Emmet
Essay on the chemistry of
animated matter

AN ESSAY

ON

THE CHEMISTRY

OF

ANIMATED MATTER.

BY JOHN PATTEN EMMET.

"Bene scire, est per causas scire."

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OF

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On the 2d day of April, 1822.

TO

WILLIAM J. MACNEVEN, M. D.

PROFESSOR OF CHEMISTRY IN THE UNIVERSITY OF THE STATE OF NEW-YORK.

Dear Sir,

It is with pleasure I avail myself of this opportunity to express my gratitude for the steady interest which you have always shown in my behalf. Prompted by your example, and guided by your instructions, I have enjoyed opportunities of which very few indeed can boast; and it shall ever be my study to profit by them.

Accept, dear sir, the dedication of this essay, and regard it, though inadequate, as a pledge of sincere esteem.

THE AUTHOR.

THE CHEMISTRY OF ANIMATED MATTER

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THE

CHEMISTRY

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FIRST DIVISION.

INTRODUCTION.

There is no subject for reflection so interesting to man as the principle of his existence. Whether we regard it in a moral point of view, or in connexion with the healing art, the most important advantages must follow the inquiry into life. Yet it is a singular truth, that no subject has met with a less candid investigation.

Whatever may have been the sources of this neglect, there seems to be abundant proof that no more designed mystery is thrown around this form of creation, than any other. We have seen the lightning of Heaven subdued, Heaven itself scrutinized by the astronomer, and the infinite spaces of its planetary orbs brought to the level of a school boy's eye. Earth has been dissected by the busy hand of man; her magnitude is measurable, her stores tangible and her general economy visible. Even man, who proudly raises his head above the range of creation and styles himself its lord, meets with as humble an analysis.

His life is sustained by the same principles as that of the brute or plant; and the fabric which gives him his superiority moulders into the common stock of matter which has served him and others since creation. All created beings are members of one and the same family, and every day's examinanation teaches us, that distinction is but in degree. "The more the phenomena of the universe are studied, the more distinct their connexion appears, the more simple their causes, the more magnificent their design, and the more wonderful the wisdom and power of their author." How does it happen, then, that with all this similarity and connexion throughout creation, the principles of animation should be pressed down, as it were, into darkness?

It has often been asserted, that to inquire into the nature of our vitality is to go much farther than ever the Creator of life intended. This conjecture (for so it is at best) has gained too easy a reception. Man is a rational being, and stands pre-eminently distinguished above all other animals. This superiority, at first sight, seems to leave between him and them nothing in common, and has hastily led to the conclusion that the principles of his existence are of another nature, and too refined to be compared with that of the brute. A review of animated beings shows how ill founded such an opinion is. It may be just as to man's superiority in the complication of his living powers, but cannot give any thing like a foundation for supposing a peculiarity of principle. It will be found, that the perfection of organization is always followed by a proportional perfection of life, in all animals alike, and that in man himself its progress is intimately dependent upon the state of his structure, during every period from his infancy upward. In what other light can we consider the life of an infant than as animal life, such as the offspring of animals are universally endowed with? If intellect at the same period of existence is to be considered as a just criterion, surely we cannot place the infant in comparison with the chicken or the calf. Metaphysical reasoners, who have built their arguments upon a subsequent superiority of mental faculty, have overlooked the formations of education. It is no less absurd to suppose that the human faculties previously existed, and were only developed by age, than to suppose that all the infinite number of human forms which have appeared since the creation, and are to appear hereafter, were originally incarcerated together in the same original ovarium. No argument can be drawn from the mental faculties without consulting their origin. Abstract ideas, and the force of recollection, are by no means more inconceivable than the operation of will, in consequence of those ideas; yet the brute has this last faculty, in some degree, as well as man. A cow, for instance, whose head is turned away from the barn, will sometimes suddenly rise up and go directly toward it, though the place she has left should be covered with provender, and external impressions, as the weather, &c., apparently more favourable to her remaining where she was. In this case, the abstract idea seems to occur in the same manner as with ourselves. So, also, we find watch dogs suddenly spring from their sleep and bark furiously, when there is no external impresssion given to the ear or other parts of the body: other dogs, of the hunting kind, will, also, during sleep, howl as they are used to do in the chase. We cannot attribute these acts to any other than abstract ideas; we know we frequently have such passing within ourselves during sleep; and we cannot attribute their appearance to habit. If habit could make the dogs bark, the more powerful one of walking should prevent them from lying still any length of time. Numerous instances of abstract ideas could be pointed out among the inferior animals ; but a few are sufficient to show the probability of more. Now, the conclusion fairly to be drawn from such facts is, that where there are abstract ideas, there must be reason ; depending, as to its perfection, upon their number. Here we must observe a similar constitution between man and brutes. Memory also has the same foundation in one case as the other. The power of recognition is even more manifest in some brutes, and the faculty of committing to memory is as strikingly illustrated in the instances of birds, when they whistle without interruption the tune which they first heard from a hand-organ, as it is in man under similar circumstances. It is gratuitous, to suppose a difference of principle ; and man, though towering in his wisdom, may yet go through the fields, and receive a lesson from the ant or bee. Whatever may have been the feeling which dictated the distinction between reason and instinct, we cannot but perceive their resemblance, and acknowledge, that their difference lies only in degree, and is dependent upon organization. Another consideration leads us to view the principle of life as similar in both, and as depending for its existence upon the body, without possessing a separate character. Man and brutes receive their original ideas from external impressions ; such are those of light, colour, figure, taste, smell, dimension, hardness, warmth, &c. ; their combination which afterwards helps to inform the mind, must therefore be considered as dependent upon the material organs, which first gave the impression. Further, the capacity to receive these ideas follows the perfection of organization through all its varieties. When the body suffers from disease, the mind fluctuates, and when the corporeal fabric ceases to exist, so must the principle of life, whether its maturity be instinct or reason. Where then do we see any superiority over the brutes, as to a difference of vital principle? I cannot perceive a single circumstance to make the inquiry into man's existence or generation in the least degree more improper than one into that of the oyster, sea-nettle, or fungus. The commencement of animation is as wonderful in one part of creation as in another; all show an invariable dependence upon the same principle, and are equally the works of one Creator. It is singular how much is overlooked in trying to hold the veil over life, and particularly over that of man. We give it independence without being able to strike off its weakest shackle; and have, in the end, to leave it as our conformation requires it to be—a consequent of material composition. If the inquiry be improper, why is not the practice of physic considered as an audacious attempt to pry into forbidden secrets? Why are not anatomy and physiology? The last, in particular, aspires to develop the sources of life. We even applaud the ingenuity of physiologists, when they attempt to introduce physical laws into the economy of the animated body. The reason plainly is, that the view of life, as generally entertained, is unfounded; for what is considered as a distinct principle is nothing more than an effect, and its regeneration takes place, day after day, in assimilated nutriment. For these reasons, I shall consider the production of all organized matter (whether animal or vegetable) under the same light, and as I cannot see any assignable difference in their principles of life, I shall not assume one; but enter upon my subject, trusting that all knowledge, which is founded upon observation and experiment, must be proper; since otherwise I conceive the light for investigation would have been withheld.

