body are performed, did not at the same time execute their appointed task. The two form equal moieties of one conjoint operation, in which each is essential to the other.

Other operations which result from the act of breathing, but such as are not local, as far as the lungs themselves are individually concerned, must be sought for elsewhere, by investigating the events coincidently executed in the various parts of the body, but to which the breathing process is also the exciting cause.

The pulmonary half of the vital circle has been already traced, and it has been found to commence at the right ventricle, and to terminate at the left auricle. It begins with blood in the "*venous*" state, which is made up of ingredients drawn from various sources, to which every part of the body contributes its proportion; and it ends by transferring the fluid, in an "*arterial*" state, to the left side of the heart, which it reaches by first passing through the pulmonary capillaries.

Having arrived at the left auricle, it is then in readiness to commence the systemic half of its journey;

and it is in a fit condition to be distributed to those organs, whence the contributions to the first were derived.

By the time it again reaches the right auricle, after having discharged its systemic duties, the particular portion of blood which has thus been traced, will have completed its peregrination through the whole vital circle. Its continuity with that just starting on a similar errand will then be discerned, and the idea ordinarily implied by the word *circulation* will be indicated. But this tracing of the successive footprints of a particular portion of the circulating fluid, departing from one particular point, following it through a succession of stages until it arrives at last at the same spot at which the journey began, is like following a mark on a rotating wheel. The circle which that particular part of its perimeter describes, does not fully convey the idea of continuity, which the circumference itself denotes.

It remains to notice what takes place in the systemic segment of the vital circle, and to investigate what becomes of the arterial fluid, which, leaving the left ventricle (after it has been transferred to it from the left auricle), starts on its mission to the capillaries, where the bodily functions are performed, until it arrives at last, in a venous state, at the right auricle, and joins with that portion, which is proceeding to repeat the same performances it has itself just executed.

The heart acts at the same moment, and by the same pulsation, on two distinct streams. It propels one of these, as already seen, towards the air-cells, to undergo the change from "venous" to "arterial" blood; the other it dismisses over the body at large, in order to endure its re-translation from the arterial to the venous condition.

Like as the former was derived from every part of the body, so this also is collected indiscriminately from every portion of the lungs, and proceeds to the same organs over the body in general from which the former were drawn.

The commencement, therefore, of one segment coincides with the termination of the other, and an unbroken continuity of the two results.

The two sets of capillaries merely intervene between the arterial and venous portions, preventing, by the minuteness of the tubes of which they consist, the intermingling of the fluids on either side, but serving as a bond of connection between them, and allowing the onward transit of a measured portion, in obedience to the vital influence transmitted through the whole circle.

The left ventricle, in close resemblance to the right, causes, by its pulsation, a wave of turgescence to flow onwards through the arteries towards the capillaries, where the ordinary functions of the body are performed; and this turgescence corresponds precisely, in point of time, with that produced in the lungs by the simultaneous contraction of the right ventricle.

In obedience to the same vital influence (derived from the air) simultaneously and instantaneously pervading the whole circle, an equivalent effect is produced in both sets of capillaries, and a corresponding result is developed in each. A definite amount of arterialised fluid passes through the capillaries of the lungs, at the same time that a parallel set of events is carried on in those of the system, and a proportionate functional effect is there produced.

The fluid, therefore, which the left ventricle despatches to the body in general, is precisely that which the right ventricle has sent to the air-cells, after this portion has there undergone its change from venous into arterial blood. Deduction must, consequently, be made from this quantity of whatever consumption this change may have occasioned.

Carbonic acid and watery vapour have been given off, and bronchial epithelium has been developed. Oxygen (and perhaps nitrogen) has been absorbed, but probably only in the proportion of one equivalent for each of carbonic acid given off. It has, therefore, probably diminished in weight and quantity. A further deduction must be made from the whole quantity, by the time this fluid has been transmitted through the general capillaries of the body, to allow for the consumption which the different functions of the body have demanded. In one of these functions, and one only—namely, in that of the portal veins—can it be supposed that any increment has been made;

and in this, the increase can only consist of water, and such matters as water may be able to dissolve. In the nature of things, therefore, a considerable diminution of the whole quantity must have happened during the peripheral journey of any given portion through the whole circuit, consisting of both sets of capillaries; and were this not compensated for by the addition of the lymph and chyle, which are poured into the vascular stream after all the functional changes have made their demands upon it, the whole residue would not only be changed in character, but would be diminished in quantity, by the time it again reached its starting point. But since the blood, by the time it arrives at the right ventricle, is precisely in the same state, both as to quantity and quality, as it was in each previous pulsation, it follows that the lymph and chyle, added to its stream before the combined fluid is poured into the right auricle, must, in conjunction with the watery solutions which the portal veins have absorbed, have accurately compensated for the total deductions and alterations which the pulmonary and systemic capillaries have made upon it. This reinstating supply of chyle and lymph joins the residuary fluid which is collected from the functional organs, after their necessities have been supplied.

But the fluid, which is thus restored to the right auricle, does not consist of a homogeneous compound, the whole of which has been collected from one source, like that which is poured into the left auricle, after having been subjected to a single and uniform influence, namely, that which the atmosphere in the lungs exercises upon that portion; but it is formed of various contributions, drawn from several distinct organs, each of which performs its own individual functions, which are in most instances quite dissimilar from the others. Some of this venous blood is derived from those capillaries by which the structure of the heart is renewed, and its contractile function imparted to it. This organ is carefully secluded by the enveloping membranes, by which it is inclosed from other parts of the body; and its residual blood must certainly differ from that, for instance, which has been sent to the brain and spinal centres, and has discharged the duty of renewing its tissue, and engendered the functions peculiar to these structures: these also, in like manner, are shut up by their enveloping membranes from the rest.

Both the heart and nervous centres receive their blood of the same kind, and from the same stream as supplies all other parts of the body; but the structure and the function of both are different. It is obvious, therefore, that the residual blood must be likewise different.

Such also may be said of the other individual organs, from which the blood is returned to the common stock, which flows towards the right side of the heart; but the combined result of the whole, when mixed together, with the further addition of the lymph and chyle, and watery solutions above mentioned, is to constitute that particular fluid called venous blood, with which the right auricle is filled, each time that it becomes dilated previously to a pulsation.

The inquiry into all the different contingencies which, in their combined result, furnish the venous blood necessary to be supplied to the pulmonary capillaries, in order to maintain that chain of vital causes which can insure the repetition of the various coincidences belonging to vitality, involves the examination of each of the functional divisions into which the fluid, circulating through the system in general, is there apportioned.

Previously, however, to entering upon that question, it will be well to explain how consecutive events, like those which occur in the capillaries of the lungs and of the system, can also be co-instantaneous.

The changes in the lungs, whereby the venous blood is altered into arterial, are consecutive to those by which the same arterial blood in the system is converted into venous, and these also are subsequent to those by which it was before made arterial; but, notwithstanding these admitted facts, it still remains indubitable, that the transition of one part into arterial, and of another into venous, is perfectly synchronous, and in obedience to one operation, in which both participate.

An illustration will, perhaps, explain this. Two players at ball may be supposed to exchange, by simultaneous throws, two balls from one to the other.

A throws a ball to V at the same time that V throws one to A; A catches V's ball at the same time that V catches A's: the balls alternate in each segment of the circle, but the throws and catches are simultaneous. Now, instead of the balls being thrown from one to the other, let it be supposed that each player rolls them through a powder of a different colour.

V rolls his blue ball through a red dust, and therefore A receives the ball changed to a red colour; but A, at the same time, rolls his red ball through a blue pigment, and V receives it tinged with that colour; and so they continue to receive each a ball of his own colour. V always receives a blue ball, and A always receives a red one. The right auricle and ventricle are represented in this simile by V, who receives the blue-coloured ball from A, representing the left side of the heart, and who has rolled it through the capillaries of the system, whereby it has become dyed of a blue colour; and V rolls it back through the capillaries of the lungs, and in so doing renders it red. But, as two balls have been used simultaneously, it results that, at the same moment while A has been rendering a ball blue, V has been changing a blue one to red: the transition from blue to red, and from red to blue, has been isochronic, and there have constantly prevailed a red ball and a blue one in opposite segments of the circle of rotation. An automaton could be constructed, without much difficulty, by which this could be more clearly demonstrated. If the mainspring, by which the whole operation was kept in motion, were placed in that compartment of the machine by which the conversion of a ball from blue to red was made, the resemblance would be more close, and still closer if the ball, on falling into the red powder, was made to open the valve which admitted the other into the blue; and if this also had the command of the orifice which allowed the former to gain access to the red, it then would follow that either would be arrested, from falling into its appointed pigment, should anything occur to prevent the opposite from performing its share of the appointed task.

While the right side of the heart is engaged in propelling venous blood towards the air-cells, the left side of that organ is forcing onwards the continuation of that fluid, now converted into arterial blood, towards the various organs of the body, to be by them returned, with certain deductions and additions, to the same locality where the circination began. When it arrives at this spot, the additions which it has received exactly coincide with the deductions which it has suffered during its transit through both segments, and the fluid then corresponds very accurately with that which the previous pulsation had to deal with. Therefore, within these two periods, *i.e.*, from that when the right ventricle receives and despatches a vital modicum of blood, to the time when it repeats precisely the same action; in other words, exactly during one pulsation and its interval are comprised the different phases which the vital pendulum constantly repeats.

The consumption, however, it must here be remarked, which the arterial fluid sustains during its mission through the capillaries of the body, is not confined to that which the vital actions demand, but comprises also that which is got rid of in other ways. Thus the kidneys form urea by the aid of their epithelial membrane, which lines their ducts of outlet; but they give off clear water and salts also, by which the urea is diluted and washed away: the former is a vital action, while the latter is a mechanical one. A similar set of events may be traced in the liver; and it would appear that the development of the portal veins between the two sets of capillaries—or the two halves of one set, as different reasoners may choose to consider them—into which the circuit appointed for digestion is divided, are so arranged for that very object, namely, to provide a means by which the viscidity of the bile may be corrected, and the ducts through which it passes may be flushed and cleared out. The perspiration may, to a certain extent, be considered, in like manner, to consist of both a vital and mechanical, or dynamical combination—vital as far as the production of the epithelial growth by which the sweat ducts are lined, and dynamical as far as the elimination of water, and such things as water can dissolve, is concerned.

The supplies, therefore, above enumerated, by which the blood in the right auricle is constantly restored to the same state as that of its predecessor, have constantly to compensate, not only for the waste occasioned by the strictly *vital* demands, but for that also which collateral circumstances may involve.

One very important effect which the vital force, generated by the atmospheric air in the lungs, exercises upon both of the segments is, that it keeps their circulating contents in a state of *fluidity*, and in so doing acts equally and impartially upon the whole. As soon as the continuity of the vascular circle is interrupted, so that the vital stream can no longer pervade it, a tendency to become solid is immediately manifested by the blood; and this effect is equally displayed on both sides of the spot where the septum, which makes the obstacle, may be interposed.

Although the blood may still remain in its own vessels, and may still be surrounded by vitality on all sides, yet unless a vascular circle in connection with the air-cells is continuous throughout, and the particular blood in question forms a part of that circle unbroken in its continuity, coagulation of the fluid will be inevitable. Even if a particular blood-vessel should be greatly enlarged, so as to bulge out all round, and allow a channel in its middle of sufficient size, so that the vital energy can be transmitted through that central part with equal facility as in other parts of the circle of which it forms a part, the blood which is contained in the remainder of this dilated blood-vessel will be out of the stream of vital impulse, and will escape being influenced by it, and will, in consequence, speedily coagulate.

It is not animal heat which can prevent this effect; neither is it motion, nor yet both of these combined: a restoration of the continuous vital circle can alone render it again fluid, when once coagulation has commenced, or prevent its further solidification.

The action of atmospheric air upon it, unless in connection with an uninterrupted vascular circle, will only augment its tendency to lose its fluidity.

The liquid condition of the blood is, therefore, a very obvious effect of the vital force which pervades the whole circle. All other corporeal or mental operations are, however, equally dependent upon similar effects, produced by the same vital force derived from the breathing, and co-instantaneously distributed over the whole living fabric by the same circulatory causes.

The spontaneous arrangement of the red corpuscles (called blood-discs) in a manner peculiar to themselves, such as in any other fluid would at once be called a "polar" state, is another evidence of the transmission through the blood of a "current" force, which is by no means identical with the mechanical one under the influence of the heart's pulsations, by which its mere onward movement is governed. This onward movement of the blood is imparted to it by the contraction of the ventricle, and the contraction of the ventricle is the result of the vitality created by the atmospheric air in the lungs, and distributed through the vascular circle, and the onward motion becomes auxiliary to the production of future vital effects; but it would be a mistake to suppose that the pulsations of the heart were the cause of the vital changes in the lungs, or in the system, and a still greater error to imagine (as is or has been generally taught) that this vital agency is derived from the nerves, or from the nervous system. These last—viz., the nerves or nervous system—are merely ministrative agents of the vascular system.

The current force which maintains the fluidity of the blood, and which causes the red corpuscles to maintain their polar attitude, may, for the present, be called "current vitality." It need excite no surprise that this should instantaneously be flashed through so admirable a conductor as the blood, when the rapidity with which the nervous impulses travel through their appointed routes is taken into account.

The creation of this current force, acting and reacting at the same moment upon the capillaries of the opposite segments, requires a corresponding degree of vascular turgescence in the vessels approaching to each of the sets respectively. This turgescence in both must obviously be greater or less, in proportion to the degree of resistance which is encountered by the fluid in passing through each or both sets.

Supposing it were possible that one set should oppose a greater resistance than the other, still, as the two sides of the heart act precisely at the same moment, were there no other cause than this, an equality of supply must be induced between them, since neither side of the heart could propel its fluid to its appropriate capillaries, except in exact proportion as it receives the same from the opposite one. Thence it must necessarily follow, that even though one set of capillaries might, hypothetically, be ready to pass the fluid, which was supplied to it, onwards with a less resistance than the other set interposed, still that side of the heart could not act, in the absence of the fluid which should be supplied from that set of capillaries where the resistance was greater; neither could it act, unless the opposite side of the heart were equally able to get rid of its contents, which would not be the case if the resistance which it had to overcome were greater. But, seeing that both sets of capillaries are kept in the most perfect harmony with each other by the nature of the vital cause itself, which influences them both, the possibility of such a discrepancy is obviated by a vital necessity, which has much more potency than even the mechanical one just hinted at. The resistance which the capillaries oppose to the transit of their respective fluids is, then, the measure of the vital cause which overcomes it. Two axioms follow :—

First. The intensity of vital force will be measured by the amount of resistance which either set of capillaries—*i.e.*, those of the lungs or those of the system — interpose. Were it possible that either of these should oppose a greater resistance than the other, then that which is the greater of the two will be the measure of the whole current intensity.

Secondly. Of that set of capillaries in which the greater resistance is afforded, and which thereby governs the intensity of the whole, should one portion of it afford a less resistance than the remainder of the same, then the current force will pass in that direction where the resistance is least, and consequently *that* will be the gauge of the potency of the whole vital current. In other words, it will be governed by the *least* resistance, which may be offered in that set of capillaries whereof the general resistance is the *greater*. In either set, the transit of the current force will be retarded, until the *intensity* of the orgasm in the other shall be exalted to such a degree as that it shall be equal to the resistance offered by at least a part of that which interposes the obstacle, and the intensity will continue to be exalted until it arrives at such a measure as shall enable it to force a passage for itself through the opposing capillaries.

The venous blood, going to the capillaries of the lungs, is heaped up by the heart's pulsation, in readiness to be pushed through them as soon as such a change is made in the shape of the globules as shall permit their squeezing through the capillaries. The same occurs at the same instant in the arterial blood, which is striving to penetrate through the capillaries of the system. They both wait for the vital impulse, which shall work the requisite change for them; and this vital impulse will be generated by the action of the atmospheric air on the blood in the capillaries of the lungs, and will be intense in proportion to the resistance which it has to overcome. At the same instant, in obedience to the vital force which operates equally on both, the air in the lungs produces its changes, and converts the venous blood into arterial; and the arterial blood undergoes a concurrent alteration in the system, and an equal modicum of blood traverses each of them. The anodes of the current force are formed by the heaped-up blood in both.

In the lungs very careful provision is made, by which the atmospheric air is elaborately applied to the blood, which is brought to them from the right ventricle; but, on the other hand, an equally careful EXCLUSION of atmospheric air is as rigidly enforced in the systemic capillaries.

The skin only affords an apparent contradiction to the law, which enjoins the entire protection of the systemic functions from the access of atmospheric air. Many of the risks and casualties of life are due to the fact, that the part which forms the surrounding boundaries of the body cannot, from the nature of things, be as thoroughly guarded from atmospheric interference as the internal organs, unless all animals were inclosed, like the armadillo and the turtle, in an external covering impervious to the air. This seeming defect is compensated for, in great measure, by clothing, either artificial or natural, in which latter the *rete mucosum* is included; and by the physiological circumstance that the action of the skin does not, in any very essential manner, constitute an independent vital function, exception being, of course, made of that whereby the hair and epidermis are produced, which are themselves furnished for the protection of the secreting blood-vessels from the intrusion of the air. The other vital functions which the skin performs are rather auxiliary to those of other organs than prominently inchoative in themselves.

To resume. The oxygen of the air in the lungs unites with the blood, with which it is brought in contact; it combines with the carbon, and forms carbonic acid, which escapes with the breath, the structure of the lungs being such that this only can occur. In proportion to the resistance which the distant vital organs oppose to the transmission of their blood through the capillaries in which their functions are performed, the intensity of the vital force, both in the lungs and in them, will be heightened, and a proportionately increased quantity of carbonic acid will be given off in the lungs. The remainder of the blood in the lungs, with which the carbon was before combined, is now made more fluid, and, in obedience likewise to the greater intensity of vital force, is driven through the capillaries of the lungs, at the same time that a similar quantity, in answer to the same vital intensity, discharges its appropriate office somewhere in the body.

In consequence, however, of the exclusion of atmospheric air from the capillaries of the system at large, the blood which is heaped up by the arterial pulsation, in readiness to be pushed through them, can only draw its supplies of oxygen, in obedience to the pulmonary call, by extracting oxygen from the contiguous fabric, which is obliged to be decomposed, in order to furnish that necessary commodity. The product, which is formed by the combination of the oxygen so obtained with the carbon of the blood, cannot be given off, as in the lungs, in the form of carbonic acid, owing to the nature of the locality: it is therefore deposited in the form of new fabric, in the place of that which has been destroyed in supplying the oxygen required for the local purpose.

The remainder of the blood is rendered more fluid by the withdrawal of this carbon, and, like that which is acting under similar circumstances in the lungs, is now enabled to be driven through the capillaries by the current vital agent. An equal and synchronous set of events concur, therefore, both in the lungs and in the system.

The residue of the fabric, however, which has been destroyed in the parts contiguous, by the oxygen having been withdrawn from it, requires to be removed from the spot. Part of it is imbibed by the capillaries leading to the veins, or by the small veins themselves, and part by the lymphatic absorbents. That part which finds its way into the veins immediately becomes mixed with the residual blood, which has given up its carbon, and which has penetrated through the capillaries by the aid of the vital force; and the restoration of the blood to its venous state is thus commenced. Its perfect resemblance to that condition in which it was before the different phases incidental to "life" began, is not fully accomplished until the lymphatic and lacteal absorbents shall have poured into its stream those materials, which it is their duty to collect for its replenishment.

The lymphatics remove that other residual portion of the destroyed fabric, which the veins are not able to dispose of, and the lacteals contribute the fresh materials which they have gathered up from the food; and the combined products of the two, suitably blended together in the thoracic duct, are poured into the mixed fluid, which the confluence of the residual blood derived from the various organs is conducting towards the right auricle.

CHAPTER VII.

ON THE VARIOUS SYSTEMIC OPERATIONS.

THE blood, which arrives from the lungs in its freshly arterialised state, is received into the left auricle at the same time as another portion, on the point of starting on an errand similar to that which the former has just concluded, reaches the right auricle.

The simultaneous expansion of the auricles is called the diastole of the heart, and is followed by their contraction, emptying the contents of both auricles into their corresponding ventricles. This event is almost instantaneously followed by the simultaneous contraction of the ventricles; and it so rapidly succeeds the contraction of the auricles that the two can scarcely be divided, and the performance which they execute is called the systole of the heart.

A pause ensues, during which the vital coincidences occur throughout the two opposite and equipoising segments of the circulation, constituting the characteristics whereby the framework where they take place is distinguished from a chemical apparatus, or from a vegetable fabric. While this interval lasts, preparation is also made in the lungs for the next diastole and systole of the left side of the heart; and in the system at large, the capillaries discharge their various functions, and execute their mission, in restoring the circulating fluid to a condition suitable for the next diastole and systole of the right side.

The systolic contraction of the right side of the heart sends a pulse through the whole of the lungs, at the same time that the left side gives to every systemic artery throughout the body its characteristic impulse.

The lungs return the arterialised fluid to the left side of the heart, after it has been spread out equally in every part of those organs, and has there undergone the one distinct operation for which it has made that journey: no other function, of any sort or kind, has been allowed to mingle with, or impede, that one solitary object.

The blood, on the other hand, which returns from the body in general, in order to fill the right auricle, previously to its departure thence on its mission through the lungs, consists of many distinct portions, each derived from organs carefully separated and insulated from the rest.

All of these organs, however, derive their blood from one source, namely, that sent into the aorta from the left ventricle, and which consists of blood which has just returned in an arterialised state from the lungs.

It goes from the aorta, which conveys the common stock to all the various parts of the body, diverging to the individual organs ; it discharges in each the function peculiar to it; and the blood which converges from all these diverse channels is subsequently mixed together, when there is no chance of the admixture interfering with the special duty of any of the functions which appertain to any single portion.

When this mixture is nearly completed, the whole quantity is replenished by the materials which the lymph and chyle contribute to it, and it is then restored, through the co-operation of all these events, to the same state, in which it was before any of the successive phases began.

While, therefore, the aggregate performance belonging to the lungs is carried into effect by the single operation which they execute—namely, that of the conversion of venous blood into arterial—that, on the contrary, whereby the arterial blood is again brought back to its former condition, is the result of several operations, in which many diverse events participate.

All of these, however, occur in the same period of time, while the opposite effect happens in the lungs, and they are the sequence of the same systolic contraction of the heart.

The combined results, whereby the arterial blood is restored to its venous character, balance, in point of time, that event which is then accomplished in the lungs, and in point of aggregate results also, and are as intimately related to it as any action and reaction, or cause and effect, can possibly be.

At the same time, nothing can be more clear, than that there is no possibility of any interchange of their materials between one systemic function and another, since there is no sort of communication between them: each of them is very carefully secluded from the rest.

The blood, therefore, which returns from each of the organs after having discharged the various systemic functions peculiar to it, must be in some degree different from the remainder; consequently no single systemic organ could return blood, which would be fitted again to pass through the capillaries of the lungs, without the due admixture of that which should be derived from the others.

The blood which travels to all these different organs indiscriminately is precisely the same, but the functions which the organs perform are different; therefore the residual blood which leaves them must also be diverse.

But all of these products, when combined, form a whole which, with the addition of the chyle and lymph, exactly restores the transmutations, which the air had previously executed upon similar blood during its transit through the lungs; and during the same period, while this restoration is taking place, a similar set of events to those which it is the province of the systemic functions to neutralise, is then being wrought upon a corresponding quantity of blood in the lungs; which blood, in its turn, is destined to repeat the same performances.