SECOND DIVISION.

I. THE POWER OF LIFE.

Man has been early taught, by observing the uniform results of putrefaction, that the living structure is composed of the same materials as constitute the inanimate world, or, in other words, that he is literally formed from the sod under foot. This humiliating analysis of nature has been invariably corroborated by the more limited power of art. After such a lesson, it appears astonishing how it could be denied, that physical laws have given us birth. It is true, the production of living matter, as we daily see it, is accompanied with the energy of life in the whole body; and this close connection has given rise to a confusion between the cause and effect. When, however, we consider that no power of life could draw together the particles of matter, or make them cohere or change their properties, we must inevitably come to the conclusion, that the animated matter derives its distinguishing character altogether from physical laws, and that life is but a consequent. To illustrate this, let us examine the vital power as it appears after such formation. "The idea of life," as Cuvier remarks, "is one of those general and obscure ideas produced in us by observing a certain series of phenomena possessing mutual relations, and succeeding each other in a constant order. We know not, indeed, the nature of the link that unites these phenomena; but we are sensible that a connexion must exist, and this conviction is sufficient to induce us to give it a name, which the vulgar are apt to regard as the sign of a particular principle, though in fact that name can only indicate the totality of the phenomena which have occasioned its formation." According to this correct view, whenever we consider life, we shall find its investigation inseparable from the corporeal system in which it exists. We know that it depends upon the mutual exercise of material organs, which are liable to be acted upon by external agents, or decomposed like other matter. The metaphysician and divine may show its importance, by connecting it, in their discussions, with the soul; but the little knowledge that we have on that subject bewilders the conception, though it may not shake the faith. Life, as we have it before our eyes, is nothing else than the *aggregate effect* of numerous material organs, endowed with an irritability which subjects them to be constantly stimulated into peculiar and appropriate actions.

The physician who wishes to support or recruit life, must give all his skill to the disordered organs; for the affections of these alone are found to be the sole causes of disease. In no instance is life found to exist without the organization of matter, and all its varieties are referrible to the same state. When a member of the body receives an extensive injury, it may mortify; and there is sufficient reason why it falls off, or has a line of separation between it and the uninjured part, without supposing a *vital repulsion*. When an extraneous substance is lodged in any part of the body, what can be more unmeaning than to say, that the consequent inflammation is an effort of nature to throw it off? The reason why these expressions are improper is, that they give the opportunity for supposing life a peculiar intangible spirit, and because they do not sufficiently imply how much the vital organs are susceptible of being affected like inanimate matter. The great distinctive character seems to be the irritability which the former possesses in such an eminent degree. But this property, so far from acting the guardian part of a medicatrix upon all occasions, very often leaves the living fibre exposed to the worst of dangers from decomposition, as may be seen in all cases of inflammation. When we examine the living body, we will find that one principle characterizes all its parts : this principle is irritability, which is as peculiar in its nature as the texture to which it belongs. Thus we know, that every part of the body can be stimulated to inflammation, although the irritability of muscular fibre cannot be made manifest to the sight. We will find that connecting organs are placed in every living part, for the purpose of concentrating their powers of life, and nourishing them. The first office is performed by nerves ; the second by arteries and veins. From both we learn a plain fact, namely, that the life of any single part, though the true type of animation, is nothing by itself, and that its power is insufficient to its own support. The parts of the body thus intimately connected together, readily co-operate, and constitute, by their amount of action, the phenomena of life. But even after taking the most favourable survey of this complicated machine, we cannot avoid concluding, that its life is but a physical effect. The property of irritability has no existence, unless when a stimulus be present; consequently, although any part should be capable of this excitement, yet, where no stimulus is concerned, it is completely dead ; and further, when this property is manifested, it must always be the result of action between two inanimate substances—the organ to be affected, and the stimulus. For this opinion there is direct evidence; we know that the corporeal organs are kept in motion during life, by the direct action of stimuli; and we know further, that after death, the action of many may be revived by the same means. What agency, then, can such irritable matter have in the regeneration of itself, when the strongest character which it possesses proves how very subject it is to be affected by the action of inanimate substances? This irritability is the true life; and it is in vain to try to establish any other principle because the living power seems more complex. We cannot deny life to plants, and yet the most fanciful inquirer has never been able to allow them more than an irritable property. To lower the vegetable power of life beyond this point is not requisite, though it has been attempted more than once. This power of life, in plants, is even more distinct than in the polypus and other inferior animals, as the following instances will show.

"The stamina of the *cistus helianthemum* are seen to move in various directions, when the sun shines upon them; the leaves of the *mimosa pudica* (sensitive plant) when touched by the hand, or when irritated by the alighting of an insect on them, immediately contract; *dionea muscipula*, (Venus' fly trap,) when a fly touches its leaves, closes the thorny fringes with which they are beset on the presumptuous insect, and crushes it to death; but the motions of the *hedysarum gyrans* are the most remarkable of all those that take place in plants. The leaves of this extraordinary vegetable are seen in constant motion through the greater part of the day, without the intervention of any apparent external impulse; and even when a branch is cut off, and kept in water, the motion of the leaves continues for many hours together. All the plants which grow above the earth expose their leaves and flowers to the warm sunshine, and when situated in a place which is supplied by light only from one quarter, they gradually direct their branches toward that part by which the light enters. In stormy weather, they retract their leaves and fold up their flowers; and when confined in the dark, their branches retain the position which they had when exposed to the light."* We surely cannot compare with such vegetable life that of the oyster, which is equally rooted to the mud or ground; or of the polypus, which is washed about by the troubled water without manifesting the least exertion of will. In these examples, we perceive that life is nothing more than irritability diffused through the corporeal structure. In the higher classes, as among testaciæ, quadrupeds, birds, and mankind, irritability is equally the principle of life; but the organization is so much more complicated that that principle becomes multiplied. Thus we say they have sensibility as well as irritability. Physiologists have endeavoured to impress the idea of a great difference between these two characteristics. They appear, however, in the end to be constituted by the same principle, and differ only in their mode of application. Nerves are necessary for sensibility, whereas irritability is possessed by organic matter, wherein nerves have never been traced. So far there is a manifest difference. But what principle constitutes the power of action in nerves? It must ultimately be dependent upon irritability, which, as I have remarked, is life in every form. The following example will show their similarity of principle, as well as an ostensible difference in their results. When a muscular part meets with a violent injury, it, in the first place, inflames in consequence of the irritability residing in its compo-