In short, the conjoint action of all the systemic functions (including the supply of chyle and lymph) precisely undoes the arterialisation, which the lungs had accomplished previously ; and this disarterialisation of one portion coincides exactly in point of time with the arterialisation of another.

All these systemic functions, therefore, balance the changes which are made in the lungs in point of time, in point of quantity, and in point of vital energy. But though they consist of separate and distinct operations, with as separate and distinct residual blood, still it is plain that, in point of *intensity* of vital and mechanical forces called into play, they must all correspond among themselves, or only be subject to such vicissitudes as the nerves, or some such governing power, may be able to regulate and restore.

Were it otherwise, the action of those organs, wherein the greater intensity of mechanical or vital power was required, in order to force the circulating fluid through them, would certainly be inoperative, because, since each of the organs possesses a circuit, through which the blood could be transmitted from the left ventricle, back to the right auricle, without passing through any of the remaining channels, it would so happen that the blood would pass in preference through those routes where the resistance was least, and those in which the greater impediments were interposed would be left out of the *circulation* altogether.

Therefore, not only does the vital intensity of the whole systemic segment exactly equal that of the pulmonary segment, but the various functions and divisions in which the systemic capillaries are apportioned must also correspond with each other as to the degree of resistance which they offer to the circulation.

It is true that there are compensating rules whereby some collateral function may temporarily relieve an excess of strain thrown upon one or more of the others; but this fact does not invalidate the equilibrium habitually sustained among them all, in reference to the vital tension which must prevail among them at any given time.

It will be convenient now to classify the diverse operations which the systemic functions have to perform; and this may be done by separating them into the following groups, whereof some may be still further subdivided, when the reasoning employed in these pages shall have been fully received, and the natural deductions involved by it shall have been fairly investigated. For the present it will be well to be content with an approximative classification, in order to avoid complication or abstruseness.

There is,—

First. The circuit through the structure of the heart, which is formed by the coronary arteries and veins, with their intermediate capillaries.

Secondly. *That* through the tissue of the lungs, by the bronchial (so called) arteries and veins.

Thirdly. *That* through the brain and nervous centres, by their appropriate arteries and veins.

Fourthly. *That* through each kidney.

Fifthly. *That* through the organs of digestion, commencing at the cœliac axis and the superior and inferior mesenteric arteries, and terminated by the *venæ cavæ hepaticæ*.

Sixthly. *That* through the spermatic organs in the male, and the uterine in the female.

Seventhly. *That* through the conjoint muscular and osseous system.

Eighthly. *That* through the cutaneous system.

The whole of these circuits are as carefully protected from the accession of atmospheric air as those of the lungs were elaborately prepared for the fullest possible exposure to its influence.

In speaking of the circulation through the skin, it will be shown how the pernicious interference of the atmospheric influence is guarded against, and how the modifying effects upon other systemic functions, which the imperfect protection of its surface sometimes occasions, are as much as possible corrected.

Each of these different sections will require a few words of explanation; but the object being to indicate the key-note which prevails among them all, and which connects them with the source of vitality in the lungs, and not to make an ultimate analysis of all the various actions which appertain to them, it will be sufficient if only such particulars as relate to the subject in hand be noticed in the following sketch of their performances :—

SECTION I.—A loop-line is given off from the aorta, which, commencing at the coronary arteries, terminates by discharging its residual blood into the common channel, into which the venous, or venous-like, fluid is collected from the various parts of the body. This circuit passes through the capillaries of the heart itself.

The pulsations which occur in the arteries of this loop are synchronous with those which happen in all other parts of the body, and are derived from the same mechanical motive force, namely, that of the systole of the left side of the heart itself.

In other words, the pulsation of the coronary arteries, which causes the blood to flow to the heart by which its structure is repaired, and its function provided for, is derived from the contractile action of the same organ to which their branches are distributed. The capillaries, also, which discharge that duty, act in obedience to the same vital influence as that by which all other vital functions are executed, namely, that which is generated by the air in the lungs; and, like all similar blood-vessels elsewhere dispersed over the body, the blood which is conveyed in them renews the structure, while it performs the function, of the organ through which its branches are ramified. It is heaped up, like them, in the arteries leading to the capillaries, by the same systole which produces like events in all other parts, and its operations coincide in all particulars of time, of force, and of comparative quantities with all the other streamlets into which the remainder of the arterial blood is split up, and from which it was detached on its special mission. But though the blood was detached, in respect of the direction in which its stream flows, it is still continuous, by means of its fluid, with that from which it diverged.

The special function, however, which the loop now under consideration discharges, is entirely excluded and separated from the direct interference of all others by the pericardium, in which it is inclosed, and by the endocardium, which divides it from the blood with which the cavities of the organ in question are filled.

The vital changes in the capillaries of this circuit create a condition in the structure of the heart suitable for the production of its muscular contraction, and the pulsation through the coronary arteries, and through all the other arteries of the body, which results from that contraction, is the special object for which the apparatus was contrived. These vital changes coincide, in point of time, with that interval which succeeds each pulsation, during which the cavities of the heart are comparatively empty, and the auricle is only slowly filling.

Hence the systolic contraction must be regarded as the discharge of a special function, which is consequent to the true vital action performed by the coronary capillaries, seeing that the changes, on which the contraction depends, require to be perfected before the contractile impulse can be produced: it resembles in this the discharge of the electrical flame by a Leyden jar, which has been derived from a force previously imparted to the instrument by means of friction, either directly or indirectly applied to it.

The heart's action, therefore, may be looked upon as a secondary result, depending upon a certain prepared condition, induced in its structure by the vital changes which its capillaries have previously accomplished, and for which those changes have supplied the primary requirements.

The ensuing pulsation, which is conveyed by the contraction to all the arteries throughout the body, is an event still further removed from the causes which give rise to both, since the pulsation succeeds the contraction, while that succeeds the vital changes: it is, therefore, neither identical nor synchronous with the changes themselves in the cardiac or in the pulmonic capillaries. These changes, from which both the cardiac systole and the consequent pulsation are derived, occur in the interval between two pulsations; and each pulsation is the result of a prepared condition in the cardiac structure, which the changes antecedent to it have brought about.

Further, as the coronary arteries are the only blood-vessels which go to the structure of the heart, and the coronary veins are the only ones which return from it, and the lymphatic vessels are the only other vessels of any kind found within the structure, it is plain that these three must, among themselves, contribute all the requisites which the functions of that organ may demand. And as there are no other ducts of outlet, it is also evident that to the lymphatic ducts, and to the coronary veins, must be deputed the duty of removing whatever materials the fabric of the organ may require to get rid of in the exercise of its function; and, by reason of its seclusion (from all other systemic organs) by the membranes with which it is surrounded, it must be accountable to the lungs only for the manner in which it performs the task allotted to it, since it has no direct relation with any other organ except the lungs, with which, however, it is connected by a continuous circle of vascularity, joining the two in an unbroken *unity*. The blood might continue to rotate through the circle thus constituted, between the blood-vessels of the heart and those of the lungs, without going elsewhere; and if the capillaries and blood-vessels of the heart possessed an adequate vital area, there can be no doubt that this circle might occupy the whole force of vitality, which the pulmonary capillaries might be capable of generating, to the exclusion of all other parts of the body; but as it is of only diminutive size, compared with the whole area of the lungs, it happens that it can only employ a limited portion of the vital force which the latter can produce.

The *quantity*, therefore, of vital energy which these capillaries can consume, must bear a direct proportion to the quantity of blood which can be transmitted through them The combined quantity and *intensity*, however, can never exceed that which the lungs are creating at any particular moment.

The combined quantity and intensity also of that which is then in exercise in other similar loops must likewise correspond with this, because, if it were greater in any, the force would cease to travel through those channels, but would go in preference through others where it found less resistance; and were it, on the contrary, not so great, it would abstract the force from those parts where the intensity was greater, and thus restore the equilibrium.

At the same instant of time, therefore, while the arterial blood of the coronary arteries is being passed through these capillaries to the corresponding veins, the same event is happening throughout all the arteries and veins in the body, including the converse set of results, which also occur in the lungs; and by the time that the prepared condition in the coronary capillaries is completed, so that the heart's structure is in readiness for another contraction, the whole of the systemic functions throughout the body are likewise so far advanced as to be fitted to receive another modicum of arterial blood.

The systole of the heart may, therefore, be considered as the climax of the systemic function; it imparts a wave of pulsation to the lungs and to the system, which is destined to fill up the void that the previous vital functions, just completed, have made there; and it is forcible or otherwise, precisely in proportion to the vacuum which has been produced in those localities.

According to this reasoning, the actual systole of the heart must be the *consequence* of the completion of the vital changes in the capillaries of that organ; and, in order that it should be developed, it must be requisite that those alterations in its fabric, which previous systolic efforts have induced in it, should be restored. A portion of the structure having been damaged, as it were, each time that a systolic contraction occurs, must be repaired during the interval which elapses, before the heart is in a condition to repeat its exertion.

The materials by which this restitution is made can only have been derived from the coronary arteries; and the force, by which these are worked up in the new tissue, can only have been imparted to them from the capillaries of the lungs (where the atmospheric air generates it), through the instrumentality of the continuous vascular circle which the coronary capillaries enjoy in conjunction with the lungs.

As regards the action of the heart itself, it is not difficult to infer that the special faculty, which the coronary arteries confer upon its structure during this process of building up, by which it becomes susceptible to the cause which shall provoke its subsequent contraction, may indicate the precise degree of exaltation to which the vital orgasm may be raised, not only in the structure of the heart itself, but also in all other organs of the body, because, in consequence of the absence of any excretory duct, there can be no collateral or indirect source by which any part of the vital orgasm may be carried off. Therefore it may be assumed, that the function which the prepared condition of its structure enables it to perform, must occupy the whole of the vital force which the coronary arteries are capable of imparting to it. When, therefore, the vital intensity of the cardiac capillaries has become such, that a contraction, and consequent discharge of vital polarity ensues, a limit must thereby have been placed, beyond which the vital force in operation in any of the other organs of the body could not have been carried; and, on the other hand, the vital action in all must have reached the same degree of intensity, otherwise it could not have been attained in the capillaries of the heart, since the current, in that case, would have been transmitted in preference through those channels where the resistance was least.

The cardiac contractions must, therefore, act as safety-valves to the intensity of vital force called into exercise throughout the body at any given instant. They must also afford data of measurement, whereby the energy, with which the functions in general are executed, can be estimated. Hence the reliance which, in all ages, has been placed on the information which experienced persons have been enabled to derive from the pulse.

Whenever there is any undue vital excitement, local or general, either in the lungs or in the system, the augmented rapidity of the heart's action strives, as it were, to reduce, by its repeated discharges of vital effort, the excessive tension which then troubles the frame; and it is evident that the vital orgasm can never exceed the insulating power by which the muscular structure of the heart is enveloped. It is well known to all competent observers, that an undue rapidity of the heart's action has a very exhaustive effect upon the amount of vital energy which may then be capable of being excited.

When such an excessive velocity of pulsation is brought into action, even though it may directly affect the heart alone, as regards the cause from which it proceeds, the lungs, by a proportionate increase of respiration, immediately endeavour to compensate for the exhaustive effects which are occasioned by it; but when, from altered circumstances, the excited action of the heart at length ceases, the vital exhaustion that supervenes proves the severity of the strain, which the rapid cardiac discharges have made on the supply, which the breathing has had to furnish.

Moreover, these inordinate pulsations must derive blood from the lungs, and from the system, which has only imperfectly undergone the changes which these organs ought to produce in them; and the effect of this must be that, sooner or later, the natural contrast, which the venous and arterial blood ought to exhibit in their respective segments, will be altered, and the arterial blood will be less arterial, and the venous less venous, than is requisite for the purpose of eliciting a vital power of the due intensity; and, while that condition lasts, the very power of producing a vital energy of proper intensity will be impaired. This provision, by which the contrast presented by the two kinds of blood is lessened by an undue rapidity of the cardiac function, is another safeguard against the excessive exaltation of the vital tension.

The actual amount of vital force, which the walls of the heart would consume during each of its contractions, must be in proportion to its size, and to the quantity of blood which would pass through its capillaries ; and the intensity which it would display would be precisely that which all other vital functions, both systemic and pulmonary, would then exhibit.

If other functions were vehement in their action, the pulsation of the heart would be energetic in proportion, up to a certain point, which the structure of the heart would not allow it to exceed, in consequence of the force then overleaping the barriers which were appointed for its insulation ; a voltaic discharge would then put a stop to its further accumulation ; and this insulation, which governs the amount of accumulation that the heart's capillaries can sustain, must be apportioned to the amount of resistance requisite to be overcome in the systemic organs. When this balance is interfered with, the systemic functions are imperfectly performed: thus, when these cardiac contractions are too rapid, and a less amount of vital tension than is needed for the performance of the systemic functions induces their repetition, the heart is said to be irritable, and irritative fever results. The systemic functions are not then duly performed; the blood passes through their capillaries without having duly executed its task. Converse results to these occur when the heart is impeded in its actions, and when its contractions become unduly tardy, and of greater force than the systemic organs require.

The volume, however, of blood which the heart would throw in consequence of any given contraction, would depend upon the quantity which was supplied to the right auricle from all parts of the body; and the actual force with which this would be propelled would be governed by the comparative thickness of its walls, in reference to the quantity of fluid which its cavities might contain. Therefore, although the force, which the heart communicates to its contents, would bear a significant relation to the vital agencies then at work in the lungs and in the system, still that would be liable to be controlled by other causes, of which the thickness of its walls, the quantity of blood, and the size of its cavities would constitute important elements. These are mechanical causes which, with many others, such as damage accruing to its valves and the like, must be taken into consideration in estimating the effective results which the pulsations would produce.

The same vital energy which would be appropriate and advantageous in a heart of the right size and thickness, and with its due supply of blood, would render it unduly sensitive and irritable, should the quantity of fluid be suddenly reduced, and be thus made disproportionate to the power and capability of the heart. Many other such mechanical derangements might be enumerated, to which this organ is subject. It is, like the lungs themselves, an apparatus which belongs to all parts of the body, to all of which it is equally essential; but in its function, by which its periodical contraction is provided for, it is merely one of the systemic organs, and occupies only a fractional portion of the blood which circulates through the frame.

It is, however, not without its power of compensation, since the whole vital force throughout the frame is governed, *cæteris paribus*, by the quantity of blood, which the heart sends to the lungs and to the system. When, therefore, no accidental circumstance has intervened to disarrange the natural proportion which the size of the heart bears to other parts, the adjustment of all the various contingencies, thus closely mixed up, to the production of an equal and harmonious result, is commonly very accurate; and, when any such disturbance has occurred, the effects which it involves are, in the usual way, very quickly corrected by the diminished or increased action, and by the diminished or increased development of the particular organ, whether it be the heart or any other structure, in which such a contingency happens.

These remarks have been allowed to extend to a larger space than it has been desired to allot to individual organs, in the compendious summary of their performances which has been aimed at in these pages, because they are, for the most part, applicable to the other systemic functions also, and enable the doings of each of them individually to be passed over with greater brevity, through the facts having been more widely discussed in the one, which may be looked upon as the type of the remainder. Those organs, of which the heart is one, which have no excretory duct, must, of course, differ in the quality of the blood which returns from them, from those which possess such an outlet. Those, too, which consist of a structure which is strikingly different, and whose function, also, is very unlike the one lately under consideration, even though these dissimilar organs may have no excretory duct, must retrude blood to the common stock of a somewhat different quality also. The brain and spinal centres afford an example of such an one. Enough, however, has been said to prove that though the *quantity* may vary, in consequence of the different size of the organs in which the blood is employed, and though the *quality* also of the surplus blood which returns to the common stock may likewise differ, yet there must prevail among them all a perfect uniformity as regards the *intensity* of force which is in operation at any given instant.

The *quality*, also, of the blood which goes to the various organs must likewise be perfectly similar, since it all proceeds from one stream, which impartially supplies the whole of them.

SECTION II.—A detachment is sent off from the aorta to the structure of the lungs.

This, in conjunction with its appropriate capillaries and veins, establishes another unbroken *circuit of continuity* with the pulmonary capillaries. The two sides of the heart intervene between the extremities of the opposite segments, precisely as was seen to be the case with regard to the segment formed by the coronary vessels, in which the two sides of the heart acted in a similar manner between it and the pulmonary segment.

The circuit through the tissue of the lungs, now spoken of, makes its own independent loop of continuity in connection with the pulmonary capillaries; and it furnishes the same necessary means for the repairs of the lungs, which the coronary arteries provide for the heart.

It derives its blood from the common stock, which the aorta sends to all the systemic organs, and the vessels, by which this is conveyed to the tissue of the lungs, are called bronchial arteries; and it restitutes its superfluous fluid into the same stream which conducts all other residual blood to the right auricle: the vessels by which this is done are called bronchial veins.

The segment which is thus formed is continuous with the arterial blood which flows *from* the pulmonary capillaries, *viâ* the left side of the heart, and with the venous blood which goes *to* them, *viâ* the right side. Thus it keeps up an uninterrupted connection with the capillaries of the lungs, by the junction of the extremities of one segment with those of the other.

In these particulars, it entirely resembles the coronary vessels which ramify through the structure of the heart.

In both these cases, as in all others, the cavities of the heart intervene between the pulmonary capillaries, and those in which the systemic functions are performed; and the fluid, which passes through those cavities, prevents the disjunction of the continuity of each of them with the pulmonary capillaries. The blood, which circulates in the pulmonary arteries and veins, can only communicate with that which is contained in the bronchial vessels, by the circuitous channel formed by the larger arteries and veins, which conducts the two streams through the respective sides of the heart on their onward route.

There is no communication or anastomosis whatever, in the lungs, between the branches or capillaries of the pulmonary, and those of the bronchial vessels. One set is occupied in conveying arterial blood to the lungs, and retruding venous blood back from them, while the office of the other is exactly the reverse of this. Scientific experiment abundantly proves this fact, and manifest *necessity* entirely confirms it.

Did any such anastomosis exist, as is commonly asserted, it is quite manifest that the greater vital force of the pulmonary capillaries, which changes venous blood into arterial, would neutralise all efforts of the arterial blood in the bronchial vessels to become venous.

But it has been already shown, and it is a fact universally admitted, that no anastomosis of any sort or kind happens in the vessels which convey the venous blood *to* the air-cells : not even that anastomosis is permitted in them, which takes place in other blood-vessels between the different branches of the same; consequently, if any such intercommunication *did* exist between the pulmonary and bronchial vessels, it must only be after the blood of the former has reached the air-cells ; in other words, after it has become arterialised. Therefore, if the blood of the bronchial artery can be supposed to have performed any systemic function whatever since it entered the lungs, it must have become less arterial ; and thence it would appear that the anastomosis, if any such indeed existed, must take place between the pulmonary and bronchial blood after the former has become arterial, and the latter venous.

But should it be for a moment supposed that this junction happened before the bronchial arteries had performed any function, and therefore while the blood still maintained its arterial character, it would follow that the bronchial arteries must have been detached from the stream which leaves the left ventricle, in order to go to the lungs, and to return to the same ventricle, without performing any change whatever, which is impossible. This prevalent hypothesis does not deserve a serious confutation.

The blood goes to the tissue of the organs through the bronchial arteries, for the performance of the natural systemic function, which the lungs stand in need of, as well as all other parts of the body; and the reparation of its tissue is made, precisely as occurs elsewhere, by the arterial blood, which is converted during that operation into venous; and the residual fluid which remains, after this purpose has been served, is conducted back to the common reservoir by means of the bronchial veins.

These veins are not large, because the arteries which correspond with them are small; the tissue, also, of the organ, which their capillaries repair, is of extreme tenuity of texture; and the whole bulk of the lungs, if compressed so as to exclude the air and blood which they contain, would occupy an exceedingly small space, and the weight which they would represent would also be found not to exceed that which, in comparison with other organs, the bronchial arteries would be adequate to furnish with materials for their preservation and repair.

The lungs have no specific systemic function to perform, beyond that of keeping their own structure in order; and a great supply of blood is not required for this purpose. Such other functions, which the tissue of the lungs executes, are almost entirely passive or mechanical: they have no excretory duct, and they have no means of collecting any addition, by which the quantity of materials contributed by their arteries to the vascular plexus might be increased.

The actual quantity, therefore, of fluid which returns from the bronchial capillaries cannot have been augmented, but must, on the contrary, have been reduced, by the functions, which they have had to discharge, since, while the tissue remains the same, the lymphatic vessels carry away a portion of the residual materials, which the arteries have to reinstate.

The veins, then, can only remove that superfluous portion which the lymphatics have not disposed of. But, at the same time, it is quite inevitable that there must be some residual blood, which the veins have to bring back to the venous store, otherwise the continuity of the vascular circle would be broken.

If the bronchial arteries merely carried exactly enough blood for the repairs of the lungs, and the arteries had, as some anatomists have declared, no corresponding veins, the very fact of a circulation would be disproved. It would be no circulation for a particular artery to go to a locality, and to stop there. Even if such an event were possible in a mechanical point of view, the continuity of the chain of vital causes would be lost by such a conclusion. The whole significance of the vascular circulation throughout the body would be overthrown, if, also, it could be supposed that the bronchial arteries left the aorta, in order to anastomose with the vessels which bring arterial fluid back to the left ventricle, from which the blood contained in these same arteries has just departed; because, unless it could be shown that the bronchial arteries had valves to prevent the reflux of blood through them, the arterial fluid which flows back from the lungs towards the left auricle might regurgitate through these very vessels, and thus make its way into the system at large, without going through the left side of the heart at all; which, again, is impossible, and an evident absurdity.

In a dead body in which the structure of the lungs is diseased, technically called "tubercular," if two fluids of different colour be pumped with equal force, one into the aorta, and the other into the pulmonary artery, that which is sent to the lungs by the very narrow and circuitous route of the bronchial arteries will speedily escape, and produce a condition resembling hæmoptysis, and the allied disease called pulmonary apoplexy. Neither of these states can be imitated by any amount of extravasation from the pulmonary vessels. These diseases depend upon an imperfect action of the systemic function in the lungs, and therefore the vessels, which are occupied in that duty, are those which indicate the mischief which that may have sustained. The pulmonary vessels, on the contrary, are those from which the general vital effects throughout the body take their origin. Any circumstance, therefore, which creates a considerable impediment in an important function in any part of the body, necessarily produces a stoppage, and consequent congestion in the pulmonary blood-vessels.

When the vital action of a particular organ is suddenly arrested, the blood which has been collected in the capillaries of the lungs cannot pass onwards, because the correlative systemic action is prevented. Pulmonary congestion, or pneumonia, therefore ensues, not in consequence of any mischief inflicted on the lungs themselves, but because the vital action of a distant part has been interfered with. This will account for the inevitable presence of pneumonia whenever a patient dies from a severe burn, although this may be in a distant part of the body. Pneumonia, pleurisy, and bronchitis depend, according to this reasoning, upon causes which influence the system at large, or some local cause, *e.g.*, drowning, which prevents the onward movement of the blood through the lungs; while phthisis and its allied complaints depend upon the systemic function, which the bronchial vessels ought to discharge, being put out of order.

It will not be necessary to discuss the anastomoses which may occur between the bronchial arteries and certain branches from the æsophageal and intercostal arteries, because the reasoning is not altered, one way or the other, by the fact, whether or not these other systemic arteries may send off communicating twigs to assist in the systemic function of the lungs. Whatever blood may reach the structure in question from these sources, must be of precisely similar quality to that which travels in the bronchial arteries, because, though they may come from the æsophageal arteries, for instance, they would be given off before these had discharged any function relating to the æsophagus: the blood in them would, therefore, not have been altered. Enough has been said in former pages to show that the vital intensity, which prevails through all the different systemic circuits, must be uniform, and correspond with that which is then in process of excitation by the air in the lungs.

It is also contended that it is quite evident that the tissue of the lungs could not be repaired by the bronchial arteries, unless a vital force were communicated through their capillaries during the same interval which succeeds the pulsation, which works a similar effect throughout the other parts of the body; and that the same vital force is, during the same interval, generated in the lungs, of sufficient quantity and intensity to pervade equally the various systemic circuits throughout the whole frame. The facts have been irrefragably proved, and the results of the experiments, by which the transmission of such a current force was demonstrated, have been already published: it is not thought advisable to recapitulate them in these pages.

Section III.—The third independent circuit which the systemic fluid forms, in connection with the pulmonary fountain of vitality, is that through the brain and spinal centres. An equally uninterrupted continuity, as in the other two instances, with the segment devoted to the breathing function, may easily be discerned in this also.

The two sides of the heart also intervene, in the same way, between the extremities of this segment and those of the pulmonary circuit, and secure that the pulsations by which this segment is influenced shall coincide, in point of time, of mechanical force, and of vital intensity, not only with those which occur in the lungs, but with those also which regulate every other systemic operation throughout the body.

This circuit begins with the following arteries:—

The internal carotid,

The vertebral,

The intra-spinal (branches of the ascending cervical, and of the dorsal intercostal arteries), and ends by delivering its residual blood into the common venous stream, into which the jugular vein and other veins (viz., the cervical and dorsal veins, which receive the portion conveyed from the spinal centres, by means of the intra-spinal veins) empty themselves.

From the time when the blood allotted to the functions of the nervous centres takes its departure by the arteries above mentioned, until the period when it is brought back, in a venous state, to the common stream which is passing to the right auricle, the circuit which is thus formed is wholly detached and separated from every other organ.

The structures to which this rivulet flows are enveloped by membranes, which preclude the possibility of interference from any other function: the whole is entirely and rigidly secluded, for the performance of the definite duties appropriate to this section of the systemic segment of the circulation.

The special function which the vascular circuit, formed through these structures, discharges, consists in manufacturing the nervous power; and as this is a product which cannot be carried off by an excretory duct, it would either accumulate or cease to be generated in the minute vascular reticulations constructed for its creation, were not some means afforded it whereby it could be distributed to other systemic parts, and thus equalise the state of orgasm between the nervous centres and those parts.

The exaltation, however, of the neurotic power, derived from the vascular plexuses of that section of the systemic circulation, expressly insulated from the rest for the purpose of its formation, cannot, however, exceed, in point of vital intensity, that which pervades the remainder of the body; but as there is a constant withdrawal of the vital orgasm, after it has been formed by the vascular efforts of certain distant organs, which discharge their functions with facility, and readily get rid of the products of those changes which the vital energy has caused, and likewise as external circumstances may also promote the same neutralising influences in many of them, it follows that, in proportion to the vital activity which prevails throughout the whole system, there would be a corresponding tendency to a discrepancy between the vital tension in the spinal centres, and that in those parts of the body in which there is a free exit given to its effects, unless there were some provision made for the equalisation of the one with the other.

Certain delicate threads, called nerves, are the agents employed for propagating to distant parts the superfluity of orgasm which may thus be created in the nervous centres.

By means of the intercommunication which the nerves establish between the nervous centres and the distant capillaries belonging to different sections of the systemic circulation, a mutual correspondence, so to speak, is instituted between them.

When the neurotic influence is comparatively exalted in any of the nervous centres, the redundant orgasm is conducted by the nerve to the distant vascular plexus with which it is in relation, and calls it into proportionately increased vascular excitement; and an equivalent functional performance is induced, which diminishes proportionately the preponderating tension in the nervous centre. When, however, owing to some local demand on the functional action of the distant plexus, its orgasm is reduced, the effect is at once notified to the central plexus through the nerve, and a proportionate effect is made upon it; therefore the nerve communicates alternately from the periphery to the centre, and from the centre to the periphery, according as the disturbing cause may influence primarily the one or the other.

These nervous centres, therefore, derive their power essentially from the same vascular continuity with the pulmonary capillaries, whence all the other systemic sections draw *their* vital efficacy; and the nerves are the agents for balancing the vital orgasm between the capillaries of the nervous centres and those of other parts, whose vital tension is liable to be altered, either by the facility with which their ordinary functions are executed, or by external causes which facilitate the neutralisation of it.

The nervous power is emphatically a result *secondary* to that whereby the tissue of the nervous centres is manufactured, and bears the same relation to the primary force by which that is done, which the special functions bear to the other systemic sections. It is the evidence of the completion of the fabric by the agency of the vascular circuit, in connection with the pulmonic generation of vital force.

The nerves, then, are the bell-wires by which the brain and spinal centres derive their information, and communicate their orders.

The power itself is secondary, in the same sense in which the magnetic influence, which may be induced in a bar of soft iron by the transmission of the galvanic current through the copper wire which is coiled round it, is to the galvanic influence itself. The voltaic pile engenders an inorganic current, which is accompanied by its allied magnetic principle; and the vascular circle creates *its* organic vital principle, which is attended by its corresponding neurotic agent.

Most of the nerves are merely rods of communication, whose office it is to notify to the vascular reticulations, at their two extremities, any particular deviation from uniformity which these plexuses may exhibit, whether that disturbance arises from an internal cause, affecting the nervous centre, and which requires to be telegraphed to the periphery, or from an external cause, which influences the distant capillaries of the body, and which requires to be responded to by the nervous centres. The insulation which distant or peripheral capillaries, as well as the central ones devoted especially to the nervous functions, enjoy, together with that of the nerves communicating from one to the other, enables a certain polarity to accumulate in either the peripheral or central capillaries, as the case may be, as the direct result of the vital actions which they perform in connection with the vascular circles, of which they each form a part.

Whenever that polarity becomes altered, either by an intrinsic or extrinsic cause, the event is immediately notified to the corresponding plexus with which that spot is in relation, by means of the nerve filament which connects the two.

The effect of this is, that the reduction of polarity in the particular locality is followed by the lowering of the same in the corresponding vascular reticulation, to which it is joined by the nerve fibre; and this reduction will be exactly half of that which its twin plexus will have sustained, since the operation of the nerve will be merely to restore the equilibrium between the two. The perturbation, therefore, will be equally divided between the two plexuses, and they will both be reduced in their polarity to half the extent of the disturbing cause, which affected primarily the reticulation upon which it was exerted.

The intensity of vital action, therefore, in both these plexuses, will be reduced by this result below that of the surrounding parts. The whole vital force will then have a tendency to be transmitted through the vascular circles, in which the tension has been reduced, in preference to those in which such is not the case, until the vital intensity between them and contiguous parts shall have been restored, because, by the previous neutralisation of the vital tension, contingent upon its discharged polarity, the vascular reticulation will interpose a diminished resistance to the current vitality.

When one particular nerve acts as the medium of communication between two vascular plexuses, one in the nervous centre, and the other at some distant part of the body, the simplest and most unmixed form of nervous agency will be exemplified. It establishes a reciprocal equality of the polar condition between the two.

The respective capillaries make no interchange of any commodity between themselves; they are merely brought into unison with each other, with respect to the polar attitudes which their respective fluids assume, by means of the nerve which equalises the polar orgasm between them.

The rapidity with which the nerves telegraph backwards and forwards the regulating influence belonging to them is very remarkable; but it bears no sort of comparison with that with which the vital force itself is transmitted through the vascular circle.

From the rudimental nerve fibre thus sketched out, progressive additions and developments may be traced. Instead of one nerve filament transmitting both backwards and forwards the regulating quality, one nerve filament may telegraph an event from the periphery to the centre, and may there produce an impression, which may be echoed back, not through the same filament to the same peripheral spot, but through another nerve, to some other peripheral locality, and may there excite results very distinct from the cause by which they were both called into existence. Thus a pungent material may be applied to the nostril, by which a particular impression may be conveyed to the spinal centre, and all the muscles of the trunk may thereby be thrown into violent commotion in the act of sneezing; and it is curious to observe how, in this very operation, a deep breath is first involuntarily drawn, in order to gain sufficient vital force with which to accomplish the sternutation. This violent muscular effort is accomplished, not by the nerve which carries the impression to the spinal centre, but by those which return from it to the muscles in question. It is also totally distinct from consciousness or voluntary intention, because the events will even more readily respond to the same causes when these faculties are quite absent, or in a totally torpid state.

There are many other functions, equally under the influence of the nerves, which, in like manner, act quite independently of volition or mental intention.

They occur as well during sleep as when the body is most alert. They are called "automatic," because they are controlled by the nerves in those actions which the body constantly performs as though it were an automaton.

Sometimes they have been called "instinctive," which is an incorrect term, because the faculty in animals which goes by the name of instinct is neither more nor less than an imperfect kind of reason.

The spinal marrow is allotted to the performance of the "*automatic*" functions.

It is the function next in advance of those primitive operations, whereby the combinations are governed, which the materials of the body enter into among themselves and with surrounding ingredients, and in virtue of which the vital functions of the body are called into existence. It is that which first springs out of the vascular chain of causes which distinguishes organic from inorganic operations. It is the first development which the vascular circles create, for the correction and re-adjustment of their different performances to one consistent whole.

The spinal nerves are the strings by which all the vascular circles are tied together, and made again to act in unison with each other, when any cause has created a discrepancy among them.

Vitality can exist in its lowest and most rudimental form, provided only there be certain vascular circles, with a spinal marrow, or something which answers to the same purpose, to compel the various circuits to act in accordance with each other.

The nerves of this class govern those muscular movements of the body, which act independently of any emotion or volition of the mind. They act in a sort of mechanical way, calling upon certain muscles in a regular systematic order, and compelling them to obey certain outward influences, which are necessary for the performance of the movements of parts of the body, without which its vital actions could not be executed. In short, they induce all those movements which are necessary to the animal without its own volition or control.

The action of the muscles, whereby the successive breaths are drawn, as far as these are independent of the will; the movements by which a young infant draws its nourishment; the muscular action whereby a bird maintains its position on its perch during sleep; many of the performances which are called into play, quite independently of volition, in the act of standing or walking, those by which sneezing, coughing, involuntary movements of the eyelids, swallowing, &c., are performed, are all of them examples of the regulating function which the spinal marrow and its nerves exercise over the involuntary muscles. Commonly the regulation of some other natural functions of the body is attributed also to these nerves; but that is probably an incorrect statement, except in as far as those functions depend upon involuntary muscular movements.

Superadded to these automatic nervous functions are others similar to them, but in a more advanced stage of perfection.

The spinal marrow bulges out in its upper part, and affords room for other nervous centres, where these improved faculties may exercise their vocation. This protuberance, which is intermediate between the true brain and the spinal marrow, gives scope to the exercise of the emotional functions; and the scale of events now becomes elevated above chemical or mechanical, or even ordinary *vital* causes, and forms a development of vital operations, which closely verges on a higher creative command than that which governs even organic matter. The effects which belong to this expansion of the nervous centres, though still automatic to some extent, yet differ from the preceding in this—that, instead of conveying an impression to the central vascular plexus, which is echoed back, either by the same nerve which brings it, or by some other nerve, to the peripheral structures, without producing any ostensible result in the centre itself, the operation of this is to make some marked effect on the centre itself, which is appreciable to the individual, and in some instances to leave traces there of its presence, which are recorded for future reference.

For instance, a certain effect is made on the retina by means of light, with its photographic pencilings; this is brought by the optic nerve to the central development, in which the first glimmerings of consciousness reside, and it leaves its impress there. The same with regard to the auditory nerve, which tells the central protuberance of the impressions allied to pain which sound produces on its peripheral extremities: the communications which the other senses also bring to the same locality are modifications of like events. Pain, pleasure, and similar sentient operations, lead the way upwards towards the corporeal passions, in as far as these are distinct from the intellectual faculty, which has another enlargement of the nervous structure, to afford space for the vascular distribution, on which *its* performances ultimately depend.

The corporeal passions—anger, fear, laughter, weeping, animal instincts and propensities—have their appropriate central development in the stratum intermediate between that devoted to the merely sentient faculty, and that which appertains to intellect itself. All of these occupy the space at the lower part of the skull, which forms the bond of connection between the spinal marrow and the cerebrum, or true brain, which is that instrument by which the thoughts assume their sway over the whole fabric.

It has been said that the impressions brought to the central brain, devoted to the sentient and emotional faculties, produce results in that locality which are appreciable to the animal, and which are displayed, not by an immediate action of recoil through some other nerves, but make the foundation of some fresh demonstrations, to which the name of "sentient" or "emotional" faculties has been given. The manner in which the intellectual nerves pick up the impressions, as it were of types, stamped on the sentient protuberance; how they convey them to the vascular plexus exclusively allotted to the intellectual functions; how these images are arranged into groups, so as to form ideas according to the patterns which they assume; how of these groups some are laid up in the memory, while of others words and acts are manufactured; and how the cerebrum sends off its own messengers, straight through the nervous centres, to take hold of those special parts which govern the voluntary muscles of the whole body, are all of them performances subsequent, in point of vital succession, to that which the intellectual power executes by its appropriate organ, the cerebrum, by means of its own vascular plexus; and this, in its turn, derives its vital force and efficacy through the vascular circle, which connects it with the source of all vital action in the lungs.

To carry the investigation still further, and to find out the ultimate nature of the intellectual power which executes these works, and employs these agents, would require a power greater than that of intellect itself, if it be sought fully to unravel its mysteries.

It requires no nice argument, however, to show that it is the vocation and the privilege of the cerebrum to control the acts of the portion devoted to the sentient and emotional impulses and to avail itself of the information which these can convey to it, but certainly not to submit to *their* dominion.

Animals, and even human beings, have been found, who have displayed the effects of limitation in the progressive developments thus rudely sketched. Experiments have also exhibited the effect of the truncation, one by one, of the different nervous centres in particular animals, and the consequent deprivation of the attendant faculty has demonstrated the uses which belong to each. Natural disease has also conveyed to observers much valuable information of the same kind.

In the administration of chloroform it is curious to observe how these successive events are exemplified.

When the chloroform is inhaled, with a due admixture of atmospheric air, the first effect produced is that the capillaries of the lungs engender, and the vascular circle transmits to all the bodily functions, a vital influence, of which the intensity has been reduced by the action of the chloroform.

If this has been done suddenly, congestion in the lungs, and in the organs where the bodily functions should be performed, ensues, because blood has been brought to those organs in quantity and with a force of pulsation calculated to produce a stronger vital result than now occurs. To avoid this danger it is requisite that the active functions in the lungs, and in the system, and consequently the cardiac impulses, should be very gradually reduced.

When this begins to happen the intellectual powers become dormant, next the emotional are included in the same condition, and unconsciousness and inability to feel pain soon succeed.

If the effects of the chloroform be pushed still further, great danger ensues; the rhythmical and automatic functions become involved in the same apathetic influence, and death ensues. The whole of these are merely successive steps, by which the vital force engendered by the breathing, and transmitted through the vascular circles, is gradually diminished. But if the administration of the drug be suspended before the rhythmical action, which controls the muscular movements essential to life, is overcome, those automatic performances may be prolonged for a considerable period, during which the vital intensity may not be sufficient to impart to the other spinal centres their due susceptibility.

When the patient experimented on begins to recover from its effects, it is found that the nervous faculties return in the reverse order to that in which they were lost.

Consciousness, pain, emotional impulses, more or less nearly allied to intellectual comprehension, succeed each other as the vital intensity becomes restored; and it frequently happens that some considerable time elapses before these animal or quasi-mechanical attributes are again reduced to the dominion of the cerebrum.

A very similar sequence of events may also be observed as natural sleep slowly overpowers the faculties. First the intellectual, and subsequently those belonging to the emotions, cease, in proportion as the drowsy influence gradually creeps on, and occasions the loss, one by one, of those supplemental powers which become superadded to the primitive spinal endowment, until at last none but the spinal or automatic functions remain; and sometimes even these are tardily and laboriously performed, as indicated by coma and snoring. The recovery from this state marks also the progressive unfolding, one by one, of the successive developments.

SECTION IV.—The fourth division of the systemic circuits is that which passes through the structure of the kidneys, and enables them to discharge their allotted function.

These organs are insulated from the rest of the body by the fibrous and serous membranes, by which they are enveloped.

A very short trunk, sent off from the aorta, leads the arterial fluid to each of them; and a short vein returns the venous blood derived from them to the vena cava, which conducts the common stream back to the right auricle.

The kidneys differ from some other organs in the fact that two similar structures, one on the right side and the other on the left of the spinal column, discharge similar functions, generally without any intercommunication between the two. Each has its own independent vascular circuit in connection with the lungs, and each discharges its own separate function.

They resemble each other in every particular, precisely as the two hands, right and left, coincide with each other; and there is no difference in the duties which they discharge: the description of one, therefore, will suffice for both.

The blood, which is taken to each kidney by its renal artery, is distributed to its capillaries; and its renal veins collect the blood which remains after the function has been completed, and return it to the vena cava.

The arterial blood which enters the capillaries of the kidney is continuous with that which leaves the capillaries of the lungs, and passes through the left side of the heart, and which travels through the aorta until the renal artery diverges from it; and the venous blood which leaves the capillaries of the kidney is continuous with that which is transmitted through the right side of the heart, and afterwards enters the pulmonary capillaries. Thus the capillaries of the kidneys, like all the systemic ones, are in direct communication with the pulmonary capillaries, both by the arterial and by the venous blood, which join the two; and the two streams of blood and the two sets of capillaries establish an uninterrupted circle of continuity, by which the function of each kidney is brought into direct relation with that of the pulmonic capillaries, and from this special and individual circle all the other systemic organs are excluded. Nothing can, therefore, take place in the capillaries of the kidneys without producing a corresponding effect on the pulmonic capillaries, and nothing can occur in these latter without occasioning a corresponding reaction in the former. The same applies to all the other systemic functions, each in its own independent circle.

The blood brought to the kidneys by the renal artery discharges two duties, one of which is mechanical, the other vital.

The former is, to a certain extent, under the influence of the nerves; the latter is not so, except in so far as the whole body may be acted upon at the same moment.

The operation of the first is to filter, through the renal structure, a portion of clear liquid, which also contains saline ingredients such as are easily dissolved in it; that of the other is to eliminate carbonaceous and nitrogenous products, in obedience to the vital impulse communicated from the lungs, in a manner similar to what occurs in all other parts of the body from the same cause.

The following difference, however, exists—that whereas the products formed in some of the circuits, which have been already discussed, are contributed wholly to the construction of new fabrics, to replace those which have been destroyed; in this case, not only is the structure of the organ repaired by the blood brought to it, but the carbonaceous and nitrogenous products, that require to be got rid of, are formed, and accordingly an excretory duct, or pipe, to drain those refuse commodities away, is furnished to the organ.

The mechanical part of the contrivance, whereby the limpid fluid is poured out, is so adjusted as to rinse away all adherent matters from the interior of the uriniferous tubes, which make up a considerable part of the structure of the organ. These tubes are lined with epithelium, and from this the more viscid formation derived from the vital function is eliminated. Each uriniferous tube terminates by one extremity in a more capacious tube, formed by the junction of others; and at the other end, or blind extremity, a vascular arrangement (derived from the artery) surrounds it, from which the clear stream, poured out in obedience to the *dynamical* function, sluices away the products of the *vital* action.

The vascular arrangements, by which this mechanical operation is greatly assisted, are called "Malpighian tufts."

The quantity of solid matter, which the *vital* process gets rid of, is proportionate to the *vital* energy in force throughout the whole body at any particular time, and it is governed by the activity of the atmospheric changes then occurring in the lungs. The quantity of clear fluid, on the contrary, is governed by other causes, whereof the greater or less fluidity of the blood itself has a considerable influence, to which also must be added the reflected agency from the nervous centres, which contribute material aid in swaying this result.

The anode of the vital current must reside, in this case as in all others, in the small arteries which lead to the capillaries.

Technically, the product eliminated by the vital function from the kidneys is called "urea."

The arteries carrying blood to these organs are large in comparison with the bulk which the kidneys occupy; and this is necessary, in consequence of the large amount of materials that they have to get rid of.

Were it not for the pouring out of the liquid portion by the dynamical process, the residue retruded by the renal vein would have been rendered more fluid by the withdrawal of the more solid materials which constitute the urea; and were the *fluid* portion alone discharged, the residue would have been rendered more viscid than before. But as the two are, for the most part, got rid of nearly simultaneously, the alteration which the blood undergoes, as regards its consistency, is exactly that which the difference of specific gravity of urine, compared with that of the blood from which it was extracted, would denote.

This would undoubtedly amount to something, and the removal of a comparatively larger quantity of fluids than of solids, (agreeing in this respect with what takes place in most other functions,) is probably one of the results of the renal operations.

But it must be evident that the functions of the kidneys are adapted to accomplish some more important end than this. The inquiry, therefore, as to what that end may be, must be one deserving careful consideration.

A portion only of the arterial blood which leaves the lungs undergoes the changes which the kidneys can produce upon it; and the altered blood, after this function has been accomplished, does not then pass on to be employed in some other organ, for which the change may have rendered it suitable, but it goes back to the lungs, and the blood which next issues from those organs is precisely like that which just before went to the kidneys.

It would be extravagant to suppose that the blood from the lungs went to the kidneys to have a certain change wrought upon it, merely in order to return to the lungs, and to be reconverted into what it was before.

Seeing, then, that only a part of the arterial blood goes to the kidneys, while other parts of it go to other organs, and that a great change is wrought upon the whole of it; while, as regards that part which goes to the kidneys, neither the blood which is altered, nor the product which is formed, is turned to any immediate or direct purpose; and that the function of the kidneys themselves, as far as this inquiry has as yet demonstrated, has not conduced to any evident advantage—the only inference that can be drawn is, that the simple removal of those products is in some way necessary to the body at large. This removal cannot have been rendered necessary by anything that has occurred in that particular circle in which the elimination is made, since nothing else has taken place in that circle except the pulmonic changes, which are common to the whole body. Therefore, the withdrawal of those commodities must be necessary, in consequence of something which is occurring at the same time in some of the other circuits; and the object intended to be gained by the action of the kidneys must be, not what they shall themselves produce, but what they shall get rid of.

In short, the function of the kidneys must have been planned for the purpose of compensating for, and remedying, those blemishes in the blood which the operation of other organs would have a tendency to produce, unless some such means for the withdrawal of an equivalent proportion of such materials, as would otherwise be left in excess, were provided. Other systemic organs execute certain processes, whereby particular commodities are withdrawn from the circulating fluid, or communicated to it, and in so doing create a tendency to a superfluity of those particular materials of which urea is constructed. (It is very probable that these ingredients of urea were previously in combination with those commodities required for the performance of some of the functions; but whether this be so or not, the reasoning is not altered.) These superfluous materials, then, are *not* removed from those circles in which they are developed, but an equivalent set of ingredients is withdrawn from that circle which passes through the kidneys; and when the whole of the residual blood is mixed together, the changes wrought by the kidneys have been such as to compensate for the excess in the materials of urea, which the functions of other organs would otherwise have created. If the kidneys were alone to act, the materials of urea would be removed, but those which other organs should have employed would then be in excess; and should these be consumed while the kidneys failed to do their duty, then the materials of urea would remain and deteriorate the blood.