* Encyc. Brit. Physiol.

nent parts, which are all injured; but if mania or sympathetic inflammation (as generally understood) supervene elsewhere, it is because the nerves and other connecting organs, by the first impression, have been irritated, and they are endowed with the power of transferring the excitement. From similar arguments we must be led to the conclusion, that there is but one vital principle, whether with or without nerves; that such irritability is peculiar to every part of the living matter, independent of the system at large; and that the nervous extension is for the purpose of concentrating this diffused animation, as well as for transferring internal and external stimuli to each part, without which, though thoroughly organized, they would be inanimate: furthermore, all this co-operating structure is constantly wasting away, though endowed with vitality; hence another system of organization becomes necessary, which, while diffused through all parts, makes up the full power of life, not by connecting those parts together, but by bringing to each a supply of blood, which preserves the irritable composition. Having thus examined the true form of life, and found it to be irritability, let us now view this property more particularly, that thus we may estimate the vital power in the formation of animated matter.

Baron Haller was of opinion, that irritability existed independent of a nervous connection, and therefore called it a *vis insita* of the part itself. We have seen in vegetables, that nerves are not necessary for life; the polypus seems an instance among animals. The umbilical cord has never shown the least trace of a nervous texture; and accordingly, when divided, occasions no sensation of pain to the female, and apparently none to the fœtus: yet we cannot but allow it has life. If nerves were necessary for vitality in this part, it is highly probable, that they would at least be as manifest as those of the fœtus, which are necessarily supplied with nutriment after the cord. The fibrine of the blood, which we can scarcely suppose to be affected by the nervous power when taken out of the body, is still susceptible of irritation. This curious fact was first stated by Circaud, and afterwards confirmed by Delametherie.* The difficulty of succeeding in such experiments must evidently be very great; for when we consider how very soon irritability is destroyed by the least change of composition, we cannot be surprised at failing to illustrate the power in fibrine. But it is of little consequence to prove the absence of nerves; since in these also irritability may be considered as a *vis insita.* The term itself is far more questionable; for irritability is not, strictly speaking, any thing else than a property of matter. Common language, it is true, gives sanction to such an application; but it is evidently incorrect to style that a power which absolutely depends for its existence upon something else. In this case particularly, it becomes necessary to preserve this view, in as much as it points to the common error, of thinking life a cause, instead of an effect. There is no such thing known as irritability, without the influence of a stimulus, and when this property is made manifest, we can only consider it as a secondary existence. We say a body is sweet or sour, but we know that such qualities are dependent upon the gustatory nerves, as much as on the body itself. So it is precisely with life, which is a quality generated by stimulus upon the organic matter. This truth, when we conjoin the mode of action by stimuli, must lead us to consider irritability as much a material property as those which we daily call so. It depends

* Bostock's History of Galvanism.

upon the chemical composition more than shape or magnitude; and is therefore very analogous to a chemical property. Such a conclusion may seem too hasty, and perhaps is, since experiments to the point are very few in number. Elsewhere I shall endeavour to do more justice to this subject, when treating of irritability, as resulting immediately from the composition of organic matter, and as being in truth a part of the assimilating process. Persons who are unwilling to suppose life any thing else than a perfect archeus, making the body his home until death turns him out, have supposed that wherever this principle has been revived, it must have existed throughout, only in a latent state. The moment, however, this opinion is examined, its truth becomes questionable, at least, as to the application in many cases. Irritability, we know, can be manifest only as long as a stimulus is present. How then can we suppose a vital action, or even a latent vital power, when no stimulus is concerned? Wharever may be the appearance, we may conclude, that whenever life appears, the organization must have remained unimpaired; consequently, in all such cases, life may really be destroyed and restored. If an egg, for instance, can after any lapse of time produce a chicken, the fœtal structure must through that lapse have remained unaltered as to its chemical composition, as well as arrangement. Hence, then, the appearance of life in this case may be reconciled with observation upon the living body itself; in which we know the vital power has no existence, without a proper stimulus, and where we see that its regeneration depends upon that stimulus. The heart, for instance, contracts violently, as long as the lungs inhale the atmospheric oxygen, but when hydrogen is breathed, or any other gas which cannot readily unite to the carbon of the blood, the heart languishes, and approaches true death. For the same reason we see why a seed appears to be dead (and really is so when without a stimulus) for many years; but when exposed to the influence of heat, air, moisture, &c. acquires life. The structure is capable of being excited at any time before decomposition takes place. In Smith's work on Botany, we find an instance where a plant, after being kept twelve or fourteeen months, as a dry specimen, obtained life upon being planted. Now, in this case all kind of nutriment had been withheld; and not only this, but the stimuli, which at other times are found to be absolutely necessary for life. Here then I think the subsequent growth plainly shows that the oganization (which in plants is always more permanent than in animals) remained so little impaired, that the natural stimuli of warmth, air, and moisture, were enabled to excite its actions, or, in other words, to *create* life. Whenever the structure is simple, irritability will remain longest; for decomposition is then slowest in its effects. For this reason, it is so difficult to preserve the life in animal substances, after they have been exposed to injury, which almost always is followed by a decomposition. An egg is rendered unfit for hatching by a few shakes; whereas the same will not affect a seed.