The blood, however, which returns from organs devoted to functions diverse from each other must, in either case, be somewhat unlike, until a mixture of the whole has taken place; but if all these diverse organs have been duly apportioned to each other, and to the whole, and each has got rid of precisely the right ingredients, and in due quantity, then the blood from the whole, when mingled together, will bear a just and suitable comparison with that which was furnished to each and all of the organs for the discharge of their separate functions.

A deliberate study of the effects produced by the function of the kidneys, together with the knowledge gained by witnessing the consequences which ensue from a disturbance of their operations, leads irresistibly to the conclusion, that the duty devolving upon the kidneys consists in acting as a means of compensation to other organs in the manner above described.

If these views are correct, the blood which leaves the kidneys must have been largely deprived of the materials of urea, which must also be in excess in that returning from other organs, until a mixture of the whole shall have taken place; because that fractional part of the blood which passes through the kidneys must necessarily undergo such a drainage of those materials as, by its intermixture with the remainder, shall restore the equilibrium to the whole, so as to correct the redundancy in the rest.

As regards the comparison between the quantity of blood sent to the kidneys, and that which returns from them, it cannot be doubted that the latter must have suffered a considerable reduction in amount, since it can have received no augmentation from any source while passing through the kidneys; but, on the contrary, materials have been given off for the repairs of the organ, and also for constructing the urea; and, moreover, the watery and saline products have been also removed by the dynamical process. But, notwithstanding all these deductions, a sufficient quantity of venous blood must still have been returned by the renal vein to the vena cava, so as to keep up the continuity of the vascular circle; because, if that were for a moment interrupted, even by a single air-bubble, the function would be instantly terminated—the vital current created by the breathing function would be annihilated.

All the vital operations executed by the kidneys or other systemic organs coincide, in point of time, with each other, and their performance corresponds with that interval, succeeding each pulsation, in which the vital changes in every part of the body occur. The quota of blood distributed to each organ by the same pulsation furnishes the necessary materials to each, enabling it to accomplish those changes; and the ensuing pulsation, which is to produce a repetition of like events, is also called into exercise by the same vital influence which the atmospheric changes in the lungs engender in the self-same interval, and cause to pervade impartially through all the systemic capillaries.

The mode by which the nerves alter the stringency of the tissue of the kidneys, so that at one time their capability of holding fluid shall be greater than at another (like a sponge, which is alternately made to suck up fluid, and afterwards to deliver it up), is a matter quite distinct from the vital operations by which "urea" is manufactured.

When the active vital changes are increased by muscular exercise, or by similar excitement, the quantity of "urea" is proportionately augmented, because the kidneys partake of the vital orgasm then excited throughout the whole body; when, on the contrary, the nervous system causes a disturbing influence, in consequence of some mental or physical perturbation, an unusual quantity of limpid urine, with a comparatively deficient proportion of urea, marks the consequences. The exhaustion caused by the undue exercise of the nervous influence reduces the tension of the body, and the vital combinations become less energetic in consequence; the mechanical resistance to the transudation of fluid is thereby diminished; and thus indirectly the nervous agency has a controlling power over the vital functions in general, though it has no direct action on the separate and individual organs in the performance of their own *vital* operations.

SECTION V.—An apparent contradiction to the events which have been described in the foregoing sections takes place in the fifth, which now comes under consideration.

The detachment which is sent off from the aorta for the purpose of accomplishing the changes in the blood connected with digestion, instead of being split up at once into its final capillaries, and then being hurried back through the veins to the general assembly of venous blood, is first divided into a preliminary set of capillaries, by which one particular commission is executed; and the residual blood, collected from this first performance, is then received into a vein, called the "vena portæ," which, in its turn, is likewise divided into a set of capillaries, from which another product (namely, the bile) is extruded; and at last the residual blood from this second operation is poured into the general vena cava by means of the venæ cavæ hepaticæ.

This residual blood, which is given up from the second set of capillaries, is consequently the final residue of both sets, and is sent back to the pulmonary capillaries through the right side of the heart, in company with the venous blood derived from the other parts of the body.

In the digestive circuit, therefore, instead of only one set of capillaries forming the bond of connection with the pulmonary segment, two are interposed, like beads on a string, and an intermediate collection of blood in the vena portæ divides one set from the other.

For the sake of clearness, and to avoid the necessity of the frequent repetition of the words, "first set of capillaries," and "second set of capillaries," it is proposed to give a name to each. The first will be called the "preliminary" capillaries, and the second the "final" capillaries.

The "preliminary" will be those that empty their blood into the vena portæ, and the "final" those that, deriving their blood from the vena portæ, give up their residue to the venæ cavæ hepaticæ, and through them to the general stock of venous blood.

It is plain that the two sets of capillaries in conjunction can only offer the same amount of resistance to the onward passage of the blood which the other circuits interpose, because, if it were greater, the blood would pass, in preference, through the other channels. It is evident, also, that the difference which exists between the blood going *to* the "preliminary" capillaries, and that leaving the "final" ones, must not only indicate the result of all the changes made by the functions of both sets of capillaries on the blood of that particular circuit, but must also be a measure of the extent to which the changes in that circuit can alter the remainder of the blood, since it can only be by the mixture of this changed blood with the residue drawn from the other organs, that any effects can be produced upon the blood at large, traceable to what takes place in those particular capillaries.

The difference between the blood brought to the digestive circuit, and that which leaves it, must be precisely such as the combined function of both sets of capillaries may accomplish in it, and must represent exactly the consumption it has sustained.

The consideration of any fresh materials, which may have been added to this residual blood, by some process independent of the vital functions performed by the capillaries, is for the present deferred. For every pulsation which brings a fresh modicum of arterial blood to the "*preliminary*" capillaries, a certain portion of residual blood will be given up by the "*final*" capillaries to the general stock of venous blood; and the resemblance of this residual portion to the arterial blood supplied to the circuit will be greater or less, in inverse ratio, according as the function of the circuit has been active or otherwise.

It is, therefore, not the absolute quantity of blood passing through any particular organ, by which the amount of function that it executes can be determined, but the degree of consumption which takes place in it.

This consumption also marks the aliquot proportion of vital force, as compared with that in the remainder of the body, which has been called into exercise in the circuit during the period allotted to any particular pulsation, since the consumption which takes place is due to the amount of vital force which has passed through it.

But as the difference between the arterial blood sent to the preliminary capillaries, and the blood retruded from the final capillaries, marks the amount of function discharged by *both* sets of capillaries in the aggregate, so also the difference between the *arterial* and the *portal* blood distinguishes the amount of function performed by the "*preliminary*" capillaries; and the difference between the "portal" blood and the residual blood, given up by the *final* capillaries, denotes the degree and force with which the latter have discharged their office.

The energy with which the functions are performed, whether considered in the aggregate or the particular, is precisely proportionate to the resistance which it surmounts. If the resistance be small, the energy or *intensity* of vital force will be small also, and such will also be the amount of function any organ discharges, compared with the quantity of blood transmitted through the particular capillaries; and the comparative amount of consumption which the blood undergoes will bear a similar proportion, according as the resistance has been greater or less, to the whole quantity made to pass through the capillaries. Should the resistance be small, while the total amount of vital force communicated from the lungs is large, the quantity of blood transmitted through the circuit will be large also; but the comparative consumption will be small, and the difference between the arterial and venous blood will therefore be small also. When, on the other hand, the resistance in the capillaries is great, all these contingencies will be reversed. Whether, however, the intensity of the vital force be increased at the expense of the quantity, in consequence of a greater resistance, or whether the reverse happens, the absolute amount of consumption will, in both cases, bear a direct relation to the amount of vital force communicated from the lungs. In proportion as the intensity becomes exalted, the quantity will diminish, but the increase of intensity will exactly compensate for the reduction of quantity. The absolute consumption will, therefore, not be altered; but the comparison which this bears to the quantity of blood which passes through the circuit, will bear an inverse ratio to the resistance, and consequently to the intensity.

When the resistance in the "preliminary" capillaries is only moderate in degree, there will be no considerable consumption of the arterial blood, taken in comparison with the amount transmitted; the portal blood will, therefore, be abundant in quantity, and not considerably altered from the arterial state. When the resistance, on the other hand, is great, the opposite effects will be displayed.

Should the degree of resistance in the "final capillaries" preponderate over that in the "preliminary" ones, a diminished transit of fluid, in comparison with the other, would take place in the final capillaries, though the absolute consumption in both would be the same, since the same vital force is communicated to both ; but in the one its quantity is bartered in exchange for intensity, and the *proportionate* quantity of fluid transmitted through the preliminary capillaries would consequently be greater, and its blood would be comparatively less changed. (The precise degree in which the increased intensity would cause a proportionate diminution in the quantity of vital force, while the product would remain the same, can be easily understood by the adoption of Ohm's algebraical formula. By doubling the intensity of the current force, its quantity would be reduced to one-half, but the increased intensity or rapidity of action would compensate for the reduction in quantity, and cause the total product to reach the same amount, and thus the intensity and quantity mutually regulate each other.)

By an increased resistance in the final capillaries a diminished quantity of blood will pass through them, and an increased relative consumption will take place. The absolute amount of consumption will, however, remain the same, as in the preliminary capillaries, in which no such increased resistance occurs. The consequence of that discrepancy between the resistance in the final and preliminary capillaries would be that a larger proportion of blood, in comparison with the consumption, would be passed through the preliminary capillaries into the vena portæ, than would at the same time be passed from the vena portæ through the final capillaries into the venæ cavæ hepaticæ, and a congestion would take place in the vena portæ, which would go on increasing as long as that discrepancy lasted; and, unless some provision were made to meet this difficulty, the preliminary capillaries would pour a larger quantity of blood into the vena portæ than it could dispose of.

This surplus of fluid could not be got rid of by an increase of the vital force, because this increase could only be made by one of two methods, neither of which would remedy the defect. Should the lungs be induced to generate an additional amount of vital force for this purpose, that would be dispersed equally over the whole body, and would go where the resistance was least, and would, therefore, only be partially effective on the capillaries where it was required; or, should some impediment be brought to bear, by the nerves or any similar cause, upon the other circuits, so as, by stopping the stream of vital force through them, to cause an additional quantity to pervade those capillaries where the resistance had to be overcome, the effect would be to cause that extra vital force to pass through the preliminary capillaries also, and to throw them likewise into additional activity, and thus the comparative relation of the two would not be altered.

The difficulty, however, is overcome by means of a local arrangement. The cells of the spleen are so contrived that, by becoming distended, they can afford a temporary lodgment to the redundant quantity of blood sent into the vena portæ, until the causes which have produced the greater resistance in the final capillaries shall have been reversed, and a remedy provided by the opposite condition being produced.

In the mean time the cells of the spleen act as reservoirs for the blood sent into the vena portæ, and the prolongation of Glisson's capsule prevents the latter from suffering any injurious distention.

When the resistance in the final capillaries diminishes, owing to the bile which it is their office to produce being removed, and the resistance in the preliminary capillaries becomes greater, in consequence of the active processes of digestion making additional demands on the vital supplies, and exciting a more energetic set of changes, the quantity of blood poured into the vena portæ becomes comparatively less in quantity than that passed through the final set; and the blood in the vena portæ and in the cells of the spleen, encountering less resistance than before, is passed with facility through the final capillaries, and the congestion produced by the former preponderance of resistance in them is remedied by the opposite state of circumstances.

Should the resistance now spoken of continue still to preponderate in the preliminary capillaries over the final ones, any injurious effects would be prevented by the fact, that after the blood, which had been previously stowed away in the receptacles of the spleen, had been consumed, any protracted operations of an energetic character would be prevented by the fact that additional supplies, with which to keep up the discrepancy, would be cut off, in consequence of the resistance which would then be offered in the preliminary capillaries; and the functions of these preliminary capillaries would also be checked by the absence of the bile, which the final capillaries would then not continue to produce, and without which the previous preparation of food, essential for the performance of the preliminary functions, would not have been made.

When, however, the resistance in both sets of capillaries is alike, not only must their vital products be equal in degree, but the fluid which they transmit must also be proportionate in amount: there will then be neither excess nor deficiency in the vena portæ. And, as the same vital force is always transmitted through them both, and as a temporary alteration in intensity, in one or the other, does not vary the absolute amount of product consumed in either, as compared with one another, but only influences the comparative amount of blood which they each may transmit, it follows that the absolute amount of function, as evidenced by the amount of material consumed by the preliminary and final capillaries, must always tally the one with the other. They must each constitute an exact moiety of the whole performance belonging to the circuit in question. But the function allotted to the final capillaries consists exclusively in furnishing the bile, which is drained off by means of the bile ducts with which the liver is supplied. The consumption of materials, therefore, which the formation of the bile occasions, must also be the measure of the consumption which the functions of the preliminary capillaries involve, since this has been shown to be equal to that of the final capillaries. The functions, however, of the preliminary capillaries consist of several distinct operations: the whole of these operations, taken in the aggregate, entail a consumption of materials equal to that which is involved in the construction of the bile.

Having, therefore, ascertained the amount of function which they perform in the aggregate, as measured by the materials consumed, it will next be a matter for inquiry, in what proportion or manner these materials are distributed among the different operations which, in the aggregate, constitute the preliminary capillaries.

The following arteries convey the blood to the preliminary capillaries, namely, the cœliac axis, the superior mesenteric, and the inferior mesenteric arteries. The vena portæ collects the residual blood from these, and is afterwards divided into the "final" capillaries, and these execute one particular office, namely, they furnish the bile; and the residual blood from these last is passed, by means of the venæ cavæ hepaticæ, to the common venous stream, which carries it back through the right side of the heart to the primary fountain of vitality in the lungs.

All the different structures with which this circuit comes into relation are secluded and insulated from the remainder of the body by the *peritonæum*, which folds around them, and prevents, except in cases of disease, any vascular intercommunication. The structures included in the whole circuit are the liver, the pancreas and spleen, the stomach, duodenum, and bowels in general. Whatever function these organs perform, either individually or collectively, belongs to this vascular circuit, and derives the vital force for its performance from the lungs.

The anode of this vital force is formed by the terminations of the arteries above enumerated, where they join the preliminary capillaries, and the cathode, by the commencement of the venæ cavæ hepaticæ, where they are continuous with the final capillaries.

The preliminary and final capillaries each, therefore, form equal moieties of the *one* function which appertains to the whole circuit.

But it has been shown that the office of the final capillaries consists wholly and exclusively in the construction of "bile," which is drained off by the ducts of the liver, and that it does this by means of the *portal* blood; while, on the other hand, the arteries above mentioned are distributed to various organs, and the preliminary capillaries which they supply perform diverse functions. These preliminary capillaries have to repair the cellular tissue of the liver, the pancreas, the spleen, and the bowels in general; they have also to discharge the special function of each of these organs except the first; and the whole of these functions, including the repairs of the cellular tissue of the liver, only equal in the aggregate the function which the liver itself executes.

All of these structures discharge, by means of the preliminary capillaries, one particular function in common, namely, they execute that process by which the cellular tissue of each is kept in repair. All the other functions may therefore be considered, in some sort, as additions or adjuncts to this, particularly as that which belongs to each is, to a certain extent, diverse from the rest.

If all the various organs of this circuit did nothing more than this, the investigation would be simple enough. One portion of the cœliac axis—namely, the hepatic artery—performs precisely this office for the cellular tissue of the liver, and does nothing more: a portion also of each of the other arteries does the same duty for the organs to which they each belong.

The residual blood derived from this particular duty is emptied into the vena portæ, and this would easily conduct it onwards to the general assemblage of venous blood, were there no other duties to be discharged by the capillaries, into which the portal vein becomes spread out. As far as the duties, which this particular blood has to perform, are concerned, it is reasonable, from analogy, to conclude that, as soon as the repairs of the cellular tissue of the various organs are made, its office is concluded, and that it might at once be restored to the other venous blood passing towards the right auricle, since, in other parts of the body, blood which has performed a precisely similar office is received at once into the common venous reservoir, and is sent to the lungs, *viâ* the right side of the heart, without any further alteration except mixture with the rest.

The blood, however, which has been engaged in the manufacture of cellular tissue in the digestive organs, is passed into the vena portæ, and is mixed with other blood which that vein contains; and the whole together is transmitted through the capillaries in the liver, into which the vena portæ becomes very elaborately reticulated, before it is allowed to join the common stock.

The only reason for this arrangement, as far as the blood which has discharged the function of repairing the cellular tissue is concerned, must be that if a junction were immediately made, by means of this blood, with the general stock of venous blood, a sufficient intensity of resistance could not be obtained in this circuit for the performance of the additional or supplemental functions: the continuity of the vital circle would be made by such a junction, and those other functions would be left out of the circuit.

But the final capillaries do not dissever the continuity of the vascular circle necessary for the performance of that operation, by which the cellular tissue of the organs (including that of the liver itself) is repaired. Did they raise such an impediment as should prevent the transmission of the vital force, their own functions would at the same time be destroyed.

The reparation of the cellular tissue may, therefore, be considered as a constant and permanent operation, going on somewhat faster when the augmented intensity of other functions compels an increased intensity of vital action to take place in it also, but still in operation when collateral actions may be comparatively in abeyance, since, so long as any vital force is transmitted through the vascular circle, this restorative function will continue to be exercised.

But other functions are knotted on, so to speak, to the telegraph wires which convey the vital agency; and these supplemental functions derive their potency from the same vital current which plays along the conducting capillaries to which they are attached, and they are indebted to an *induced* condition, which the primary current imparts to them, for the ability to discharge their special duties.

The supplemental duties which the preliminary capillaries discharge, over and above the restoration of the cellular tissue of the organs already mentioned, consist in performing the peculiar functions which the same organs, except the liver, have specially to perform; that is to say, the functions of the spleen, of the pancreas, and of the stomach and bowels in general, fall to the lot of these preliminary capillaries to execute, over and above that of furnishing the materials for the repairs of the cellular tissue of these organs, and of the liver. A portion of the blood sent to these particular capillaries goes to each of those organs, and the blood from all of them is emptied into the vena portæ; therefore the arterial blood has the choice, as it were, to which of these it will go in preference; but as it goes to all of them alike, it is evident that the resistance in each of them must be equal. Each of these organs discharges duties somewhat different from the others, and acts under circumstances to a certain extent dissimilar; but in one particular they resemble each other; that is, they all execute their special functions by means of the epithelium which they construct.

In order to arrive at a more distinct understanding of the proportionate effects which these adjuncts to the circulation produce by the exercise of their special functions, it will be convenient to notice *seriatim* the provisions made in the structure of each for their performance, as follows:—

I. The stomach and bowels. II. The pancreas. III. The spleen.

I. In the first of these divisions—namely, the stomach and bowels—a difference is observable, not only as regards the other branches of the same vital circuit, but with reference to the remainder of the body, since in no other case (unless one other doubtful instance be also admitted), except in the primary operations, by which vitality itself is excited in the lungs, are materials which do not form an actual part of the body itself allowed to participate in the duties, or come in contact with the vascular structure occupied in the performance of any vital operation. In the intestinal capillaries, however, the presence and co-operation of food form an essential requisite for the due performance of the vital functions.

The whole of the internal surface of the stomach and intestinal canal is covered with a minute vascular formation, which gives it the appearance of velvet.

The branches from which this minute plexus is derived are furnished as offshoots from the same artery, or its branches, which supplies the reticulation by which the repairs of the cellular tissue are made.

The whole of the velvety surface is covered by epithelium, which is constantly being renewed; and it is the office of the vascular plexus to do this.

II. Another set of offshoots from the arterial branches, engaged in the formation of cellular tissue, is found to ramify in the structure of the pancreas, and around the internal surface of its ducts, and to supply the epithelium whereby its function is performed.

III. A corresponding provision is made in the spleen. A vascular distribution is found in it, altogether disproportionate to the size of the organ, on the supposition that its structure alone required to be maintained, without having to discharge any positive or special function, which would consume an additional quantity of blood. The epithelium which lines its lymphatic ducts is, doubtless, contributed for a purpose analogous to that for which that formation is supplied to other organs; but this alone would not be tantamount to what its artery is obviously adapted to accomplish. A difficulty arises in determining precisely what other results are obtained in this organ, seeing that the spleen possesses no excretory duct, and that the product of its function, whatever that may be, becomes immediately mingled with the portal blood, and is therefore incapable of being examined separately. It is an undeniable conclusion, however, that some considerable alteration must take place in the blood brought to it by the splenic artery, over and above that involved in the reparation of its cellular tissue, because of the great supply of lymphatic vessels which the organ enjoys, since it is impossible to suppose that lymph should be eliminated from the blood without a proportinate change in the arterial blood from which it was drawn, and without an equivalent effect on the residual blood also.

But as that proportion of ingredients, which in other organs is carried off in the shape of an excretory product, is not, in the case of the spleen, removed by any excretory duct, it results that those commodities must either be delivered to the venous blood, with which its cells are filled, or they must be given up to the structure of the organ itself.

It is certain, also, if they were imparted to the tissue of the spleen itself, they could not do otherwise than produce some direct result in the act of being so delivered; and likewise, even in that case, it would be necessary that they should be soon transferred to the residual blood; and the circumstance of their being transmitted from the spleen to the residual blood would necessitate a second tangible effect, since it is impossible that they should remain for an indefinite time in the tissue of the organ, because such an event would tend to produce a permanent and constantly increasing congestion, which the organ would have no means of ridding itself of; and, in the absence of an excretory duct, or of any active functions, causing a great consumption of materials, there is no other way in which it could be disposed of.

It is clear, therefore, that the complementary matters which, together with the lymph, make up the amount of materials of which the arterial blood is composed, must find their way into the residual blood, and therefore this must differ from other venous fluids in containing the materials which, in other organs, are consumed by the functions which they perform, or which are removed by their excretory duct, when that is provided. It is fair, therefore, to conclude that the products of the changes wrought on the blood conveyed by the splenic artery, which in other organs would be extruded by means of an excretory duct, or employed in some definite function, are mingled with the residual blood itself, and work a corresponding change upon it.

There are also other reasons which the

microscope reveals, as to the condition of the residual blood, which strongly confirm these inferences.

One important office which the function of the spleen discharges, in virtue of the vital influence communicated through its capillary plexus, consists in maintaining in a fluid state the venous blood with which its receptacles, in connection with the portal vein, are filled, and in restraining all tendency in it to coagulate. Nothing but an abundant supply of vital force could enable it to do this, and that vital force could only be imparted to it from the pulmonary organs; and the vascular circuit which the splenic artery, with its capillaries and veins, makes in connection with that source of vitality, could alone impart sufficient vitality to enable it to overcome the tendency of that blood to coagulate.

The residual blood, then, from these three sources—namely, from the stomach and alimentary canal, from the pancreas, and from the spleen—is passed into the vena portæ, and is mingled with the ordinary venous blood derived from that process whereby the cellular tissue of these organs is restored, to which quantity that also which performs the same function in the liver itself is soon added.

The final result of all these operations, as far as the blood only is concerned, amounts to the fact that the portal blood is formed—that, from which the bile has next to be extracted. A certain amount of vital force generated by the lungs has been consumed in producing this result, and this amount exactly equals half the vital force which is called into exercise in this particular circuit, namely, that in which the whole digestive process, in as far as that is a vital operation, is concerned.

The formation of the portal blood is, therefore, a composite performance. Four different results have been obtained by the operations engaged in its production, namely,—1st. The formation of the cellular tissue of all the organs belonging to the circuit, the liver included. 2ndly. The residual product of the intestinal action, after that portion which is excrementitious and that which enters the lacteal ducts has been removed from it. 3rdly. The residual portion derived from the pancreas, after that part of its materials which constitutes the pancreatic fluid, and that which the lymphatics have removed, are withdrawn from it; and, 4thly. The residual portion, which is derived from the blood brought by the splenic artery, after the materials withdrawn by the lymphatics of that organ have caused a particular change.

This portal blood, then, derived from all these sources, and operated upon by the vital changes which all those organs undergo, ascends through the final capillaries, into which the portal vein next becomes dispersed. The previous effects have all conduced to the formation of a fluid suitable for the production of bile, which is the next and only duty that this blood is now called upon to perform, previously to being returned to the lungs in company with the venous blood from other parts of the body, to be there restored to the same condition as that it was in before any of the events described in this section commenced.

No force of pulsation now helps it on its course; but it continues to mount upwards, in opposition to its own weight, precisely as oil creeps up the cotton wick of a lamp.

Any increased quantity of blood which the preliminary capillaries may transmit, beyond that which the final capillaries can immediately dispose of, will flow along the splenic vein in a retrograde direction, and distend the chambers of the spleen, and will remain tranquilly there until the capillaries of the vena portæ can pass it upwards through the structure of the liver.

The capsule of Glisson prevents any undue distension of the vein itself; but the secondary effect of too protracted a superfluity in the portal vein would be, that the preliminary capillaries would become impeded in their action; and the whole digestive process would, if this state of things continued, be brought to a stand-still, and certain distressing symptoms, of which hæmorrhoids may be quoted as an example, would probably supervene. Undue deposit of fat in the omentum is also a very common result of retardation of the portal blood, through an impediment in the final capillaries.

Having ascended into the substance of the liver, the portal blood becomes distributed through the capillaries spread out in its substance.

These capillaries envelope the biliary tubes, and ramify over their interior with a minuteness, of which none but those who are familiar with the microscope can form any conception. They supply the epithelium which lines these tubes, and separate the peculiar commodity called " bile " from the blood brought by the portal vein; and they return the residual blood, which then remains, into the venæ cavæ hepaticæ, and these conduct it to the common assemblage of venous blood from all parts of the body.

This residual blood constitutes the final residue after both sets of capillaries (the preliminary and the final) have made their deductions from the arterial blood contributed to the digestive circuit.

The functions performed by this circuit may be thus summed up.

The arterial blood is converted by the preliminary capillaries into portal blood, and the portal blood is converted into residual blood by the final capillaries. The whole circuit is not completed until the functions belonging to both sets of capillaries have been performed.

With each pulsation, which brings a supply of arterial blood, a corresponding result occurs both in the preliminary and final capillaries, and both these sets of capillaries execute their functions on different portions of blood at the same identical instant; and this event is also synchronous with what occurs in the lungs, whereby the supply of vital force for the execution of these and all other systemic vital operations is produced. And the whole digestive circuit, like the other systemic circuits, depends upon its uninterrupted continuity with the pulmonary capillaries, by means of the arterial and venous fluids passing through the two sides of the heart, for the supplies of vital force, generated in the lungs, necessary for the performance of its local functions.

The distinct and special operations of the circuit treated of in this section are isolated, and rendered exclusive from all other systemic performances elsewhere called into force, by the *peritonæum*, which incloses the organs in which both sets of capillaries are distributed.

But it has been seen that, in this circuit, there has been a performance of one particular set of functions, which coincides with what takes place in all other parts of the body, namely, that by which the cellular tissue of the whole has been repaired; and to this has been added another set of operations, which constitutes the peculiar and special functions of this circuit in particular, and of the different organs in detail of which it is made up. And it has been shown that the formation of epithelium has been the ostensible means by which these additional or special properties have been conferred upon those organs.

It will be well, before dismissing this branch of inquiry, to glance at one or two particulars relating to the method by which that auxiliary chain of causes thus tacked on, as it were, to the regular systemic circuit, is brought into communication with the food, to accomplish the due adaptation of which to the purposes of the body was the object for which the whole of this diverticular arrangement was contrived. Except in this instance, and that of the air which is brought into contact with the pulmonary capillaries, and in one other instance which it is not necessary now to expatiate upon, no sort of communication with the outer world, or with matters extrinsic to the vital fabric, is ever permitted.

But like as the air, by its influence on the pulmonary vascularity, excites corresponding effects throughout the whole frame, so also the food, when brought into contact with the vascular fringes, which are semi-detached, as it were, from the main trunk line of the circulating current of this circuit, seems to initiate those changes that especially appertain to the vegetable processes, by means of which the materials requisite for the reinstation of commodities withdrawn from the blood are extracted from the food, and are brought to their necessary degree of perfection previously to being admitted to the more advanced operations strictly belonging to vitality.

The vascular plexuses in the digestive organs, consequently, form the intermediate bond of connection, between the changes which go on in the lacteals and the thoracic duct on the one hand, and those more energetic and constant effects which belong to the direct vascular circuits on the other.

The results, which the changes occurring in these ducts give rise to, have been already compared to vegetable operations, while both the effect and the direct action of the undeviating vascular operations are of a strictly vital character; and those events that admit of alteration by the quantity of food, or by the state which may prevail with regard to the quasi-vegetable processes, are controlled by the sort of offshoot or adjunct to the main conductor of the vital force, which is provided by the vascular loops adapted for the construction of epithelium. This last function, therefore, inasmuch as it is variable, and liable to be influenced by causes not strictly vital, may be considered as something composite, or intermediate—between the quasi-vegetative and true vital operations: the vascular structure by which it is accomplished exhibits, likewise, a sort of diverticular or superadded arrangement in its formation.

It is not necessary now to enlarge upon the function, analogous to the quasi-vegetative processes belonging to the lacteal vessels, which the lymphatics also perform in collecting nutritive materials from all parts of the body itself.

The construction, however, of epithelium lining the digestive organs, by means of the vascular fringes, is in itself a vital operation, and is the result of the changes made in the blood contained in these fringes, and depends upon the vital current which passes through them, though the subsequent dynamical application of the epithelium thus formed, entitles the whole process to be considered a mixed one. The character and quality, also, of the residual blood resulting from that vital operation are due exclusively to the vital chain of causes which has influenced the changes themselves.

The withdrawal, however, of the materials required for the construction of the epithelium of the intestinal tube, does not constitute the only difference between the arterial blood brought to the organ, and the venous-like fluid which returns from it into the portal vein. The same vital process which manufactures the epithelium elicits also another product from the same vascular plexus; and this is not discharged, as in the pancreas, by a special excretory duct, because the tube of the intestines themselves obviates the necessity of any such; neither is it removed by the true lymphatic ducts, as in the case of ordinary systemic functions, *e.g.*, the brain or the muscles; but it is poured out where it is formed, and is turned to account in the quasi-vegetative processes which supervene.

This excretory product resembles bile itself, if it be not, indeed, actually bile; and its after-functions correspond very closely with the properties of that fluid.

The formation of epithelium, then, is a vital operation: not so its subsequent employment.

The epithelium absorbs, by a dynamical process, the fluid nutriment with which the bowels are filled, and which is already in a state of almost complete preparation to be taken up by the lacteals.

By the absorption of the nutritive fluid the epithelium swells, and then the product (analogous to the bile, derived from the vascular plexus) eliminated during the manufacture of fresh epithelium, destined to take the place of that distended with nutriment, becomes mixed with it. Immediately that this takes place, the contents of the epithelium are divided into two parts.

One of these is milky, and enters the lacteal tubes; passes through certain agglomerations and contorted arrangements, by which those tubes are lengthened and gathered into bundles, called mesenteric glands; and at length reaches the thoracic duct. It undergoes successive alterations and improvements during its transmission through those structures, similar to those by which the sap of plants is gradually ripened, so as to be fit at last to produce the fruit. By the time this milky fluid, which is called chyle, reaches the upper end of the thoracic duct, it has undergone such an amount of preparation as entitles it to mingle with the blood itself, and fits it to restore the consumption which the various vital functions have made upon that fluid.

The other part, together with the *débris* of the epithelium itself, is rejected altogether from any further use in the body, and passes off as excrementitious matter.

In the vascular changes whereby the epithelium has been formed and employed, no fresh product of a nutritive kind has been received into the circle of blood. It seems essential, before any such can be admitted, that it must perform the initiatory process of passing through the thoracic duct, and be there duly prepared for its future destiny; but water, and such things as water can readily dissolve (*e.g.*, salt), which require no preliminary preparation, are received at once into the intestinal veins, which terminate in the portal vein; but the addition of these is not effected by a vital process, but by a dynamical one.

This latter operation is the principal means whereby the liquidity of the blood is duly provided for, and by its instrumentality a means is also secured, by which the biliary ducts, in the subsequent operations which the portal blood has to perform, can be washed out, and the more viscid vital product cleared away, in the same manner as the uriniferous tubes were seen to be cleansed from any adherent urea, in the former section, when the functions of the kidney itself were under consideration.

A result very similar to that which occurs in the intestines may also be traced in the pancreas, with this difference—that in the latter case no nutrient materials mingle with the epithelium, causing it to burst; but the product of its epithelium is poured forth without the assistance of any such exciting agent, and is drained away from the organ by an excretory duct, and is afterwards used for a digestive purpose, at a distance from the spot where it was constructed. In other respects, the use to which the pancreatic secretion is applied corresponds, with some degree of accuracy, with that to which the material resembling bile, given up by the intestinal fringes during the manufacture of its epithelium, is turned.

The formation of epithelium occurs, in both instances, as the immediate result of the vascular action, and its construction seems equally essential in the intestines, pancreas, and liver.

It is needless to say more of the spleen, in the obscurity which hangs over the actual method by which it discharges its function: suffice it to remark, that the residual blood derived from it also is that which remains after its function has been performed, and that its suitability to perform its future duties in the body is proportionate to the success with which the special function of the spleen, whatever that may be, has been accomplished.

The residual blood, then, from these three sources —namely, from the spleen, the pancreas, and the alimentary organs, after these have executed what appertains to them—is received into the vena portæ, together with the water and saline particles which may have been added to it. The portal blood also receives the residual blood, derived from the reparation of the cellular tissue of the above-named organs, and likewise of the liver; and the whole ascends through the final capillaries, into which the portal vein is next divided, and when those capillaries are thoroughly incorporated within the substance of the liver, they are so arranged as to embrace all the biliary ducts, and also to line their interior with a minute plexus, from which the epithelium belonging to those tubes is formed.

The bile itself is produced by the aid of the epithelium thus supplied by the portal blood, and it is washed away from the interior of the biliary tubes, along the larger one leading to the gall-bladder, by the clear liquid which is dynamically poured out, at the same time, from certain of the portal capillaries, which are so arranged as to resemble the Malpighian tufts already described, in the appropriate section, as performing a similar office in the kidney. The previous absorption of fluid by these portal veins prepares the means by which those capillaries execute the dynamical function now alluded to, of washing away the too viscid bile from the interior of the bile ducts.

The bile having been manufactured by the vital process, and washed into the gall-bladder, or on at once, as the case may be, into the duodenum, into which the duct of the gall-bladder empties itself, may be used immediately for the purposes of digestion, or may be stored up in the gall-bladder, where it may also become inspissated and concentrated, and may afterwards be used at leisure, in that preliminary preparation, which it is necessary that the food should undergo, before its materials will be fitted to participate in any strictly vital operation.

The changes which the food undergoes, under the influence of the bile, coincide with those to which the same materials could be very well subjected in a mere chemical apparatus, and therefore resemble ordinary "inorganic" changes. The changes next succeeding these, which the nutrient materials have to perform, are those which occur during the passage of the nutrient particles through the lacteal tubes and thoracic duct, and correspond with such as are met with in vegetables, while the changes subsequent to these latter are those of a strictly vital character, and are under the influence of the true *vital force* derived from the breathing.

Thus the analogy of the successive gradations of inorganic operations, first leading to vegetable developments, and these passing onwards into vital or animal fabrics, is maintained, with respect to the new commodities employed in the body, even after those new ingredients have been swallowed and received into the digestive cavities.

The effects, which the bile produces upon the food in the earliest stages of digestion, are similar in kind to those which the analogous fluid, furnished during the formation of epithelium in the intestines, performs in the most advanced stages of the digestive processes.

The fluid, therefore, which accomplishes the more finished results belonging to digestion, whereby the nutritious juices just previously to, and in the very act of, being received into the lacteal tubes, are rendered finally and completely suitable, is drawn from that part of the vascular circuit which is in immediate relation with the arteries bringing the supplies of new blood; while that, from which the earlier processes of digestion are performed, is drawn from that blood (namely, the portal), which may be considered, in some sense, as the residue or refuse of the former.

By the ascent of the portal blood into the liver, the product, which it is the office of this organ to eliminate, becomes advantageously placed, so that it can with facility be brought into contact with the food in the very commencement of the alimentary canal.

The food, previously to being passed into the duodenum, where it becomes mixed with the bile, is first reduced into a pulpy condition by having been masticated, and afterwards churned and conglomerated in the stomach, and mixed with the excretory products of that organ. (While in that pulpy condition it is called chyme.) Up to the point where that product is completed there has been no withdrawal of any of the materials contained in the food; but the nutrient ingredients have undergone a sort of mechanical or culinary preparation for the future changes which are to be induced in it.

The true digestive process may, therefore, be considered as commencing when the chyme is subjected to those operations, by which that portion suitable for the purposes of the body begins to be separated from that which is inappropriate.

This first occurs in the duodenum, and is effected by the admixture of the bile with the chyme recently delivered by the stomach.

By means of the bile a milky product, approximatively adapted for nutritious purposes, to which the name of chyle is given, is separated from the refuse, which is only fitted to be expelled as excrementitious materials.

The chyle, thus eliminated from the chyme by the agency of the bile, is afterwards further improved by means of the secretion, poured out from the vascular plexus of the digestive circuit during the fresh formation of the epithelial growth; and this intestinal secretion performs a second disintegrating process on the chyle, similar to that which the bile executed on the chyme. The selected portions are immediately taken up by the lacteal absorbents, which are spread throughout the greatest part of the alimentary canal, and they then enter upon their course of probation in the quasi-vegetable processes, by which they are finally brought to a state suitable to be mingled with the blood itself.

After the new materials have been mixed with the blood they become liable to a fresh set of changes, quite distinct from the quasi-vegetable influences to which they have been previously subjected, being now brought within the operation of the vital force which the lungs, with the assistance of the atmosphere, develope, and which the circle of blood conveys to all parts of the body.

From the effects which the products of the vital action in the alimentary organs (*e.g.*, the bile, the pancreatic fluid, the intestinal secretion, &c.) develope in the food, an analogy may be drawn to the results which certain fertilising materials bring to pass in the soil from which plants draw their nourishment. Many of these fertilising agents, though not themselves received into the structure of the plants, produce beneficial effects on the soil in which the plants grow; and even the plants themselves sometimes, by means of an exudation from their own roots, modify the soil, so as to render it more salubrious to itself.

In all these particulars the food received into the digestive organs strongly resembles the soil whence plants derive their sap.

The whole ascent of the nutritious fluid, when received into the lacteal and thoracic tubes, is extra-vascular (a quasi-vegetable process): still the tubes themselves, and the epithelium which lines them, must be under the control of the vital causes which influence their blood-vessels; and the same reasoning which has been applied to similar structures is equally cogent with regard to what takes place in the blood-vessels, which supply the lacteal absorbents and thoracic duct with their vital attributes. They not only derive a supply of arterial blood from the same stream, which distributes its streamlets to all the other organs, but they must also contribute their quota of residual blood to the general venous stock.

The whole of the performances described in the digestive circuit, to which this segment is devoted, is the sequence of each individual arterial pulsation ; and the sáme pulsation which accomplishes the vital results in this circuit, bears the same relation to the vital effects which other organs execute at the same instant, which it does to these particular ones.

The organs engaged in the digestive process derive their efficacy from the same vital force, communicated to them from the lungs, which is impartially distributed to all the systemic circuits, and they contribute their residual blood to the same auricle and ventricle to which the other organs promiscuously send theirs; and the same pulsation which evokes the vital powers belonging to the digestive circuit, exercises its corresponding power on every vascular loop throughout the whole body.

SECTION VI.—As regards the circuit through the spermatic organs, it will be sufficient to say that the same principles prevail as have been remarked upon in the previous sections.

The spermatic organs in the male and the uterine in the female are isolated and inclosed by membranes, precluding the interference of any other functions, precisely as in the other circuits.

They receive a supply of blood fresh from the common arterial stock that has not been previously used for any systemic purpose, and this branches out into the set of capillaries, through whose operations the special functions deputed to the organs are discharged.

Residual blood is returned from them to the general assemblage of venous fluid journeying towards the left auricle; and a distinct vascular circuit, independent of all others, is formed by the arteries, capillaries, and veins. The spermatic organs are brought by their vascular circuit into direct relation with the pulmonary capillaries, through the connection established by the arterial and venous blood; and the functions which the circuit performs are, like all others, made amenable to vital influence, which it is the office of the pulmonary capillaries to evoke.

The vascular circuit formed by those arteries, capillaries, and veins, is set apart for the exclusive purposes for which the organ has been constructed.

The intensity displayed by their functional operations bears a direct ratio to the energy of the vital principle called into existence, at any given time, by the breathing organs; and the greater or less employment of them depends upon the regulating influence of the nerves, which can interpose a greater or less resistance to the vascular transmission, and can thus exalt a local tension at the expense of vital energy due to other functions.

When other active corporeal functions carry off all redundancy of vascular excitement, these are reduced to a passive and healthy performance of their office; but undue vascular action in the nervous centres, without a corrective influence of bodily or mental labour, insufficient employment of the intellectual qualities, and excessive stimulation of those parts of the nervous structures appertaining to the emotions, are the pernicious causes of uncontrolled and inordinate appetites, whereby first the mental and afterwards every other vital attribute becomes involved in one common ruin.

It may be positively affirmed, that no mental achievement possessing those qualities understood by the words " masculine excellence " can ever be obtained, except in proportion as the undue activity of the functions of this circuit is held in check.

Feebleness of judgment, vacillation of purpose, a fanciful and unnatural estimation of things, credulity, imaginativeness, as opposed to sound reason (though sometimes dignified by the name of " the ardent poetic temperament "), and the like, betray an action in these organs beyond what is appropriate and in just equilibrium with the other bodily functions.

Alas ! for the effeminacy, mental and moral, apparent at a glance to the physiological eye, exhibited by many in all ranks of society, springing from an absence of this control, which the brain itself ought to exercise, particularly in those who are exempt from the corrective demands on their vital organisation which daily labour entails.

But other causes, even those ordinarily considered innocent, and even almost meritorious, whose indulgence implies an unnatural employment of those parts of the brain allotted to the emotional impulses, have similar injurious effects.

Public orators and popular writers, who deal in feverish appeals to the hysterical impulses, should remember that these exhibitions betray a condition of mind far from masculine or healthy in themselves, and have a pernicious and immoral tendency on those who witness their display, and suffer themselves to be influenced by them. It must not be supposed that such animal passions or propensities can be appealed to with impunity.

It is lamentable and true, though the announcement of it may develope some indignant emotional excitement, that eloquence itself, as far as it is an appeal to the emotions and passions, is, after all, not an intellectual attribute; it is much more nearly allied to the sensual properties; and those races of men by whom it is most fervidly manifested are precisely those who have least moral control, and the least development of the reasoning faculty.

Section VII.—The circuit through the conjoint muscular and osseous systems now claims attention. The blood-vessels, by means of which the vital attributes are conveyed to these structures, constitute a sort of adjunct or offshoot to the cellular tissue, and, properly speaking, ought to be taken into consideration in connection with that vascular circuit, whose office it is to construct and repair that tissue spread out through the whole body. In order to make evident the gradations whereby the osseous and muscular systems gain their peculiar endowments, it will be necessary to institute a cursory investigation into the physiological events incidental to the formation of cellular tissue itself.

The construction or renewal of cellular tissue, in all parts of the body, is the primitive systemic action which the atmospheric changes in the lungs give rise to.

Whenever vital action is set up, whether in the albumen of an egg, where the earliest vital operations are discernible, or in the albumen that exudes from blood-vessels, in which vital action has been stopped, and a restorative action is on the point of being re-established, the circumstances attending each process strongly resemble one another.

The construction of cellular tissue is a very early result, and the manufacture of this membrane in all parts of the body is an essential antecedent to the other more complex systemic operations.

A semi-liquid *albumen* is the material necessary for the commencement of all vascular action whatever.

When atmospheric changes commence, a vascular loop of a crescentic shape is the first result.

If the horns of this crescent can meet together, a vascular circle is formed, and while these horns remain to some extent apart, and are in the act of bursting across the intervening albumen, the tension of the crescentic vascular loop will amount to just so much as the atmospheric influence can impart to it. The resistance to the passage of the vital force, by the intervening space, will be the measure of the intensity which ultimately overcomes it. Should the circuit not be completed, mere chemical decomposition, and not *vital* action, will be the result.

Such is the primary and rudimental indication of a vascular circle.

Let this circle be supposed to be partially broken or interrupted in two opposite places, where a resistance, not met with elsewhere, is offered; in one of these let it be supposed that atmospheric influence has play, while in the remainder of the whole it is jealously excluded; let it be further assumed, that the "force" engendered at that place where the atmosphere has access, passes along each horn of the vascular crescent to the *other* locality where resistance is encountered; that it there struggles to establish a junction between the two extremities of the crescentic horns, by penetrating across that second interval; but inasmuch as, at this second interval, no atmospheric changes occur, the only means that present themselves, whereby the obstacle may be overcome, are such as can be communicated through the crescentic horns from that part where the atmospheric efficacy (ἐνέργεια) is in process of being kindled. It is then projected through the semi-liquid albumen, and establishes the continuity of the positive and negative poles of the vascular circle. Such is the primary idea of a vascular circle. In *one* part where resistance occurs, the atmospheric changes are in operation, and this is the beginning of the pulmonic causes; in the *other*, the resistance can only be surmounted by the current force sent to it from a distance, which pulmonic changes can call into operation, and the local effect there produced is a representation of systemic operations in general. When, as the result of numerous progressive developments, the circle becomes greatly magnified, and each crescentic pole becomes narrowed in its circumference so as to form a tube, containing the liquid conductors of the vital influence; when, in each of these tubes, an auricle and ventricle are added, to give to the conducting fluid a mechanical onward movement commensurate with the distance it has now to traverse from one resisting interval to the other; when the resisting intervals, appropriate to systemic or passive actions are cut up and subdivided into sections, each with a distinct duty, detached and somewhat different from the rest, but in harmony and unison with all, and subjected equally to one vital operation, called into efficacy during the pulmonic interval; then the whole vital or living entity is foreshadowed and prototyped.

The first effect, however, is the creation of the cellular tissue, in which the systemic capillaries are dispersed. All other operations are added, like the cogs and spindles of a clock, adjusted to its primary "movement," and are subsequent developments, owing their source to the primitive cellular tissue. A basement membrane, composed of cellular tissue, forms the groundwork of the pattern of all the structures, the canvas on which the carpet is woven.