By keeping in view that irritability is a property of matter, and not a separate power, we will be enabled to value its influence over the formation of animated matter. As such, it must be confined to the substance possessing it, and in no case can effect a change of composition in adjoining matter. We might as well suppose that the sweetness of sugar could convert things of an opposite nature into sugar by mere contact. Before our food becomes assimilated, it must be totally changed in composition and properties; it generally also passes from the solid to the fluid state. Now, it is an unsupported supposition that vitality can affect cohesion, or a change of chemical constitution, and it becomes apparently impossible, when we consider that this vital power must, under such circumstances, be supposed to exist in tubes and cavities, where there is no animated matter. No part of the living economy has been more mistaken than that of regeneration. In spite of daily observation, that chemical phenomena take place in some of the vital functions, and the still more imperious truth, that no process in nature is known to be capable of altering the composition of matter, except that resulting from chemical affinity, yet every subterfuge is grasped at to limit this universal law. We can behold the arm move with mechanical advantages; the eye regulated by the laws of optics, and the ear by those of accoustics, and yet though the laws of chemistry equally bespeak wisdom and design, we take upon ourselves to disturb a harmony which pervades the whole created world. It is doing no less if we deny the power of chemical affinity in the composition of matter, merely because it is, or is to be animated, and that too while we confess a total ignorance of the vital power. The undeniable truth is, that the living system is made and supported by physical laws, and that the only power of life consists in making them co-operate. All the changes which take place in the body must be affected by these laws; even to the acquisition of vitality. They are all absolutely necessary, and those of chemistry the most extensive. Let our prejudices be what they may, we should be open to conviction. If we cannot conceive the mode, we should rather set it down to ignorance, which will long be the case as to our extent of chemical knowledge. Besides, it should be borne in mind that the misdoubt is, after all, about a trifle. The application of physical principles to the phenomena of life, cannot make the nature of either more insignificant to the eye of philosophy. On the contrary, it completes that chain which binds the universe, and connects the gradations of its substances, from the simple atom to the most complicated form of organization and life. Can the wisdom of God's works be less divine because they exhibit connexion and uniformity; or does the wisdom displayed in them appear more limited because it becomes more manifest? Certainly not. And the individual who shuns or neglects the examination of His works, is far more likely, from ignorance, to err, than he who aspires to trace their symmetry and connexion. Whatever may be our doctrines, it never can derogate from the divine stamp of life, to prove that it derives advantages, or even existence, from regulations which we all must feel were framed by the same wisdom.

But now it may be asked, if there is no power of life in the organized compound to protect it from the laws of chemistry, how does it happen that the structure is able to resist decomposition? This I shall attempt to illustrate upon principles which, in my opinion, lead to the true vital economy; since they show that chemical changes can take place at all times upon a living solid, but that our functions are regulated so that the circumstances under which they occur shall not be long injurious. Physiologists who deny the power of this action, evidently draw their conclusions from the life of the body at large. Let them take the whole to pieces, and then value the inherent power of life. If the corporeal structure does not perish by every *local* decomposition or injury, it is because that derangement is adjusted before it extends to the most important organs. This surely is not to be considered in the light of a contra-chemical power! The injury really takes place, and the wisdom of our conformation consists in making amends for the action of laws which cannot be subdued as long as matter exists. Take the mortifying leg of an animal; do we not there see the true life diminishing? It is a portion of the general stock, which evidently is insufficient in its nature to prevent chemical decomposition. Here, also, we may value the power of life, which consists in the *arrangement* of parts, and not in giving them magic. As long as the blood vessels, nerves, and other *connecting* organs remain undecomposed, they will possess perfect irritability, and so long will be enabled, by the increased stimulus, to bring a share of blood to the mortifying limb, sufficient to *re-compose* its parts. The absorbents at the same time, and by the same means, take up and separate the detached portions; thus preventing their further reaction on the limb. But if all this beautiful connexion looses the capacity for life or irritability, in consequence of being involved in the decomposition, no power or spirit can support the limb. Chemical changes progress as they did from the beginning, but the structure which they destroy is not rebuilt, and the whole sloughs away. It may indeed be removed by fluids secreted from the living extremities, as well as by those which result from the decomposition. These terminations generally prove successful in preserving the life of a portion, and indicate the most perfect design.

Very few will have it in their power to disprove the true character of the chemical changes which take place in the forgoing example; but it may happen that the living texture shall meet with a similar exposure, and yet no fatal results follow. Whatever may be the appearance, we are justified in applying to all such instances the foregoing principles; since the organic arrangement being still the same, the mode can only differ in extent.

The parts exposed, even if they should suffer incipient decomposition, are immediately roused where life (or as we consider it, irritability) yet remains, in proportion to the complexity of structure; fluids are thrown out on the living surface, which they shield from decomposition, by removing the chemical agent *beyond* the sphere of its action. Here we see no proof that the life of the parts exposed resisted the chemical tendencies. That which follows being a proof that the animated matter has not the slightest power of defending itself, but that it melts with all its success in consequence of connexion and arrangement.

If the chemical agent be small and light, it becomes washed away, in a similar manner to what takes place when a grain of sand or dust enters the eye. This may be done before even the fluid which is employed, can suffer decomposition from the same substance. But when this agent is lodged to any depth, or is too heavy to be washed away, a chemical action always takes place independent of mechanical irritation. If a small quantity of white arsenic (arsenious acid) be swallowed, it enters one of the most vital organs of the body; yet it may pass through the whole course of the stomach and intestines, without producing more than a trifling inflammation, wherever it meets with detention. The reason is obvious, and shows how very feeble any specific life (or that which belongs to a single part,) must be. We find that a fluid is always necessary to bear away the foreign material, and from this we conclude, that the provision has been made, not to destroy the *tendency* towards action, but by interposition, to remove the materials from each other, and they prevent a result which otherwise would as soon take place in the body as out of it. Such an arrangement, instead of diminishing the wisdom of our construction, infinitely exalts it. It shows a consistency with the rest of matter, without having to suppose that the life changes properties which are immutable elsewhere.

Persons who deny the power of chemistry over animated matter, contend that the absence of gaseous matter is a proof. But here again, the system at large is considered instead of any single part; we all know that when chemical action takes place to any extent in a limb, in the intestines, or, in short, in any other portion, that gases are abundantly formed. But the objection, when even applicable to the whole system is unsupported. What else can we consider respiration but a chemical function? It is idle to object to this example, because respiration is not performed within the *substance* of the body; but merely on the pulmonary surfaces. Are we to dispute about trifles, when the principle is unimpeached? Surely, if respiration be necessary to life, so must the chemical changes; which may therefore, as to principle, take place as well in the body as out of it. If we expect gases to be liberated in any quantity during the exercise of the functions, we are evidently going too far; since, after all, chemical changes of the most varied nature may take place without the production of any gas. We know that all corporeal changes during life are in appearance very gradual; and therefore, although gases should be formed, they must pass away unobservable in magnitude, by the circulating blood. As long as the decomposition subtracts only one ingredient at a time, as carbon, and as long as health remains to re-establish the original compound, by speedily furnishing new, but similar matter, so long it must follow, that little or no gas will be manifest. The chemical changes of the living body need not, of necessity, be the same as those which take place in the cadaverous mass, where all the constituents are liberated nearly at the same time, and where it would indeed be singular if gaseous products were not formed. But after all, if nothing can satisfy such doubters but facts, I need only refer to Professsor Brande's experiments, as related by Sir Everard Home, where two cubic inches of carbonic acid gas were obtained from every ounce of fresh-drawn blood. This, it may be remarked, is the gas which always results from organic decomposition, and agrees, in quantity, with the gradual changes of the living body.