Whenever a vascular loop is projected through semi-liquid albumen, so as to establish the continuity of the positive and negative poles, and to complete the circle of vital causes, it carries with it a streamlet of blood; and the distance which *that* can be made to shoot across, through the liquid albumen, marks and measures the "*power*" of the current vitality.

As soon as the continuity is established, secondary results begin to occur.

In proportion to the intensity and vigour of that vital transmission, the surrounding liquid is thrown into a state of greater or less "tonicity;" fresh vascular loops are thrown out from the first, which form other loops, increasing the area for the transmission of the current force, and a sort of meshwork is formed; and in the meshes of this various degrees of dryness are produced in the liquid intervening, according as secondary forces pass from one loop to an adjacent spot, and *lines* then begin to mark out the more dry, and therefore more rigid parts.

These lines interlacing each other, and becoming more and more distinct and of a darker colour, are called "yellow fibrous tissue."

If there are nerves in the vicinity, they exercise an influence on these, increasing their dryness as the nervous influence passes along them, and causing them to squeeze out, as it were, some of the liquid they still contain, and by so doing producing a shortening of their length.

This is the primitive type of contractile tissue, and an assemblage of these circumstances constitutes what goes by the name of "erectile" tissue.

If there are no nerves in the neighbourhood to determine this secondary process, the fibrous tissue remains, and goes on increasing according to the activity of the vital current, and subject only to natural changes of a chemical sort. Part of the product of these vascular changes is taken up by the lymphatic absorbents, and a succession of molecular changes of a particular kind ensues.

In the absence of any collateral cause, such as nervous agency, to disturb the further development of those operations, the events above described continue to progress, rendering the toughness and rigidness of the structure more and more distinct; and the molecular creations, which also continue to multiply, becoming at the same time more numerous and closely packed, cartilage begins to be formed; and at length, by a still further prolongation of similar effects, a gritty deposit remains, which indicates the commencement of the construction of bone.

Consecutive events of this kind may continue until the whole is converted into bone; and should they still proceed in the same direction, to the extent of intercepting the transmission of the circulating fluid through the primary cellular tissue, from which these secondary circumstances take their origin, then death (necrosis) takes place.

But short of that event—*i.e.*, while blood is still supplied to the part—the deposit goes on, and bone of suitable shape and strength for the purposes of the body is formed.

The product so constructed can only be removed from the spot by its materials being again reduced to a fluid state, so that they can be taken up the lymphatics, except, indeed, by its local death, and then a fresh process is brought into action, called suppuration, which it would be entering too much into detail to expatiate upon in these pages.

All of these processes are extra-vascular ; *i.e.*, they are out of the direct line in which the true vital agency travels, and are under the dominion of a force possessing the same relation to the primary vital current which *magnetic* influences bear to the *galvanic*.

The contractility communicated by the nerves to the fibrous tissue, compelling the removal of water from its construction, forms the primitive type of muscular action of the non-voluntary kind ; *i.e.*, of that which obeys the interposition of the nerves, without acknowledging any control of the will.

As these muscles become more perfect in their formation, they are grouped together in bundles, acting in unison. In proportion as they do so, their fibres become more and more insulated by surrounding cellular tissue, forming sheaths to inclose them.

By means of this insulation they are rendered more amenable for the contractile effort, when the nervous influence calls it forth; so that, when this takes place, it is more forcible and regular in its action.

When, however, the muscular fibres become so much more perfect in their formation as to be placed under the dominion of the *voluntary* nerves, or rather of those more forcible demonstrations which the action of the cerebrum, and the nervous centres most nearly allied to it, have the power to call forth through the operation of their nerves, the insulation of the whole, and of each individual fragment, becomes much more perfect; and instead of consisting of mere parallel rods of greater or less thickness, each a representation of a minute ribbon, the muscular fibres are now formed into round or square rods, placed side by side in bundles, each insulated from the next, and are also cut up transversely by parallel markings, so that each individual fibre represents a series of strung beads, capable of assuming a "polar" attitude, in obedience to the contractile influence, when the nerve calls it into operation.

The "readiness" to acknowledge that influence becomes accumulated in the assemblage of muscular fibres, so that, by the time the contraction takes place, it assumes the character of a "voltaic" discharge.

This condition, preliminary to a muscular contraction, is the natural result of the vital changes derived from the vascular current in the surrounding cellular tissue, and can only be elicited in exact proportion to the intensity of the current vital force at that time called into action by the breathing organs. Hence the necessity, whenever a muscular effort is called for, that a preliminary deep breath should be drawn, and that its escape from the lungs should be prevented until the muscular effort is completed, or until a second relay of breath shall accomplish the continuance of the vital orgasm, on which the muscular force depends.

By the sudden discharge of the polar force from the muscular fibre, the contraction is completed, and an opportunity is given for its renewal by the repetition of the vital changes by which it was first created.

The abstraction of a watery product is the inevitable result of each of these performances, and the removal of this, in the form of perspiration, is the appointed means by which the muscles get rid of this part of their structure; and it is the duty of the lymphatics to carry away another portion, while a third remains to enter into combination with the new materials, and therewith to construct fresh muscular fibre.

Thus, not only the muscular fibre itself is rebuilt, as a sequence of the muscular action, and the vital condition of the part intensified, but the system at large is re-invigorated by a fresh supply of lymph, more essential to it than the lacteal fluid itself.

The exhaustion and fatigue occasioned by the action of the voluntary muscles are not due to any injury done to the muscles themselves, but they are occasioned by the effects on the nervous centres, in consequence of the reiterated demands on their controlling influence.

Those muscles which act without the necessity of this interference from the voluntary nerves do not suffer fatigue.

The demand also on the quasi-vegetable process, which should maintain the blood itself in a condition to answer all the calls made upon it, is, of course, increased by anything that occasions an unusual consumption of its materials, since not only local changes, such as those occasioned by muscular efforts, have to be reinstated, but the proportionately increased claims made by the pulmonary organs upon the blood, in consequence of these efforts have also to be met by fresh contributions drawn from the food.

A regular scale of gradation has thus been traced from the most simple fibre, with its feeble power of contraction, up to the most perfect muscular action.

In consequence of the prevalence of the yellow fibres in cellular tissue, it has of late been proposed to call this structure "areolar" tissue, instead of by its old explicit and very correct denomination.

Enough has been said, it is presumed, to show that the contractile efficacy enjoyed by the muscular fibre is derived from the vascular plexus in the surrounding cellular tissue, communicated to it as a secondary operation from that store of vital influence, primarily derived from the respiratory function; that the muscles are indebted to the nerves for the immediate power of calling that contractile force into demonstration; and that the nerves themselves are merely auxiliary agents, whose office it is to communicate backwards and forwards the messages inaugurated by the various vascular plexuses, either in the nervous centres, or in the tissue surrounding the muscles and other systemic parts.

SECTION VIII.—The circulation through the skin claims a short notice.

It has one distinguishing feature, which gives to its performances a separate character from that prevailing in other systemic circuits, inasmuch as in it the atmospheric air gains partial access to the capillaries, where its functions are carried on.

While the free admission of air to the pulmonary capillaries is provided for with great solicitude, so that the whole construction of the lungs conduces to as ample an exposure of the blood to its influence as possible, in the systemic capillaries, on the contrary, the opposite condition is as sedulously cared for, and every approach of atmospheric air is rigorously guarded against.

The reason is obvious. In the lungs the conversion of venous blood into arterial by the intervention of the air is aimed at; while in the system the change of arterial blood into venous is an equally important object. Could atmospheric air be admitted to the systemic functions, it would interfere with them quite as much as the introduction of carbonic acid into the pulmonary organs would operate to their disadvantage.

The object, which the systemic circuits have to promote, consists in abstracting oxygen from the tissues of the body, and constructing therewith, by the assistance of the arterial blood, new formations, resembling those which the special functions of each organ destroy, and they do this at the anode pole of the capillaries; while at the cathode they receive the carbonaceous results, derived from the reliquia of the functional destruction, and of the vital replacement.

It is quite evident, therefore, that the introduction of air would militate against this process.

But as there must be some external boundary to the systemic current, it must necessarily happen that that portion of the systemic circulation forming its perimeter must be more or less exposed to the atmospheric influence, unless the whole body were to be inclosed, like the armadillo or the turtle, in some covering impenetrable to the air.

The injurious consequences that might result from such an exposure are guarded against as much as possible by clothing, artificial or natural; but it cannot be doubted that many and almost all the vicissitudes, by which the proper performance of the vital functions are brought into difficulty, originate from this one vulnerable part of the frame.

The disadvantage, however, is guarded against, to a very great extent, by the fact that the cutaneous function is made as little essential as may be to the whole, and is that which can best afford to be checked, and also by the circumstance that it is covered by the epidermis, which discharges no active function, but merely protects the subjacent skin, by its scales arranged one over the other like armour, or like the scales by which the bodies of fishes are guarded.

The epidermis, or cuticle, resembles partially the epithelium, with which the inner surfaces of the membranes lining internal cavities and tubes are shielded, with this difference—that the epithelium acts an important part in the active functions exercised by those surfaces, while the epidermis and hair are wholly passive creations.

By its flexibility the epidermis, or cuticle, is well adapted to protect the skin, while it permits the various movements of the body to be performed without impediment.

Whenever this cuticle is removed, as by a blister, for instance, its utility, as a protection to the cutis beneath, is sufficiently manifest.

Another security against the access of air to the capillaries of the skin consists in the fact, that those other carbonaceous products, which in organs would either contribute to a direct excretory performance, or would form fresh constructions, part of which would be available to be taken up again into the circulation, in this case become merely lubricating agents to the skin itself, and are smeared over its surface like a varnish, gluing together the layers of epidermis, and excluding both air and fluids from penetrating to the vascular plexus beneath.

In order that the skin itself should be kept in a healthy state, it is necessary that its arterial and venous blood should effect their ordinary changes relative to each other, through their capillaries, without any interference from the air, and, accordingly, this is excluded as much as possible; and the skin itself may be considered as only a thicker insulating membrane, which does for the whole body what the serous membranes do for the individual organs.

Should atmospheric air gain access to any of the vascular plexuses, by which any systemic function is carried on, one of two things must happen: either it must increase the vital energy by acting in accordance with the pulmonary function, or it must diminish it by acting in opposition.

Should it operate by making the arterial blood more arterial, and the venous more venous, in that case, it is evident, it would engender a current, which would increase the destructive and reconstructive processes beyond what occurs in the remainder of the body; and, as a necessary consequence, short vital currents, distinct from that pervading the whole body, would be created, and local inflammation would ensue; and should this excitation become so extensive as to include the whole natural circuit, then general inflammatory fever would result. But should the air, on the contrary, render the arterial blood more like venous, and the venous more like arterial, it would, in that case, put a stop to the ordinary function, which should be performed by the skin: it would tend to generate a vital current, exactly in the reverse direction to the natural one, and to that extent would reduce the function of the skin to that of a passive conductor.

In proportion as it does this, it would reduce the orgasm of all the other circuits. It is more than probable that the benefit sometimes derived from blisters is simply due to this very fact.

A word may here be introduced respecting disturbances sometimes produced in the carbonaceous materials, which it is the ordinary province of the skin to evoke from its vascular capillaries.

These oily or soapy materials are occasionally brought to the cutaneous surface in a state of actual putrescence, as in certain exanthematous diseases; and when that is the case, instead of the skin being duly repaired by the vascular action, it is partially destroyed and eaten into holes by the putrefactive fermentation, as in cases of small-pox.

In order to explain these events, it would seem that only a limited quantity of fat-globules are found circulating in the blood at any one period; these fat-globules are more liable to rancidity than other products, and they are less nearly allied to those formations resulting more immediately from vital action, whose tendency is to correct such abnormal events as putridity and the like; and it sometimes happens that these fat-corpuscles are themselves in a state of incipient putrefaction, even while they are floating in the blood, and that they then have a power of communicating the same condition to other parts, in which the vital force is imperfectly exhibited.

When once such a fermentation is set up, it will continue so long as there remain any fat-corpuscles in the blood, in which it can produce a repetition of the same process; and it is only brought to a conclusion by the absence of any similar molecules, upon which the same condition may be induced.

Exanthematous diseases and their allied complaints, erysipelas, boils, plague, malignant fever, and the like, can be explained on these principles; and the exemption from future attacks of the same malady, secured in some of them, may be accounted for by the destruction of the particular material which first lights up the series of subsequent occurrences, the tinder (diastase) whereby the fat-globules are first brought under the influence of the disorganisation

Seeing, however, that it is the natural function of the skin to get rid of the materials deposited from its vascular plexuses, and that no outward commodities ought to be absorbed or taken up by it, the importance of cleanliness, and the diligent removal of all products, after they have accomplished their function of varnishing and lubricating the skin, becomes very apparent, since afterwards they must be liable to a decaying tendency, very pernicious to the body at large, if they, by any means, should find their way into the circulation while in a state of decomposition.

The protection offered by the cuticle depends in a great degree on the firmness and solidity with which its scales are glued together, and on the polished and varnished surface which it presents. Anything, therefore, adhering to this may enable it to become softened, and may transmit, like blotting-paper, liquid matters that ought to be excluded from the skin, and from the circulation in general.

This being premised, it is as well to add that excessive grooming, by rough towels and hard brushes, is also noxious in its way, by rubbing off and abrading the surface of the cuticle, which ought to be kept sound and entire. Also the too frequent indulgence in the warm bath and similar softening influences is often otherwise than beneficial, from similar reasons. The remaining long in bed with large quantities of bed-clothing, whereby a bath of perspiration is maintained, is still more pernicious for this and other reasons.

The skin is divided from the other vascular organs by a layer of fat and cellular membrane, spread immediately beneath it.

It receives arterial blood, which has not been employed for any other purpose since it left the pulmonary capillaries; and it returns its residual fluid to the common stock, and this likewise discharges no additional duty until it reaches the lungs. By these two channels of communication, the functions performed by the capillaries of the skin are brought into uninterrupted connection with that central source of vitality in the lungs, whence proceeds all vital power. The vitality, therefore, in this circuit balances, in point of intensity, that which occurs in the other loops of circulation; while the amount of function it performs, being dependent upon the resistance it encounters, must be controlled by the secondary action of the nerves appointed to regulate the local tension.

[CONCLUSION OF THE SEVENTH CHAPTER.]

If a retrospect be taken of the events already described, as occurring in the blood of the whole body, three different states or conditions may be discerned during its transit through all the circuits.

When the blood leaves the pulmonary capillaries it is "arterial," and so it continues until it reaches the systemic capillaries. When it has passed through these latter it is in a state which may, for the sake of distinction, be called "sub-venous;" and when the fluid from the thoracic duct has been added, it may be considered to be in a perfectly "venous" state; and, when such is the case, the same qualities and peculiarities are found in it as prevailed in the blood, which previously left the same part of the circle on its tour through the body.

In the localities where the blood is found to be "arterial" it is always equally "arterial," neither more nor less; where it is "sub-venous" it is always "sub-venous;" and where it is "venous" it is always "venous."

By the time the blood has reached any of these localities, the effects wrought upon it in the other parts of the circle, since its last departure, have been annihilated or compensated for, and all the alterations which the blood has undergone since it last left the same locality have been neutralised: the blood has resumed a condition exactly corresponding with that which it exhibited before any such changes were wrought upon it.

The fact has been already sufficiently enlarged upon, that the effects produced on the blood in the pulmonary and systemic capillaries are due to a vital operation, and that they correspond with each other, and equipoise one another. Were it necessary, the same truth could also be demonstrated by a simple mathematical equation, the circumstance being taken into account that the blood is always in the same condition at certain definite situations.

The vital operation, therefore, which converts the venous blood into arterial, is exactly equal, in point of combined intensity and quantity, with that which converts the arterial into "sub-venous;" while the addition which restores the sub-venous to the truly venous state is not a vital operation, but is of a mechanical nature.

But since the blood, by the addition of the fluid brought by the thoracic duct, is restored to the same state as it was in before any of the vital changes, pulmonic or systemic, were made upon it, that addition must have reimbursed the blood for the loss of those materials which the vital functions have consumed; and as it has been shown that the vital functions in the opposite sets of capillaries are equal, it must follow that the consumption of materials by each of them must be equal also. Each must, therefore, consume materials exactly equal to half of those which are restored by the thoracic duct.

By the time, therefore, that the blood has passed through the pulmonic capillaries, it must have appropriated to itself one half of the fluid, supplied by that duct, in restoring the commodities which the blood has had to give up in the execution of its pulmonic functions. The other half, though mixed with the blood that passes afterwards on to the systemic organs, cannot as yet be in a state of vital combination with it, until the functions in the systemic organs shall have been completed, which will not be the case, as regards that particular blood, until after the next pulsation, or succession of pulsations, which may be necessary to cause any single modicum of blood to travel through half the vascular circle.

The blood, on which the pulmonic changes are being performed, is not the same blood as that on which the systemic operations are being executed, as the sequel of the same cardiac pulsation. Both portions of the blood are continuous with each other, and the changes in one re-act upon the other, and they are simultaneous in time and equal in effects; but that identical blood which is carried to the system has been conveyed to the lungs by a previous pulsation, and that which goes to the lungs is, in like manner, the same as that which a former pulsation conducted to the system. But the blood which goes to the lungs is the only part that receives the fresh contributions of chyle and lymph. That which goes to the system, on the contrary, contains only the unconsumed moiety remaining after the pulmonic changes have been performed, and their necessities satisfied.

But although the fluid brought by the thoracic duct furnishes the means by which the pulmonic and systemic blood is compensated for the demands made upon it, yet it is certain that these materials themselves cannot be primarily employed in restoring the corporeal fabric, nor in the pulmonic changes, until they have themselves been first converted into blood; and the mere admixture of those ingredients with the blood does not accomplish that end.

It is by the blood itself, and not by the chyle and lymph, that the changes made in the execution of the vital functions are performed; and until a vacancy has been made in the blood, by the consumption of some of its materials, the new contributions of chyle and lymph, though they may be mixed with the blood, cannot be vitally combined with it.

But in the execution of any vital function, either in the lungs or in the system, although the blood furnishes the materials, it does not follow that the whole of any particular portion of the blood is entirely consumed in the operation; on the contrary, as the supply of lymph and chyle restores what is removed in this process, and as lymph and chyle are not the same as blood, it follows that, in furnishing those materials, a residue must be left. By the immediate combination of this residue with a proper proportion of the uncombined thoracic fluid, *new blood* is formed, which takes the place of that which has been decomposed in supplying materials for the performance of the vital functions.

The process by which this new blood is constructed may be signified by the term hæmaphyia, (αἷμα, blood, and φύω, to beget,) now proposed for that purpose.

This process must be rapid in its performance, and must be the immediate reaction of that by which the functional performance (which it succeeds) is completed, and the restoration of the blood by its means must be as sudden as the vital function itself.

Therefore it will follow that, by the time all the vital functions throughout the body, both pulmonic and systemic, are finished, a quantity of chyle and lymph, *equal to* the whole quantity of thoracic fluid, contributed during the same period which those vital performances have occupied, will have been converted into new blood, to replace those materials which the vital operations will have consumed. With every pulsation, one moiety of the newly-contributed thoracic fluid is converted into blood during the pulmonic operations, and one moiety of the unemployed thoracic fluid, remaining after the pulmonic changes of a *former* pulsation, is at the same time turned to account in the systemic functions; and at last a quantity of uncombined thoracic fluid still remains in the arterial blood, which has passed through the pulmonic capillaries, ready to make good the systemic demands which shall be made during the *next* pulsation.

The thoracic fluid is made up from two distinct sources, namely, from the chyle and from the lymph. The portion which the chyle contributes cannot have been influenced by any previous vital processes, except those which belong to the digestive function. It is probable, therefore, that it varies according to the quantity and quality of the food. But some degree of adaptation to the necessities of the vital functions must prevail even in it, since the activity of the digestive process coincides, with tolerable accuracy, with the efficiency with which other vital functions are performed; and unless food should be absolutely withheld, chyle, in quantity appropriate to the demands of the vital functions, will be added to the blood; but the quantity of lymph supplied by the thoracic duct must bear a very close relation to the activity of the vital functions, since it is itself an important item of the products of those changes, and must be abundant in quantity, in proportion to the energy with which those functions are discharged. The adaptation, then, of the chyle and lymph, and particularly the latter, to the necessities of the vital operations must, under ordinary circumstances, be very accurate.

It is unnecessary to inquire how many pulsations may intervene before the identical blood, which is transmitted through the pulmonic capillaries, shall make its tour through the systemic half of the circle. It is sufficient to know that a precisely equivalent quantity of fluid will be consumed in both as the result of the same pulsation, although the identical blood which passes through the systemic capillaries may have undergone several pulsations before it may have advanced so far on its journey as to have reached them; and the thoracic fluid also, by which it is accompanied, may be dated from a pulsation still further back in the chain of events.

The process of hæmaphyia, by which the thoracic fluid is converted into blood, must be closely allied to the functions which the various organs of the body, including the lungs, discharge. It must not, however, be confused with another set of events, by which the blood is influenced, and to which the name of hæmauxesis (αἷμα, blood, and αὐξάνω, to increase) may be given.

This is a very slow process, and may occupy weeks, and even months, instead of being comprised in the period occupied by a single pulsation, during which an equivalent quantity of blood is manufactured by the process of hæmaphyia, to correspond with what is consumed, during the same time, in the pulmonic and systemic capillaries.

Hæmauxesis is that slow development whereby blood may become gradually restored to a healthy state, and to an adequate quantity, when from any cause it may have been reduced in quantity or quality below what is requisite for the due performance of the bodily functions, constituting a condition known as "anœmia."

The process, to which the name of hæmauxesis is ventured to be given, is analogous to the gradual growth of the body from infancy to maturity, and must be looked upon as secondary and distinct from that to which the name of hæmaphyia is diffidently given.

When hæmauxesis has reached a certain point, and the blood has become adjusted accurately, both in quantity and quality, to the purposes of the body, a state of "health" is the result; but when the process is carried beyond this, then a condition known as "hyperæmia" is the consequence.

It will next be convenient to examine what alterations are made in the solid fabric of the body by the vital functions discharged in it, the effects of which upon the blood have been already considered.

As the sum total of the effects, which take place in the lungs, coincides with that which the systemic organs in the aggregate perform, it will be sufficient if attention be directed, in the first instance, to those of the latter. The simpler operations belonging to the pulmonic changes will then be easily inferred.

The systemic operations can be divided into two groups, namely, those which are supplied with an excretory duct, or some similar means of getting rid of some special product, and those which have no such provision. The operations also may be classified into those whose product is discharged spontaneously, when a certain ripeness or completeness has been attained, (like the seed-vessels of particular plants, which open and set free their contents when the fruit has reached maturity,) and those which require some outward effect or stimulus to be communicated before the functions can be executed, although the previous events may have made adequate preparation for its performance.

The action of the voluntary muscles is an example of a fabric requiring a stimulus alien to itself, in order to develop the function which its construction is adapted to accomplish; and the action of the involuntary muscles is an instance of a fabric controlled by a dehiscence of its own when the structure is ripe for its performance.

The function of the kidneys is an example of those organs, whose duty is not only to effect a restoration of their own fabric, but which have also to construct excretory products, for which excretory ducts are necessary. Such organs require a supply of blood beyond what would be commensurate with the size of each organ, were it only occupied in reconstructing its own tissue, since an additional quantity is requisite to furnish the materials for the excretory product; or, if this is derived from the destruction of the tissue of the organ, to replace what is thus withdrawn from it. An additional structure, consisting of epithelium, is required for the elimination of the excretory product.

The effects upon the tissue of the organs, occasioned by the discharge of their functions, are as follows:—

It must be assumed that previous occurrences have rendered the structure of any organ under consideration ripe and fit for the discharge of its particular duty. Such being the case, either this very fitness and ripeness, or the application of an appropriate stimulus, as the case may be, occasions a disruption of the fabric.

To this operation the name of sarcolysis (σὰρξ, flesh, and λύω, to dissolve) may be given. The effect is to rend asunder the constituents of the fabric, and to divide it into three parts. One of these finds its way into the lymphatics, another into the veins, and a third remains, and, with the assistance of materials supplied by the blood, constructs new flesh in the place of that which has been removed.

In those organs by which an excretory product is furnished, it is evident that a fourth quantity is developed from the fabric, as the result of the sarcolysis occasioned by the function.

To the reconstructive process the name of anasarcosis (ἀνά, from, and σαρκόω, to produce flesh) may be given. When this is brought to completion, the whole process is capable of being repeated. It is obvious that the processes of sarcolysis, anasarcosis, and hæmaphyia must be almost co-instantaneous, and must be coincident with the completion of the function

CHAPTER VIII.

CAUSES CONDUCIVE TO VITALITY.

In considering the subject of animal life, the general anatomical features and outlines being admitted, three topics of meditation arise.

First. The materials of which the body is composed, and the special form or arrangement which it is necessary that they should assume in their minute particles, in order to be susceptible to the vital influence.

Secondly. The particular movements or alterations among the particles, by which that form or shape is adopted, and in which the phenomena executed by the living fabric essentially consist; and

Thirdly. The nutritious supply which furnishes materials, by which the waste occasioned by the vital operations is compensated for.

As regards the first. The living body is composed of solids and fluids, mutually acting and reacting upon each other. Neither the fluids nor the solids *alone* constitute the living entity.

The fluid and the solid parts differ from each other, not merely in their fluidity and solidity, but in the ultimate physical attributes which characterise the constituent parts of each.

If the fluid portion be examined by the microscope it will be found that it is made up, in a very large degree, of spherical bodies, called cytoblasts, consisting of nucleated cells; that is, of minute globules, each containing the germs of other similar bodies in its interior. These cytoblasts, by bursting, set free their nuclei, which immediately begin to grow, and to develope in their interior other nuclei, that repeat the same processes. The fluid portion, in the commencement of the operation, is called "albumen," and when this is duly ripened it is called "fibrine." Both the albumen and the fibrine consist of carbon, oxygen, hydrogen, and nitrogen, to which iron, lime, sulphur, and soda are added in limited proportions.

These materials, worked up into the form and condition of the above-named cytoblasts, furnish the ingredients whereby the operations peculiar to life are conducted. From these things, variously interlaced, all the different structures of the body are formed.

Muscular fibre, nervous tissue, cellular formations, bone, skin, &c., are all constructed from the fibrine, which is brought to a condition fit to be employed for that purpose by the agency of the molecular globules, of which it is in a great degree composed.

In the formation of the solid structure, on the contrary, the molecular shape of the ultimate constituents is destroyed. If the solid tissue be minutely examined (exception being made of the fat-corpuscles, which are a sort of irrelevant material, not deserving to be classified as a portion of the solid structure of the body, but as a reserved commodity, to be employed when other supplies happen to be deficient), no trace of the globular formation will be discernible; and more than this, if the red particles of the blood be examined, it will be discovered that these do not possess the same globular forms as those exhibited by other portions of the blood. These red particles are the intermediate agents, by which the vital current is transmitted from the lungs through all parts of the body, and by which the solid parts of the body make their interchanges of materials with the fibrine: they are flattened in shape, and are not, like the globular corpuscles, reconstructed and multiplied by spontaneously setting free nuclei from their interior, but their development is a natural result of the performance of their own special duties as go-betweens to the solid parts and their nutrient fibrine.

In giving up ingredients to the new tissue, and withdrawing equivalent materials from the fibrine, by which the red particles are surrounded, these last insure their own reconstruction in increased numbers; and the faculty to do this is wholly due to the vital current transmitted through them, and not to any independent growth or dehiscence of their own.

The extent to which the molecular bodies lose their globular shape, and become changed into the solid tissue of the body, is an index of the degree in which the red particles of the blood become reconstructed and multiplied; and this may likewise be taken as the measure of the current vital force which occasions their conversion.

The transmutation, through the instrumentality of the red corpuscles, of the molecular formations of the blood into the solid tissue, in which that particular shape of the atoms is no longer discernible, constitutes the operation to which the name of "anasarcosis" has been given in these pages. The restoration of that fabric to a fluid state, in which the globular bodies make their re-appearance, indicates the performance of that process to which the term "sarcolysis" has been allotted. The expression "hæmaphyia" denotes the process whereby the sanguineous portions—namely, the red particles—are destroyed, and again manufactured in increased numbers at the expense of the fibrine, as the immediate consequence of the function which they perform. The expression "hæmauxesis" comprises not only the gradual ripening of the molecular parts of the blood, by the repeated burstings and fresh formations of the globular bodies, but also the due and persevering performance of the process named hæmaphyia, since the construction of fibrine, without the proportionate increase of the red particles, would not suffice to render the blood suitable for the healthy performance of the *vital* functions. The disease known by the name of "chlorosis" particularly exemplifies this fact.

Before the materials of which the blood is formed can arrive at that state of maturation, so that they should be rendered fit to form an integral part of the body, a very elaborate and protracted course of preparation must be undergone. It is necessary that the creative hand of the Almighty should be exercised in many successive stages.

The dew of heaven first dissolves the primitive ingredients from the dust whence they originated, and the conversion of them into vegetable molecules marks their transition from the inorganic to the organic state.

The sun, by his heat and light, brings them to vegetable perfection, and then the products being cropped, masticated, and swallowed by an animal, must endure another similar process of a quasi-vegetable kind in the lacteal and thoracic ducts, before the originally inorganic elements, from which they were constructed, can be fitted for the special mutations called "animal life," and be converted into animal flesh. In their passage through the lacteal and thoracic ducts, the heat of the body contributes an assistance, similar to that yielded by the sun during the strictly vegetable probation of the materials; and the saliva, the pancreatic secretion, the bile, and the lacteal and lymphatic fluids resemble the various juices which plants produce in succession as their sap advances towards maturity.

But though the processes by which the results are brought about have been slow and protracted, the condition suitable for the reception of the vital influence, when at length attained, is very transient. The materials, when once brought to perfection, cannot long remain stationary. Unless immediately caught up in the vital stream, and subjected to the influence of its current force, these materials, thus carefully arranged, will rapidly decompose; and that state of preparation, which it has taken at the very least a year to elaborate, will, in an incredibly short time, be destroyed, and the products rendered totally unfit for any vital purpose, until they have been reduced to their primitive elements, and have again undergone all the preliminary transmutations.

Man, therefore, has his roots, from which he ultimately draws his sustenance, planted in the ground itself; and the circle which his food takes, in reinvigorating his frame, begins with the ascent of the sap from the ground, and ends by the replacement which is made of the materials, when they have executed their appointed task, to the same earthy bed from which they were drawn. Truly all flesh is grass.

II. With respect to the second point—namely, the actual motions or alterations assumed by the particles under the influence of the vital force pervading the vascular circuit—it may be compendiously stated that they depend upon the current polarity which the vital force imparts to them. Laws precisely similar to those which regulate the electrolysis of inorganic bodies prevail with respect to these also, and results analogous to electrotype influence the construction of the solid parts of the frame.

To what extent the development of the molecules in the fluid, prepared for the re-organisation of the body, may be governed by the current vital force pervading the fluid in which those events occur, may be left for future inquiry. A set of changes, similar to those now under discussion, have been seen to take place in the vegetable productions, in which there is no such vital current. The causes to which those developments are due may, however, reasonably be attributed, at least to some extent, to the persistence of impulses similar to those from which they took their origin. The gradual working up of events to the attainment of a condition suitable for the transition into a higher series of events, in which the perfection thus reached merges into a new class of operations, may be reasonably inferred to take place in this case also; and the conclusion may safely be embraced, that the gradual development of the constituent parts of the blood to a state suitable for the purposes of life may so far be considered as a part of life itself, as that without it the events more strictly and distinctly appertaining to vitality could not take place. The operations antecedent to the true vital changes, which the breathing induces, may be looked upon, therefore, as the result of causes "conducive" to vitality.

And, III. As relates to the nutritious supply, it will be sufficient, in a summary way, to state that the fibrine furnishes the materials for the vital operations, and that this is constructed from the albumen by the aid of the cytoblasts before mentioned, and that it is the office of the preparatory quasi-vegetable process to furnish this fibrine, and to bring it to perfection.

This process is completed when the fibrine is formed : the appropriation of it is due to vital causes, and not to those which constructed fibrine.

But though the construction of fibrine is the termination and completion of the molecular changes accomplished by the cytoblasts and their nuclei, it does not follow that the fibrine is necessarily in a state of perfection, immediately that this fluid is mingled with the blood. As these materials have undergone a series of gradations in their preliminary (quasi-vegetable) preparation, it is reasonable to infer, by analogy, that they may continue to advance from stage to stage, after being received within the circulation, although accompanied all the while by an equal and impartial current force.

The same heat which produces the rise of the sap, developes from the same fluid the successive parts of the plant, namely, the stem, the branches, leaves, buds, sepals, petals, stamen, anther, and ovary; and the same causes which induced the commencement of those events, and which gave to the spongioles of the vegetables their power to originate them, may not improbably continue in force up to the time when the corpuscles are consumed by the more energetic action of the vital current, flashed through them in the pulmonic or systemic capillaries.

Although the changes which the molecules undergo, while circulating in the blood, are concurrent and in unison with the vital polarity which pervades the fluid, still the slower developments which take place among the molecules themselves may probably not be exclusively due to it.

Gravitation, the laws of imbibition, mutual friction, and the like, may be named as instances of forces continuing in operation, though modified, even while the current force is in full and vigorous activity. The polarisation of the particles may not interfere with particular physical changes of a dynamical character in the corpuscles, but may furnish the very conditions by which these changes can be most advantageously conducted, even though it only be by suspending other changes of a contrary tendency; and yet those changes may not be due directly to the polar force itself, nor have any immediate relation to its intensity.

Such may be the circumstances under which a progressive development may continue to be attained by the materials after they are mingled with the circulating fluid, and perhaps even after the same materials may have more than once been subjected to the action of the air in the pulmonary organs, and may also have already been influenced by the decomposing force, in one or more of the circuits, where systemic functions are performed. At each of these transitions the nutrient materials may have undergone changes, and have derived fresh products, which may, in their process from stage to stage, be occupied in their own independent development.

A churn may fill the milk with air-bubbles, and supply the commotion whereby the films which inclose its corpuscles may be ruptured; but it requires another independent cause to induce the fat-corpuscles to cohere together, and separate themselves from the residue; and, in the same manner, a very different set of causes from those by which the vital operations are performed, may excite the preliminary changes by which the suitable materials are prepared.

The causes above hinted at, whereby the cytoblasts floating in the blood gradually advance to individual perfection, after they have been caught up in the current, which forms, as it were, the mill-stream of vitality, and while they are being subjected to its seething influence, may be considered as secondary and auxiliary to the true vital cause itself, like the sorters of letters in a railway carriage, who prepare appropriate employment for the different stations as they approach them, though the work which they themselves are engaged in is not directly connected with the motion of the train, nor with the force from which it derives its velocity, but might, in point of fact, be executed while the train was stationary.

A progressive preparation of materials for future contingencies may very reasonably be inferred to take place, while the blood is travelling through the blood-vessels; and to this effect the heat of the body and similar dynamical influences may contribute much assistance; while, on the other hand, the appropriation of the ingredients may depend upon a totally different chain of events, and may only be possible at certain definite localities.

While this specific preparation proceeds, the suitableness of the blood, to act as the conducting agent of the current force, may not have been in any degree impaired by those slower and independent circumstances, which have anteceded or coincided with that more energetic power.

The arrangement of the blood discs in the systemic order which they naturally occupy, as already mentioned, evidences a polar force in the circulating fluid itself; and the power of these to imbibe or give off fluid, even while under its influence, will exemplify the reasoning now adduced.

It is fair to conclude that the actual decomposing effects, which are due to the current force called into existence by the act of breathing, are exclusively confined to those parts of the circuits where the *resistance* is interposed, namely, in the minutest capillaries. Elsewhere the intermediate blood can merely act as the conducting agent; and the only immediate effect of the transmission of the current force in those places where there is no resistance (*i.e.*, in the larger blood-vessels), would be to induce the polar condition of its corpuscles, and, therefore, the *changes* which happen in this part of its course must be attributed to other causes than those belonging to the decomposing action of the vital current.

And it is impossible for any careful observer not quently to have noticed a gradual improvement, or the reverse, in the very materials of which the circulating fluids are formed, in persons under the influence of climate and similar external causes, and which alterations have been spread out over months, and even years, while there has occurred nothing which could have wrought any direct change on the vital power itself.

These facts go far to prove that a development of the fluids of the body may progress simultaneously with those more energetic agencies on which vitality itself depends, but exempt from their control, both as to the causes and the rapidity with which the latter are performed.

But as regards the different products which are formed in the body, it may possibly be contended that, as the arterial fluid which goes to all is the same, and the vital force which governs the vital changes is also the same, the products, consequently, ought to be identical.

To this it may be answered, that the construction of each of these organs is originally unlike; that this primary difference has an innate power of sustaining the same difference, and that the function of each organ produces such changes on the blood, that the diverse action of each of the others becomes constantly necessary; and thus they all conduce to the separate performance peculiar to each organ, by perpetuating such a condition of blood as renders each variety of function indispensable, while it serves to maintain the peculiar structure of each in a state suitable for its performance.

In inorganic electrolysis it would be quite possible that various deposits might be produced in different cells or compartments by artificial contrivance. Such deposits might be simultaneous, or the arrangements might be such that they might even be in succession, and yet the force which governed them all might be derived from one action or combination in a particular locality remote from each of them. Each of these results might not only be different from the others, but from the parent combination from which they gained their efficacy. Certain known effects of electrotype may be symbolically pointed to, as secondary results of a totally diverse nature from the primary decomposing operations, from which they take their origin.

In a similar manner the different organs of the body, though controlled by one pervading force, which influences them all impartially, execute distinct functions, for which each is specially adapted. Thus the kidneys, by way of example, must be governed by a vital force which is common to the whole body, and equal throughout. The blood from which this particular function is supplied is drawn from the aorta by means of the renal artery, and returned to the vena cava by the renal vein. There is nothing to distinguish the blood, thus leaving the aorta, from the remainder, which goes on to other parts of the body;

neither is there anything external to the kidneys themselves to show why a difference should exist in that which returns to the vena cava, from that which returns from all other organs. As far, therefore, as the blood is concerned, it is clear that the particular causes which create the difference in the products educed from it must be comprised between the two points, where the blood enters the kidney, and where it takes its departure from it.

The blood is the same, and the vital force is the same: the difference must, therefore, be in the kidney itself; in other words, in its structure.

That organ secretes urea, rather than any other product, for which the blood itself is equally suitable, because its anatomical structure fits it to do so; but it may, nevertheless, require a prepared condition of blood to enable it to accomplish its office; and if so, it is also evident either that other organs must perform that requisite concoction, or else the blood itself, in its preliminary stages, must have the faculty of developing it, and the reason why every other organ, supplied with the same blood, does not accomplish the same thing, in obedience to the same vital influence, must simply be owing to a difference in its structure.

It cannot be doubted that the action of the other organs must, in the aggregate, be such as to produce that particular condition in the blood which, by the time it reaches the kidneys or any other organ, shall be appropriate for the purposes of its functions, and it is also clear that other blood, similarly adapted for the same object, is carried to other parts of the body by the aorta, and does not perform the same task for want of a structure adjusted to that particular purpose; and that this very blood, on which the kidneys execute their special powers, is equally well adapted for the production of such changes as are performed in other parts, had it so happened that it had been directed to them, instead of to the kidney.

From the preceding facts it must be inferred that the circulating fluid, passing onwards in different streamlets through various routes, to each of which any part of the whole is equally liable to be sent, must continue to develop within itself that prepared condition, in virtue of which, when it actually reaches the individual organs, it may possess such a construction as shall be suitable for the functions it may be called upon to execute in any of them; and, likewise, that any fresh blood, which has been contributed to the stream whence all the organs are promiscuously supplied, must have been brought to a similar state of maturity.

It must also be deduced, for the same reasons, that the condition of the blood, in preparation for the functions peculiar to each organ, must constantly (as a general rule) be maintained at nearly its maximum or saturation point, not only for the purposes of the function which the kidneys discharge, but for those of all the others, since they each derive their blood from the same original quantity which has just left the air-cells; and the portion which goes to each has gained no additions, and has performed no intermediate operations, since it was subjected to the atmospheric influence in conjunction with the rest.

The study, therefore, of the actual atomic change, which each individual organ executes upon the blood in general, is narrowed to what takes place in that limited portion of it which leaves the main channel, and diverges through any particular organ. The difference which exists between the blood leaving the organ, and that going to it, is the measure of the whole change which the organ in question has wrought upon the system at large. Consequently, instead of the blood going to the organ having a preponderance of those commodities which the organ has to eliminate, as compared with what is contained by the other blood, the residual blood returning from it will exhibit a deficiency, which will have to be remedied by fresh contributions drawn from without, and it will also be comparatively deficient of those same ingredients, even as regards the venous fluid in general. It is only by the mingling together of the residual blood, drawn from all the different organs into one common stock, that the deficiencies caused by the functions of each become divided and equalised among the whole; and the aggregate of the deficiencies has to be compensated for by the nutritive fluid, which the thoracic duct pours into the general stock.

This reinstation is all comprised in the period of time which elapses after the residual blood leaves any organ, until it is again brought back in an arterial state to the same spot. This event would just occupy the precise time that it would take the heart to pump all the blood contained in the body once through the whole circle. Supposing it employed a certain number of pulsations to transmit the entire quantity of blood once through both sets of capillaries, and thus to compel it to make the tour through the systemic and pulmonary capillaries, and to arrive at last at the same spot as that from which it started, it would occupy precisely the same time to restore the whole of the abstracted ingredients, which all of the functional organs, or any of them in particular, may have withdrawn. And as every one of these pulsations resembles each other in all particulars it follows that, as the sum of the materials poured into the blood during the period occupied by all of them would compensate for the changes made in the whole duration of time, the amount of materials contributed to the blood during one of the pulsations would also equipoise the amount of alteration made in its constituents during the time occupied by that pulsation. Therefore the continued oscillation which occurs between the changes made by any function in particular (or of all of them in the aggregate), and the restoration of the blood to a condition to repeat them, must be comprised in the narrow limits of one pulsation and its interval.

But in the same way as the mixture of the whole residual blood compensates for the special functions of each individual organ, causing a due equipoise of deficiencies to prevail in relation to them all, and as the functions of all, together with the fresh supplies, produce such a condition of blood as that it shall be again rendered suitable for the performances of each, it may with equal confidence be asserted that the due performance of each individual function is, in its turn, very essential to the well-being of the whole.

As a failure in the preliminary processes, by which the nutriment should be furnished, would, by withholding the supplies, defeat the performance of the various functions, without doubt an incapacity on the part of any particular organ to execute its duty would be attended with perils of an opposite nature, since it would be as disadvantageous that materials which ought to be removed should fail to be got rid of, as it would be that materials which the various organs might require should not be obtained.

The special means, however, by which the blood is rendered fit for the performance of the various functions, must in their nature be analogous to those by which the quasi-vegetable processes occurring in the thoracic duct are gradually brought to maturity, although they act, in the latter part of their proceedings, in concurrence with the vital force which imparts to the molecules their polar characters, since even after the thoracic duct has emptied into the stream of blood the milky-looking fluid drawn from the food by the quasi-vegetable action, a similar commotion continues among the molecular atoms as before. The complete preparation of the nutritive materials is attained by the time the blood has completed its circuit through the vascular circle, and the new ingredients recompense the blood for the losses it sustains in executing the functions of the different organs, in obedience to the vital influences which the blood communicates from the lungs. A ripening, therefore, of the fruit by the quasi-vegetable process is arrived at after the sap has been mingled with the blood.

The progressive improvement of the molecular materials, subsequently to their reception into the stream of blood, can only be attributed to the continued operation, but more perfect development of the same principle, already recognised as prevailing in the original vegetable structure, which communicates the first commencement of organisation to the crude fluids supplied from the earth.

The manner in which cryptogamous plants multiply and spread themselves gives a good proximate idea of the subsequent events (not of a strictly vital character) now endeavoured to be classified and arranged ; the spread of cancerous and similar growths confirms the same inferences.

The transition from the quasi-vegetable to the strictly vital operations is made as little abrupt as possible, since by the persistence of the former operations, even after the nutritive fluid has become mingled with the blood, the two processes actually coincide, acting in harmony with each other. The distinction, however, between the actual performances of each is marked and decisive, though at the places where vegetation ceases, and true vitality commences, the two overlap each other, and a concurrent action unites and adjusts them to one another.

Three distinct sets of events may therefore be traced as the ultimate effects of what happens in the body, of which two are so mutually dependent upon each other, as in point of fact to constitute one set of phases, bearing the same relation to each other as cause and effect, or as action and reaction: they are absolutely opposed to each other, yet so allied that each is essential to its antagonist.

The three may be thus enumerated :—

First. The vegetable and quasi-vegetable processes by which the inorganic substances are gradually fitted to become a part of the animal frame.

Secondly. The analytical operations (in a great measure identical with the active functions of the various organs) by which portions of the fabric of the body are rent asunder, either by a natural dehiscence, or as the result of an external stimulus.

Thirdly. The strictly vital or synthetical causes by which the fabric is rebuilt.

The functions of the second and third are very intimately connected, and neither of them could be performed without the concurrent activity of the other. Their effects upon the solid structure have been classified as sarcolysis and anasarcosis, while their reaction on the blood has been comprised in the word "hæmaphyia," which embraces both the analytical and synthetical operations that are carried on in it, as the immediate evidence of the vital changes. The effects called hæmauxesis are slower in their operation, and may be considered as the result of the protracted execution, in a perfect manner, of the quasi-vegetable processes, in conjunction with the due discharge of the duties of hæmaphyia.

Should the analytical and synthetical processes be thrown into disorder, so that either the one or the other be incapable of its due performance, then vitality itself ceases; and though the operations allied to vegetative action may still, for a short period, continue, these also will soon cease, in consequence of their products not being employed, and the chemical and inorganic agencies will resume their uncontrolled sway.

The onward flow of blood enables the oscillation between analytical and synthetical operations to succeed each other, like the motions of a pendulum; and the continuity of the different vascular segments with the one paramount source of vitality combines the whole of the synthetical operations in one single unity, and, by the reaction which these exercise over the analytical processes, binds the whole together in the construction of the single entity which the various parts of the body, in their conjoint character, embrace. The vital influence called into exercise by the act of breathing is, through its instantaneous effect on all the vascular circuits, the direct agent by which this is done.

The quasi-vegetable processes, by which the fresh contributions are drawn from the food, demand some further observations.

The food, whether animal or vegetable, or both combined (it matters not to particularise, since it all undergoes the same quasi-vegetable training, in order to be fitted to enter into combination with the animal structure, and to form part of the new flesh by which the body is rebuilt), is masticated, mixed with the saliva and natural juices of the stomach, and a fermentative process is excited in the conglomerated mass. The bile is next mixed with it, and the whole is then divided into two portions, one of which is milky, and the other refuse.