Another objection has been advanced, which at first sight appears forcible. One of the great phenomena of chemical affinities is, that the more complex a substance is in composition, the sooner it yields to spontaneous changes. Thus, when a body has two constituents, it is more firmly constituted than when one of these becomes multiplied, or where a third ingredient exists. During life, however, such parts which are always the most vital seem the least prone to decomposition; and it is said that life must be the cause, since when such parts are dead, they readily obey the common law. I have already said, that the laws of matter have all their force in the living body as well as in the universe. This, I feel persuaded, is infinitely more consistent than to suppose that matter can exist any where without them. The present subject furnishes a demonstration which, to me, appears capable of upholding such an opinion.

It is impossible, by any process of reasoning, to devest ourselves of the conviction, that the living substance has most of its properties in common with the dead. In composition it certainly is similar, (as, for instance, the dead and living muscle,) consequently, although the decomposition may be more manifest in one than in the other, we must suppose its principles alike for both. This general, though correct consideration, leads us to expect the foregoing law of composition should hold true in vital and highly organized parts of the body; accordingly the *appearance* which such parts have of resisting chemical changes admits of an explanation agreeable both to the phenomena of life, and the general law of matter.

All parts of the body which are most complex are also most vital; or, in other words, they are most largely supplied with *blood-vessels*, nerves, and other connecting organs. These are considered, in vague language, merely as characteristics of life; but I conceive the design of our conformation can be traced much farther. They appear as constituting an arrangment, not to subvert chemical affinities, (without which no organized substance can exist,) but to make amends for their undeviating sway. To the complex structure we may apply the general law, and by the living properties, which seem in opposition, prove its truth. We may say that the complex vital structure undergoes decomposition quicker or more readily than the simple one; and for this reason it is furnished with a much greater supply of blood, that thus it may be rebuilt without the whole system being injured. Other parts, as the nails and hair, are of uniform composition, and are well known to resist chemical decomposition; they, therefore, need not be furnished with blood throughout, and are inanimate when compared with the foregoing. This destruction, previous to absorption, is not a mere conjecture; the cohesion which could take place at the mouths of the absorbents must evidently be too powerful, subsequently, for those mouths to eat down, as Mr. Hunter supposed, or to be nibbled as by the mouth of a worm. " A mere conjecture, and most improbable. The solids are raised by the agency of the vessels on the chemical affinities of the circulating fluids. They must be resolved by a process reducing them again to the state of fluids, or the secreting vessels throw out fluids which dissolve them; an operation anterior to their absorption."* The brain is an instance of a very vital part, so is the womb; accordingly we find, as John Bell remarks, that they "are the most liberally supplied with blood." Again, as the brain is the least firm of the two, we should conclude that it must, also, be most liable to decomposition; and, as if to make amends for this state, we find that it has "two great arteries on each side; it has two carotid, and two vertebral arteries; they far surpass those of the womb; their inosculations are so particular that there are no others like them in all the body. The injection of any one artery easily fills the whole; the preservation of but one artery saves the life of the creature when the others are stopped." What can be more reasonable than to suppose that this singular inosculation is for the purpose of supplying, under the worst of circumstances, a ready stock of blood to obviate the fatal effects of rapid decomposition? "The brain, which weighs not a fortieth part of the whole body, receives one tenth of all the blood: a proportion which must occasion surprise." Every person who has made repeated dissections of this organ must have observed how very soon it becomes destroyed after death has taken place; and the same tendency cannot but exist during life. The spinal marrow is also well supplied with blood from the anterior spinal artery, which descends along the medullary column in a furrow formed for itself, and sends innumerable branches into its substance.

* J. Bell's Anat.

Thus are obviated some of the principle objections against the anti-chemical power of life peculiar to the solids. If there be any truth in the position, how shall we deny the tendency to chemical changes among our various kinds of food and the fluids generally, which are within cavities, and appear to have no permanent connexion with the solid structure? If changes in them are not fatal to the whole system, it is because they are kept in progressive motion through these cavities and canals, until they receive suitable changes of composition, from chemical agents placed in their way, being then separated from the mass by absorption, or expelled from the body before injurious accidents can take place. Another reason why the body escapes chemical injuries during its progress is, that the substances which enter by the mouth, are in general mild nutritives, which readily submit to the changes of assimilation. When by accident or design, chemical agents of a more powerful nature are made use of, we see too clearly that life is either prostrated or extinguished.

As to fluids, a few remarks will show why they in particular undergo ready changes of composition. Let us take the blood as an example, since this gives evidence of possessing irritability. This fluid is of a compound nature, not only by its own constitution, but by the continual intermixture of foreign materials. Its contact with the vital texture, is incessantly changing; it has no diffused organs through its substance, for the purpose of repairing chemical changes, and without the slightest arrangement to concentrate its vital property. What then has it to make amends, but this simple quality of irritability? We have already seen how poor a protection this is to the solid texture; how much less, then, must it be to the blood, which, as a fluid, has not even a perceptible affinity of aggregation, to oppose decomposition ; its fluidity not only assists its own destruction, but gives the same power to the intermixed matter. We accordingly find that the blood does meet with such changes to a certain extent. They are always made more manifest in diseases with languid circulation; and would undoubtedly have a fatal issue, were it not that a provision is made to separate these foreign substances, and to purify the blood itself, at the end of every round. Circulation has this for one of its important objects. Each part of this fluid undergoes a complete review, as it were, in the lungs ; and before the course of circulation becomes complete, a great part of the blood itself, as well as its admixtures, are timely disposed of, in the form of secretion and excretion. Similar exposure and provision may be observed for all the other fluids. In this way, injury is prevented ; not by *destroying* chemical action, but by withdrawing the materials from each other, which otherwise would display their affinities, nowithstanding the supposed check of an inherent vital principle.

CHEMICAL AGENTS IN THE FORMATION OF ANIMATED MATTER, AND ITS FUNCTIONS.