This process, thus far, has been called, by a very great man, to whose memory all medical men are bound to pay deference, "primary assimilation;" and it has been so named because it is, as it were, the first attempt of the food to render itself "like" the blood and flesh, with which it is to be hereafter combined.

The nutritive portion passes on through successive stages of improvement until it is poured into the blood, and then it goes to the lungs, and its white or milky colour is lost, and it can afterwards be no longer distinguished from the arterial blood, with which it is intimately blended. This event has been named by the same author "sanguification;" and then the commodities proceed onwards to the various organs, and are converted into animal flesh; and this has been called "secondary assimilation," because it is then made actually and entirely to resemble the various structures of the body.

With all possible respect, however, to Dr. Prout, it will not be too much to say that this is a statement, but it is not an explanation; and it is contended that the views which have been set forth in the preceding pages are more explicit and more correct. The facts are now diffidently laid before impartial judges.

When once the fluid, drawn from the food for the restoration of the body in general, has been mixed with the blood, it becomes subjected, like the rest of the body, to vitality itself as an active and energetic power, and thenceforth progressive development of the quasi-vegetative kind becomes only one of several collateral agencies; and the future performance of the nutritive ingredients can neither in sound reason nor as a matter of convenience be disjoined from the operations in general which the blood executes.

The process of sanguification, therefore, is not confined to the breathing organs, but consists in that change in the blood, and in the uncombined nutriment with which it is accompanied, which has been shown to take place wherever any vital function is performed, and the operation itself has been named "hæmaphyia."

CHAPTER IX.

VIEWS ADVOCATED IN THE FOREGOING CHAPTERS CONTRASTED WITH PREVALENT DOCTRINES.

It will be advisable, before closing the present inquiry as to the nature of animal life, and the functions by which it is maintained, and to which it gives rise, to take a summary and compendious view of the doctrines at present ordinarily held as authoritative on the subject of the "nutrition" of animals, in order that the point of divergence now assumed may be clearly defined, and the distinction which it is desired to establish between the views advocated in these pages, and those currently received, may be plainly demonstrated.

"Nutrition" is a word which has been used in a very loose and extended signification, and it has been employed to comprise considerably more than the mere supply of nutritious matter, and to embrace many, if not all, of the attributes of life. Thence it happens, that when the "nutrition" of the body is mentioned, it is almost impossible to define exactly the limits within which it is proposed to confine one's view.

In every sort of derangement of health it is customary to make use of this expression, so that if a person is suffering from some hallucination of mind even, it is not uncommon to hear it attributed to a defect in the *nutrition* of some part of the brain, and so with all other complaints not easy of explanation.

Whether originally any defect can arise in the body, except through its materials of nutrition becoming in some respect defective, is an abstract question, which it is not requisite to discuss, because it is obvious that, before any outward cause can have produced established disease, the faulty constituent must itself again and again have formed part of the body, and have undergone repeated changes, under the influence of the "vital" causes; and therefore, to say the least, those diseases become as much "vital" as "nutritious," and their causes are to be sought for in the body, as much as out of it.

There are only three portals by which disease from without can enter the body.

First. By the air which is breathed.

Secondly. By the materials which are swallowed.

And thirdly. By the application of pernicious agents to the outer surface, *i.e.*, the skin or mucous membranes.

All other diseases must originate within the body itself, and the excessive, the deficient, or the improper and irregular employment of the corporeal functions, afford very abundant opportunities for the creation and multiplication of deleterious causes.

Except in certain very virulent and active results, immediately productive of mischievous consequences, those diseases which derive their origin from external causes, introduced to the system by one or other of the entrances above mentioned, owe their prejudicial influence, in a great measure, to a subsequent disturbance which they institute in the functional operations within the body, rather than to the immediate corrosive or destructive action of the noxious ingredient itself.

It is generally admitted, and it is not disputed in these pages, that the nutriment, which it is necessary that animals should consume, consists of four kinds of aliment. 1st, aqueous ; 2ndly, saccharine ; 3rdly, albuminous ; and 4thly, oleaginous.

That is to say, that food, in order to be nutritious, must contain—1st. Water, and certain salts which water can dissolve. 2ndly. Compounds, having the same chemical elements which belong to sugar, of which starch, gums, and vinegar are instances, since they are identical in composition with sugar, but require a change in their composition before they can readily be dissolved in water, and are not admissible, in an unaltered state, to be mingled with the blood : they are, therefore, considered as a separate group. 3rdly. The albuminous, namely, those which are supposed exclusively to supply materials for renewing the flesh of the eater, and possess qualities similar to those which belong to the white of an egg ; and 4thly. The oleaginous or oily compounds ; those by which the fat of animals is furnished, and the other purposes served, which the fatness of the body conduces to. Of all these, the albuminous alone contain azote.

Food containing all these four groups of materials, having been masticated, swallowed, churned in the stomach, and acted upon by the acid and rennet of that organ, is converted into chyme. It is then passed into the next cavity, where it is mixed with the bile, which renders the albuminous parts more liquid, converts the oily parts into a soapy state, so that they can mingle with the rest, and causes also the chyme to be separated into two parts—one the milky-looking fluid, called "chyle," and the other consisting of the colouring matter of the food, and of the bile and other refuse.

The chyle contains the watery and saline ingredients; the sugar and its like; the albumen, or the part which resembles white of egg in its composition, and other qualities; and the oil or fat.

These are taken up by the lacteals, within which myriads of the little bodies called cytoblasts, or nucleated cells, are ready to gorge themselves with the albumen in particular. This fluid nutriment makes its way through the delicate film which envelopes each cytoblast by imbibition (endosmose or heterogeneous attraction), precisely as blotting-paper sucks up any fluid.

When these small bodies have thus become distended, they burst and set free numerous nuclei, before contained in each parent cell, and these nuclei become themselves cells, precisely similar to the former, but much increased in number, and fresh nuclei begin to grow in their interior; and fresh crops of cytoblasts, or nucleated cells, succeed each other again and again, until, by the time the materials of the albumen have reached the end of their journey through the thoracic duct, a change has been produced upon the albumen, whereby it is converted into fibrine, a product resembling albumen in chemical composition, but which is brought more nearly to correspond with blood or liquid animal flesh in some of its physical qualities. Some of the above-named cytoblasts, which have failed to burst, and therefore contain fibrine, are now called "white corpuscles," or exudation corpuscles, and these also accompany the other ingredients, of which the chyle is compounded. They are now, with the fluid called lymph, discharged into the blood, which circulates in the body. All these preparatory changes are comprised in the term "primary assimilation."

The lymphatics are a number of minute, colourless tubes, dispersed in the finest and most elaborate meshwork over every part of the body, so finely dispersed, that it would be impossible to take a square inch of any part of the animal structure that would not contain great numbers of them. Many of these collect together and form larger tubes: these, in certain spots, become folded and convoluted in a very intricate manner, and form round bodies called lymphatic glands, resembling very closely, in anatomical characters and functions, the mesenteric glands, which bear the same relation to the lacteal tubes as these do to the lymphatics.

These lymphatic glands are scattered over the whole body, and are to be found in all its various parts; they finally, either directly or by their communications, discharge their contents into the thoracic duct. The lymph which they convey is a colourless fluid, and resembles fibrine: it is collected, by means of the lymphatic tubes and glands, from materials which the living body itself supplies, in a manner quite similar to that by which the chyle was absorbed from the nutritious fluid contained in the bowels.

In the ordinary explanation of what is called "primary assimilation" but little account is usually taken of the lymph, since that is supposed already to have arrived at that state of maturity, to which it is the object of the "primary assimilation" to conduct the chyle during its probationary career, the former not requiring, according to the usual authorities, to undergo that preliminary ordeal, in consequence of having already formed part of the same animal structure to which it is destined to be again appropriated, primary assimilation having been already accomplished in it. But there are strong reasons for believing that a certain large portion of lymph, derived from the body itself, is essential in the production of those changes in the new material, so as to render it suitable to be received into the tissues of the body at all; for experience shows that, if there is any derangement in the lymphatic system, appetite entirely ceases, and not a particle of new material, even if swallowed, will be received into the lacteals, much less worked up into new fabric. Derangements of the lymphatic system are much more speedily fatal than deprivation of food: this is shown in those cases in which the lymphatic absorbents become diseased, as a sequence of even slight surgical injuries. Whenever symptoms betokening this result make their appearance, the case is always considered by experienced persons to have assumed dangerous features. But this by the way.

The fat, the sugar, that portion of the fibrine which has been set free, the water, the salts, and the exudation corpuscles, now arrived at the jugular vein, become mingled with the blood contained in it, which they find very similar to themselves, except that they here meet, for the first time, with a new acquaintance, namely, the red corpuscles of the blood, which are certain little flat discs containing iron in their composition: they consist of an outer transparent case called globuline, which incloses a red fluid called hæmatine.

They seem, according to the office assigned to them by the chemico-physiologists, to be the lord's chamberlain, whose office it is to conduct the fibrine, &c., to court; but they seem also to act the part of the fox in the fable, for they first obsequiously conduct their guests to the lungs, and afterwards devour them, according to this theory.

The chemico-physiologists, instead of considering the contents of the blood-vessels to be blood, and contenting themselves with treating these new materials as the supply for *its* renovation and permanence, persist in still treating them as chyle and its compounds, and go on to lay down rules concerning its "secondary assimilation," or the "nutrition" of parts by its influence, forgetting that the properties of animal life strictly belong to the blood, and not to the chyle, and that every attribute of life is effected by and through the blood itself, acted upon and stimulated to its work by the operation of the air in the lungs.

But this is a digression.

Resuming, then, the account which the chemico-physiologists give of the matter.

The fibrine, the oil, the sugar, the water, and the salts set out on their journey, but stop at a place called the "great centre of the double circulation" "the heart." This organ, according to the same authorities, does what is necessary to cause these materials to travel, not only to the lungs, but back again to the same heart, after having undergone the changes which the air works upon them; while a similar propulsion is, at the same time, given by the same "centre of the double circulation" to the blood which has just previously returned from the lungs, by which impulse it is caused to flow in divided streamlets to all the various parts of the body, from which it finds its way back again to the same central fountain of the "double circulation," *i.e.*, the heart, by the combination of many very complex causes.

It may possibly be argued by some that the whole of this motion is not attributed, by modern writers, to the direct propulsion by the ventricles, but that something is allowed to the expansive action of the auricles, and something also to capillary attraction, muscular pressure, &c., and that the valves in the veins cause these combined actions to exercise their influence in one direction, though this argument has no application to the blood returning to the left auricle.

But due allowance being made for these circumstances, still the facts now under discussion are not altered nor invalidated by their recognition.

Arrived at the lungs, the red particles are said to take in a supply of oxygen, and the blood to give up the carbonic acid, which it has been carrying from the distant capillaries; and it is declared that the chyle then undergoes the process of "sanguification," a sort of initiation. What this consists in is not very clearly defined, since the fibrine is still fibrine, and the exudation corpuscles still exudation corpuscles; but it is said by some that the fibrine, which before was deutoxide of protein, is now a tritoxide of the same. It is difficult to reconcile this statement with the doctrine still held by the same writers, that the red particles are the only oxygen carriers.

Part of the nutriment is then described as supplying the carbon for the purposes of respiration, and as being burnt up by the process. It becomes very difficult to reconcile this doctrine with that laid down by the same authors, that the carbonic acid is only brought from the distant capillaries, being the product of the combustion there accomplished, and that it is merely bartered or exchanged in the lungs for oxygen by the laws of the diffusion of gases.

That mode of reasoning, in point of fact, goes to the length of asserting the hypothesis, that the active results of breathing do not in reality take place in the lungs, but at a subsequent time in the distant capillaries of the body, which would be an approach, in one particular at least, to the deductions which these pages are intended to enforce.

In following out the consecutive order of things as generally described, very glaring improbabilities present themselves, so that, in enumerating them, it is difficult to avoid the appearances of an appeal to ridicule as a means of their confutation. That intention is earnestly disclaimed.

As a matter of fact, it would seem probable that the consecutive events sketched out above would not be seriously defended upon philosophic grounds, and it is not unlikely that the theory has only been adopted to meet the inaccurate requirements which *vivâ voce* lecturing calls forth; and thus, by the frequent repetition of symbolical expressions, the actual undiluted truth is in danger of being lost sight of.

Still the theory on which the hypothesis is founded has had, and continues to have, a pernicious effect on physiological and pathological reasoning.

To return to the usual method of explanation. From the lungs the blood travels to the left side of the heart, which claims the first share of the commodities brought from the lungs, namely, the oxygen carried by the red corpuscles, the tritoxide of protein, &c.

In return for these—and much stress is laid, by reasoners of this class, upon the fact of the heart's structure being the first recipient of these bounties through its coronary arteries—that organ is enabled then to distribute them to all parts of the body in succession, or rather in detachments; and though the heart itself must have contracted before these same coronary arteries could supply its structure with the blood, yet this very transparent fallacy, and the incidental pathological deductions therefrom, have hitherto prevailed quite undisputed. It is evident that the structure of the heart can only receive its arterial supplies from the coronary artery, at the identical instant that every other part of the body receives the benefit of the same pulsation.

In this journey the blood is described as furnishing to the various organs, in the order in which it reaches them, the materials derived from the chyle, under the direction of the blood discs.

These various organs are, by that theory, supposed to be made up of a multitude of cytoblasts of different tastes and qualities, according to the class to which they belong. So the cytoblasts of the kidney have a great craving for the materials of which urea is formed, except when they become sickly and fastidious, as in albuminurea (Bright's disease) ; the cytoblasts of the liver will only notice the materials for the formation of bile ; and so on with all the other organs, the blood being, according to these authorities, merely the passive fluid with which the chyle is mixed, from which all these parts extract, by the aid of oxygen supplied by the red globules, the particular ingredients which they may require, the white corpuscles making their escape occasionally from the blood-vessels, and acting according to their own independent attributes, constructing tissue where it may suit their purpose to do so.

Thus neglecting "vitality," the most prominent characteristic which the blood exhibits, and making that fluid merely the highway by which materials are conveyed to distant parts, authors of this school attribute a sort of special vitality to each of the myriads of minute corpuscles, of which the different organs are made up ; and overlooking the concurrent and mutual harmony existing between all the various great functions of the body, they suffer it to escape them that the blood is a compound, which can only be kept in the liquid state by the vitality which resides in it, and that each man constitutes a single individual, and is not a mere collection of polypes, or corallines ; that, in short, the life of any animal is in the *blood* thereof, and that its continuance is maintained by the breath of his nostrils.

To infer that the degree to which blood becomes charged with carbonic acid is the only *stimulus* required in the lungs to call into action the process of respiration through the nervous system ; to make the functions of parts dependent solely upon an indefinite supply of nutriment brought to them by the blood ; and to make the structures of which the organs are composed almost volitional, that they may be enabled to select the right commodities to give to one part, which grows more than the rest, the attribute of greediness for nourishment, and to call it "hypertrophy," and to another, which wastes, the opposite quality, and to call this "atrophy" (forgetting that the very process of wasting implies an increased absorption rather than a deficient one), are all mere assumptions, which it is now contended ought to be expunged from the pages of medical literature.

All these conflicting and contradictory postulates have been mingled together, and currently received as facts, under the term "secondary assimilation," and life itself has been made to consist of these assembled together and conjoined, and presided over by the "nervous system;" or rather, the nervous system, which, in truth, is secondary, and results from the peculiar operations conducted by the blood, is made by many the very mainspring of the whole chain of sequences—the very synonyme of life itself.

It will be convenient to get rid of the errors, by abandoning the words with which they are associated, and to class all the changes which take place in the new materials after they have been received into the ducts, but before they are mingled with the blood, under the name "nutrifaction," or trophemapœesis, (τρόφημα, nutriment, and ποιέω, to make), and to consider all subsequent changes as belonging strictly to the life of the animal (and not merely to its nutrition), but as dependent upon laws of affinity peculiar to living materials, and of which those changes, which have been already classified under the term "vitality," form the leading characteristics, even although other contributing causes may still concur in promoting the vital operations.

Blood is a fluid specially prepared and constructed for the operation of those peculiar vital changes.

If its physical condition or chemical composition be only slightly altered from that which ordinarily belongs to it, disease is immediately produced; if that alteration is considerable, death inevitably results.

The physical condition, as distinguished from its chemical composition, assumed by blood during life, is strikingly contrasted with that which it exhibits the instant it ceases to live.

By its physical condition is meant such properties as the following: its fluidity, its temperature, its tenacity, its viscidity, its homogeneousness, and the like. These are obvious visible attributes; and as they are easily recognised to be very different, while the fluid is contained in the body and circulating in it, from what they are the instant it is withdrawn from it, or when life has ceased, they may reasonably be set down as the result of that "principle" itself.

One provision for securing the permanence of the physical condition, as well as its chemical formation, adapted for the exercise of "life," consists in the regular supply of certain materials, already enumerated, whereby a standard, fixed, or nearly so, is maintained by the blood, from which it does not materially deviate. It may be received as a truth, established by all sound medical experience, that whatever deviations do take place in the qualities of the blood are most gradual in their progress, and dispersed over a long period of time; and it may safely be asserted that such changes *never* take place in the living blood, as that it shall at one time of the twenty-four hours be acid, and at another alkaline, as has been incautiously asserted lately.

In order that this supply of new materials should be precisely apportioned to the wants of the fluid, a great many precautions are provided, and numerous checks and adjustments employed to regulate that supply, and to keep it in just equilibrium with the consumption which takes place. Many of these are the secondary results of "vitality" itself, although the actual process of preparing the nutritious fluid is governed by laws distinct from those which operate upon the blood itself, and impart to it "its specific qualities."

The nutritious fluid brought by the thoracic duct must, therefore, be considered as the means whereby a standard condition of the blood is prolonged. It can no longer be looked upon as a special fluid, having properties diverse from those of the blood, after it has become mingled with it; for it is now brought within the influence of causes which act upon that fluid in its compound state.

Healthy blood, then, is a fluid with which chyle and lymph, in due proportion, recently mixed together, so as to modify the qualities of both, have become incorporated and blended.

The governing causes, to which this compound fluid is now exposed, are strictly those of "animal life." They are such as affect simultaneously the whole of the blood contained in the body at the same instant, and not, as the chemico-physiologists assert, in succession.

The means by which the properties of this blood are directed to the performance of unanimous events have been already sufficiently enlarged upon; and the mutual co-relation maintained among them all by the pervasion of one circulating fluid, with a joint partnership in one vital force permeating them all, and linking them together in a single entity, needs no further exposition.

The blood performs one conjoint operation, which consists of an oscillation between two changes, namely, the pulmonic, whereby it is made arterial, and the systemic, whereby it is made venous; and while one portion of it is engaged in its pulmonic efforts, another completes an exactly proportionate amount of systemic ones, and, in the aggregate, they each precisely balance the other. But outward vicissitudes may alter the aggregate amount of force which they both execute, and may vary temporarily the relative amount which some of the systemic segments bear to each other, though they cannot alter the relative proportion which the whole of the systemic sections bear to the pulmonic segment.

By means of the reciprocative compensation, which the different systemic sections are enabled to afford to each other in cases where they are exposed to the influence of sudden disturbing causes, the dangerous results which would otherwise follow are often averted, and the effects greatly modified, by the fact that a particular contingency, happening to one segment, is dispersed and divided among several others; and thus events which might be very destructive, if concentrated on one part, become comparatively harmless when split up into numerous other channels. For instance, if the weather becomes colder, a greater resistance to the transmission of the vital and vascular current through the skin takes place, perspiration is also checked, the breathing becomes at first slower, and the vital force generated by the lungs becomes diminished, and this might be extended to such a degree as to efface the vital function altogether; but the vital force, thus checked in the skin, acts with augmented force upon the kidneys, in which the vital transmission has not been impaired, and these, in consequence, for the instant, enjoy a larger aliquot portion of the whole current vitality than before: their secretion, therefore, is increased, and the intestines and other systemic circuits receive, at the same time, an additional vital impulse, and aid in the dispersion of the checked vital impulse.

The sudden application, therefore, of cold, if it be not long maintained, does not reduce the whole amount of vital force to so great an extent as otherwise would result, from impeding its transit through so large a portion of the conducting channel as that furnished by the capillaries of the skin. Every one who has felt the gasp in the breathing, which a sudden application of cold to a large surface of his body necessitates, will readily understand how great a portion of the force created by his breath has been neutralised, and apparently annihilated, by such an event.

He is compelled, by an irresistible impulse, to breathe more rapidly and deeply, in order to replenish his body with vitality; and unless increased intensity, sufficient to overcome the resistance in his cutaneous capillaries, technically called "reaction," ensues, serious mischief, probably inflammation of the lungs, and possibly death, may soon follow. But the increased intensity, thus thrown upon the other sections, may be sufficient to overcome the resistance which the cold has occasioned to the transit of the vital force through the capillaries of the skin, although the temporary impediment may even have occasioned a slight coagulation of the blood in those capillaries, which has to be overcome by the succeeding transmission of the vital action, now increased in intensity, so as to be able to surmount it: local inflammation or chilblains may mark the spot where the struggle has been most vehement.

But this sudden impediment may be such, that the vicarious functions of other parts may not be able sufficiently to modify and to redress the disturbance. In that case a portion of blood will have been brought to the lungs, greater than the whole vital functions in those organs may be able to dispose of (even in this case a kind of safety escape is provided, as already explained, when describing the return of blood from the pulmonary capillaries) : a superfluity in the tissue of the lungs themselves must, to a certain extent, be then impending. Should this not be removed by augmented functional action in the systemic organs, it must be retained there: it dies, and becomes as much a foreign body in the lungs as an arrow or a bullet would be.

But the amount of impediment may be so great, and neutralise so large a proportion of the vital impulse, that not only the other organs may be incapable of transmitting an increased amount of vital influence, by performing the work of the parts thrown *hors de combat*, but may not leave sufficient vitality in the body to enable them to discharge their own functions ; and consequently sudden death may occur, under such circumstances, from what is technically called "shock." But usually, when such an occurrence happens to a person in health, a sudden check of the vitality for an instant occurs; the blood accumulates in the lungs; breathing, which for an instant was stopped, now becomes greatly more rapid, because the air acting upon the blood generates a vital force which operates, in the first instance, with peculiar energy upon the muscles employed in the breathing; and panting takes place. This rapid motion of the muscles supplies air, while it affords a channel for the current force, which becomes intense in proportion to the activity of the breathing function; the internal organs, which have been sheltered from the vicissitude, soon participate in the increased action, the urine becomes abundant, the liver and intestines take on more active secretions, the muscles in general are probably put into involuntary activity, the mental qualities also, and finally the skin itself partakes of the increased intensity, and glows with functional activity. All these events imply and necessitate a proportionate activity in the vital changes in the blood contained in the lungs, and therefore the accumulation there, which was the first result of the check given to the vital powers, is speedily removed. All these events may happen in so short a time, that the injurious changes—that is to say, the coagulation and chemical action to which the blood becomes liable as soon as its vitality ceases—may not have commenced; and the final effect of the brief impediment may be, that the blood may be left in a more healthy and highly vitalised state by the rapid changes ensuing upon its temporary check than it otherwise would have been.

By an easy transposition, the effect of any other sudden vicissitude affecting the vital force in exercise in any organ, may be computed.

THE END.

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