We have already anticipated a great deal of the part which chemistry performs in the vital functions. The more these are examined the more one must be convinced, that the proximate cause of all organic formation is chemical affinity. It is not reasonable to expect a detail of operations, so varied and unobservable in their nature ; neither is it neccessary. But we have general rules which are sufficient to establish the truth, without requiring that every ambiguous point should be cleared up by experiments. The laws of chemistry, are the only ones capable of effecting a change of composition ; its agents are not only surrounding the living structure; but they pervade its most important organs, and must of necessity characterize every material production within the system. Irritability which is the true type of life in the parts themselves, cannot prevent decomposition, as has been shown, but, on the contrary, must always be the proof of action, no matter how indefinite. The phenomena of life when connected from part to part, cannot be regarded as showing that chemical affinities are subdued, since they admit of an explanation perfectly agreeable to both. When examined, the true vital economy is found not to consist in destroying such laws, but interposing materials which have the power of acting chemically; and these, by the uniformity of their nature are generally attended with the designed end. Hence, then, we can safely say that, whatver be the form of structure employed, the changes of composition which take place during life are of a true chemical nature, as well as the agents employed. Our want of power to imitate or illustrate these, argues only our ignorance of the science. Every practical chemist knows how much difficulty he has in managing the few articles which may be placed in a crucible or retort; and every new compound which he encounter requires the same kind of labour before he can presume to announce its nature. It would be the height of presumption to take up a few simple minerals, and say these constitute the living fabric; but it never can be, to suppose that chemical affinity is employed as much for one as the other. Neither is it to be supposed that analysis will enable us to succeed in the composition. It is easy to consume the brilliant by a burning glass and to prove that it consists of carbon; but this success gives no power to form it anew. Though possessed of the materials, and perfectly convinced, that they still have the same chemical tendency as at other times, the only constant result is, to be convinced that it is much easier to destroy than constitute, notwithstanding the similarity of principle for both processes.

When we confine our attention to the higher range of animals we are inclined to consider that life effects all their phenomena, and so it does remotely; since it is the result of organic arrangement, and operates by presenting materials. So does the chemist, when he pours sulphuric acid from one glass into another of carbonate of soda, remotely produce the sulphate. But we must not confound the operation of his hands with the affinity which constituted the salt, or occasioned the effervescence. The life of a plant is considered as a very humble one; and if such, so must be its power. Yet the secretions formed under such circumstances have as much constitutional difference as those of the most perfect animals. Here, then, there is infinitely less opportunity to intoduce this mysterious influence; and turn where we may, the same outline is observable. With this we should be satisfied, without trying to oppose laws which we can not alter.

MOISTURE AND FLUIDITY.

This state of cohesion is observable all through the living stucture, and is so important in promoting chemical action, as to give rise to the rule "*corpora non agunt nisi sint soluta.*" I am not to be understood as implying that such is their most important use in the body; on the contrary, when intermixed, or in contact with solids, they are of the most obvious use in facilitating motion, defending surfaces from chemical action by interposition, in preventing, as well as sometimes in effecting adhesions. It is equally true, however, that where they effect a solution they give a greater opportunity for chemical changes ; and this result is always independent of the fluid. Furthermore, we may say, that all the important combinations are effected by the agency of solution. Even supposing, with Mr. Hunter, that the "modelling absorbents" eat down the solid parts, still their solution must be effected before, or shortly after their being swallowed. Such is the state at least when they are examined in the *thoracic duct*, and such must be their state before they can circulate with the blood. Every part of the solid texture has a moist or liquid matter pervading it; hence it is but reasonable to suppose that this is a means employed to render the different parts fit for being absorbed, as soon as their texture looses its aggregation. As the fluids are not united to the system at large by interwoven nerves or blood vessels, we cannot suppose them capable of resisting chemical changes, or of making amends for themselves, after such have taken place. With them, as with every other part of the body, extensive and uninterrupted connexion is necessary. Fluids, therefore, are absorbed, and thus brought into new ranges of affinities, suitable to the general economy, or are by the same act checked in their tendency, by dividing the mass before it can take place. Another arrangement, also, effects the same end. The slowest motion among the particles of a fluid, unless they possess a very powerful affinity for each other, tends to prevent their remaining in contact long enough to combine. This is also aided by the water which constitutes so large a portion of their bulk; as a solvent it separates the particles beyond the sphere of action. But with all these provisions, there can be no doubt but that the fluids are proximately the field wherein all the organic formations and destructions take place. In their arrangement we behold a constant view towards their chemical and physical quality. The mucous fluids are generally secreted upon surfaces which have outlets through the body; because, as they have the property of coagulating under circumstances, they would often prove injurious by occasioning improper adhesions, unless there were means of expelling them. The serous fluids, since they have not the chemical property of the other are deposited upon the surfaces of enclosed cavities, as within the *peritoneum*, *pleura*, or the capsules of joints. There are other fluids secreted for the express purpose of chemical action; such are the gastric and pancreatic juices, the bile, saliva, and various others, but it is not necessary to consider them in this place more minutely, since their chemical agency depends upon their composition rather than their state of cohesion.

ANIMAL HEAT.

This is also an auxiliary. We find it nearly equally diffused throughout the body; and its presence is sufficient to promote chemical changes, without inquiring into its origin. It is the degree of temperature which seems most active in giving bodies their solid, fluid, and gaseous forms. As such, it must be regarded as similar, in its agency, to the foregoing; that is, in influencing the aggregation upon which chemical action in a great measure depends. It must be confessed, however, that it seems more useful in keeping up a constant excitement in the irritable texture. We feel how completely sensation ceases when the hands or feet become cold; or when the whole body is labouring under a shivering fit. As to its origin, there has been a great diversity of opinion; and the general failing arises in making it too particular. No doubt I think should be entertained, as to its resulting from chemical changes, when the same can produce it out of the body. But we cannot suppose that these are the only sources. A flush of confusion, or anger, will throw the face and neck into a glow; but here it is absurd to introduce chemical changes. Such phenomena seem more referrible to the nerves, or rather their irritability. This excitement may even depend upon physical causes, without entitling us to draw such conclusions. It is the property of alcohol, when tasted to act on the nerves so as to produce a sensation of heat; the same is felt in the stomach, and no doubt can be entertained but that the same physical property afterwards affects the nerves of the heart and arterial system so as to occasion the fever from intoxication. We may even suppose that all exciters have this power over the nerves, in consequence of their chemical composition; yet it does not follow that they should always have chemical action. The two branches of a pine tree, for instence, though constituted upon these principles, do not, when rubbed together, produce heat by chemical action. Most of the animal temperature seems occasioned in a similar manner. When we rub a benumbed limb it becomes very soon glowing with heat; our muscular motions always produce the same; so must the incessant action of ths heart and arteries. And when we consider that the same happens when two pieces of wood or stones are rubbed together, we should view the result as depending, not upon life or chemical combinations, but upon one of the most common material properties. The observation of Crawford, upon the difference of capacity for caloric, between venous and arterial blood, is no doubt illustrative of a uniform supply, but cannot be considered as sufficient to establish a theory on animal heat.

GALVANISM, ELECTRICITY, &c.

The process of secretion has long been a subject of investigation; but manifest as its effects are, and notwithstanding the great importance which the nervous system appears to have during its complicated stages, no facts have been brought to light sufficient to illustrate its nature. We find the greatest variety of these products among vegetables, yet few have been willing to credit the existence of nerves in plants. The polypus, also, is an instance among animals where the process of assimilation takes place most perfectly, and to all appearance without a nervous system. To these we may add the formation of the umbilical chord, and some examples of fœtuses. M. Le Gallois mentions, in his treatise, several where neither brain nor spinal marrow were to be found. Clark (I think) relates in the early part of the Philos. Trans. an example where not a single trace of nerves could be found, although bones, flesh, cartalage, membranes, &c., were distinctly formed. These considerations lead us to view the nerves merely as constituting an apparatus for the secreting agent; but without which that agent may, in some instances, be effectual. Several difficulties will occur if we regard the nervous, or even any other division of the vascular system as necessary for the formation of animated matter, and therefore most probably for all secretions. We find, for instance, that all the corporeal texture which is concerned in such offices have blood vessels which supply materials for secretion as well as others which support the organ itself; now, whether nerves be necessary for the last or not, we must suppose such a minuteness of vascular structure, by continuing this arrangement downwards, as will evidently be absurd, or else we must draw the conclusion, that the formation of animated matter does take place upon principles independent of the vascular arrangement. Let us illustrate the idea by an example, which will at once be allowed applicable to all the rest. When a nerve is injected, its substance is found to be interwoven with minute blood vessels.* These are for its support; and, according to the general economy, should be accompanied with nerves for the purpose of secreting freshnervous matter; but, be this as it may the coats of these minute blood-vessels must be supported. How is this effected? If by another and minuter vascular apparatus, how is the substance of this last secreted? Thus we will be driven to fancy the existence of blood vessels and nerves as small as it is possible to divide matter; and even here the dilemma cannot cease, since for the very last, secretion of substance will be as requisite as for the first and largest set. On the other hand, we are led to think that secretions can proceed from the blood by the influence of an agent not necessarily limited to the nervous apparatus. This I really conceive is best supported; for if the foregoing descending series of vascular arrangement be inadmissible, then there appears no alternative but to suppose that the smallest set of nerves and blood vessels had their solid texture formed from the blood without further apparatus. At a subsequent part of this essay it will be in place to state experiments which go to prove that arterial tubes with their ramifications can be formed directly from the blood by its chemical or physical properties. At present I shall rely on the foregoing, and

*Bell's Anat. 2d vol.

consider nerves and vascular structure as established for convenience more than from absolute necessity in the process of converting the blood into organized matter. Supposing then that the nerves are mostly for the purpose of forming a perfect conducting apparatus, we must approximate nearer to the true nature of the agent transmitted, when we experimentally become acquainted with any which has the property of readily passing through the same medium. The similarity is much farther heightened when we learn that this last is a powerful chemical agent. Such a one is galvanism, (including its modifications of electricity and magnetism.) It is not my attention to present a history of this very extensive agent, but merely to examine some of its greatest claims to being considered the nervous principle, and that employed in the formation of animated matter.

Dr. Galvani of Bologna, as early as 1791, published his discovery, that the muscular fibre of frogs could be instantly excited by transmitting through its nerves the minutest quantities of electricity. He also proved, that this muscular excitement would take place without any external supply of electricity, when a *conductor* was made use of to connect the nerve and muscle, but that no such result ever occurred when new conductors were substituted. This discovery was clearly sufficient to prove, that nerves are among the best conductors of electricity. After that time inquiry was set on foot, with the most unreasonable expectations, and was in turn as rapidly abandoned because, unfortunately, experiments did not warrant every scheme of the investigator. Without considering that the functions of life depended upon numerous co-operating principles, it was idly hoped, that they might be regenerated in the inanimate structure, where every other principle was extinct, except the fictitious one. It is not necessary, however, that all such anticipations should be satisfied, in order to show the similarity between galvanism or electricity and the nervous agent. There are no less than four kinds of fish, which have a natural apparatus in their bodies, capable of imparting shocks, not only similar to those from a Leyden jar, but upon similar principles. These are the *torpedo*, the *gymnotus electricus*, the *silurus electricus*, and another found at the Comoro Islands, which seems of the genus Tetrodon. In each of these, there seems to be a distinct organization, for the purpose of accumulating and transmitting electrical power. In the torpedo this structure consists of perpendicular columns, reaching from the *under* to the *upper* surface of the body. Hence on the principles applicable to the opposite poles of a galvanic battery, this fish must be touched so as to make a circuit between its under and upper surface. Then a strong shock will be felt throughout the connection; but only a chilliness, when either one is singly touched; here we perceive a perfect coincidence as to principle. In a very large torpedo one electric organ was found to consist of eleven hundred and eighty-two columns, each with a diameter of one fifth of an inch. The shock which is given by the torpedo, when standing in the air, is about four times as strong as when standing in water. This fact shows another similarity; for water is a much better conductor of electricity than air, consequently, in the latter position, more will be transmitted by a conductor. The torpedo shock is interrupted by nonconductors of electricity, and transmitted through those that have the power. Even though the circuit should be formed by several persons joining, the shock will be felt by them all at the same time.*

* Walsh's paper, Phil. Trans. vol. 63.

Dr. G. W. Schilling, in 1764, made experiments upon a torpedo about six inches long and one thick. The account, though it seems extravagant, cannot but be considered as demonstrating a very close resemblance between the power accumulated by this fish, and magnetism, which appears to be a modification of electricity.

He put it into a vessel of water when its vigour was greatest. A magnet with a power of four ounces was then applied near the fish, which immediately began to move about with violence, though not touched. The desire to escape seemed greatly to increase, as the magnet was brought nearer. The magnet was then placed in contact with the water, and the torpedo, after slowly approaching, and at times endeavouring to escape, at last adhered to it, like a piece of iron. After being cautiously removed to some distance, it recovered the power of motion, but was totally incapable of giving a shock. The magnet again attracted it, where it adhered for half an hour, and then spontaneously fell off, evidently debilitated and without the power of giving shocks. It is also stated, that after the immersed magnet had destroyed that power, iron filings, when thrown into the basin, occasioned its restoration. Something analogous to this may be seen in the human body, during the paroxysms of neuralgia. It is a fact well authenticated, that when this nervous affection attacks the cheeks, a magnet, by being kept in the mouth, has the power of allaying the pain. A very intelligent physician, who had long suffered from this excruciating disease, remarks, that he relied upon a magnet which he kept in his mouth next to the affected cheek, and found it capable, for a time, of affording him perfect rest, but that afterwards when that influence had ceased, being led by analogy to try a more powerful magnet, the result proved of a most contrary nature ; the pain returned with such violence upon every application, as to render the attempt almost insupportable.* With the view of checking this nervous disease, physicians have effectually recommended the use of magnetic belts.

From some experiments performed by Mr. Todd, it is shown that the shock of the torpedo passes from the electric organs through its connecting *nerves*. An incision was made round the circumference of both organs, so as to leave no attachment between these organs and the animal, except by nerves ; under such circumstances shocks were received as powerful as before the operation.† In this fish, therefore, we see that a power very similar to the electric, is naturally accumulated and transmitted through nerves as conductors. The gymnotus electricus in my opinion establishes their identity.

Cavallo remarks, that "the strongest shocks of the gymnoti, which were exhibited in London, would pass through a very short interruption of continuity in the circuit. They could be conveyed by a short chain when stretched so as to bring the links into a more perfect contact. When the interruption was formed by the incision made with a penknife, on a slip of *tinfoil* that was pasted upon glass, the shock in passing through that interruption showed a small but *vivid spark*, plainly visible in a dark room. This animal showed a peculiar property, namely, that of knowing when he could, and when he could not, give the shock ; for if non-conductors or interrupted circuits were placed in the water, he would not approach them ; but as soon as the circuit was completed, he would approach the extremities of that circuit, and immediately

* Dr. Jones' letter to Dr. Rush. † Phil. Trans. for 1817.

give the shock."* In other respects this animal resembles the torpedo; so also do the remaining two, the silurus and that from the Comoro Islands; but less is known of them.

I have been particular in describing these facts, because they furnish the most manifest exhibition of the nervous energy, and prove, at the same time, that it is the same as the electric, galvanic, or magnetic. We can hardly have a more beautiful illustration of physical phenomena subservient to the vital economy. They do not result from fortuitous circumstances, but depend upon a separate structure well adapted and apparently acting upon as definite principles as a galvanic battery. On this subject Sir Everard Home remarked, in his paper on secretion, that these arrangements prove, "that a voltaic battery can be formed in a living animal, and that nerves are essential for its *management*, for in these fish, the nerves connected with the electrical organs exceed those that go to all the other parts of the fish in the proportion of *twenty to one*. The nerves are made up of an infinite number of small fibres, a structure so different from that of the electrical *organ*, that they are evidently not fitted to form a voltaic battery of *high* power; but their structure appears to Mr. Davy to adapt them to receive and *preserve* a small electrical power." In the same paper an experiment is stated which shows that the animal structure when detached has the power of accumulating nervous energy, or in other words of forming a voltaic battery. When the two hind legs of a live frog have been recently cut off from the body, the muscles of both will be excited to contractions if the circuit be completed by making each crural nerve pass across from its own limb, and touch the muscular part of the other leg.†

* Elements of Philos.

† Phil. Trans. for 1819.

Lagrave states, that by placing alternate layers of brain and muscular fibre together, and separating them by a porous body soaked in salt water, a galvanic pile will be formed, having the usual effects.* Here we see that the composition of animated matter qualifies it to accumulate, under certain circumstances, the galvanic influence, and although the arrangement of the parts is not naturally so regular as this of Lagrave, the experiment just mentioned, of the frog's legs, shows that the natural one is sufficient. We thus learn that galvanism is accumulated by the structure alone, both during and after life ; we are also aware that its power is able, according to its extent, to effect the most varied chemical changes ; what then, I would ask, can authorize us to consider that this power, when excited during life, does not occasion new chemical compounds whenever materials are presented ? Many circumstances lead us to give credit to this power as a secreting agent. We know its influence over compounds, out of the body ; we know that it can be accumulated in the living system, and though there should not be nerves to transmit it, yet any organic compound, as the animal fluids, which by their position can direct it, or concentrate its power by forming circuits, must lead as directly to changes of composition. Nerves, however, are almost always present in the greatest abundance. Whatever may be the apparent use of this structure, we know that whether for secretion, motion, or sense, all are open to the galvanic influence. But it may be asked, if such is the arrangement, why are not the nerves of sense and motion constantly giving rise to secretions ? To this it may be answered, that one circumstance can always prevent them, even when galvanism is excited in their

* Bostock's History of Galvanism.

neighbourhood. Under all circumstances its course will be through the *shortest circuit*, and for this reason *most* of its power will be confined to the same extent. This we know from experiment. If the knob and outer surface of a Leyden jar be touched by the thumb and fore finger, the violence of a shock will be confined to their extent, but if the two hands be substituted for the thumb and fore finger, we will feel the shock in the *arms* and *shoulders*. To confirm this further, let a person standing behind, place his hands, one on either arm, or either shoulder, so as to form a second circuit, and although his is connected with the first, yet as it is the longest of the two, he will feel no shock. Hence we see, that if one or more anastamosing branches of nerves intervene between the accumulated galvanism and the nerves of sense or motion, little or none of its influence can extend to them. If, however, these nerves of sense are *included* within the circuit, they transmit galvanism with perfect freedom ; and what is still more singular, as Fourcroy observes, impart the sensations of smell, flavour, pain, warmth and vision.* Ritter, also, states, that the electricity of the positive pole augments the actions of life, while that of the negative diminishes them. Tumefaction is produced by the former, depression by the latter. The pulse of one hand in contact with the positive pole for a few minutes is strengthened, and gives the *sensation of heat ;* that in contact with the negative, is enfeebled and gives the feeling of *coldness*. When the eye is positively electrified, objects appear larger, brighter, and real; while, to one negatively electrified, objects seem smaller, less distinct, and bluish.† Even the smallest galvanic action has the power of strongly affect-

* Connais. Chem. † Ure's Dictionary.

ing these nerves. When a piece of silver is placed between the upper lip and gums, and a piece of zinc under the tongue, this simple apparatus is capable, whenever the mouth is closed so as to bring the metals in contact, of giving a sour taste to the tongue, and a flash of light to the eye, perceptible in a dark room. Other, and more familiar ones have been noticed; but it is not my object to enumerate them.

The influence of galvanism on muscular motion, through the connecting nerves, is far more striking. Small pieces of zinc and silver are sufficient to convulse the limbs of a frog, or other small animal, so as even to throw them from place to place; but the magnitude and intensity of such effects have never been illustrated so forcibly as upon the human body. Few can read and credit Dr. Ure's experiments upon the executed convict without allowing that even if our vital motions are regulated by an unknown agent, none better need be sought after than that of galvanism. With his battery he made the dead chest heave as in respiration—the eyes open and shut with the motions of life, but the ghastliness of death;—the mouth and lips ran into distortions as true and impressive as when prompted by the strongest or worst passions, and the whole face became impressed with characters so energetic as to sicken the bystanders, and force them to withdraw. The hands, arms, and legs, were also thrown into motion far beyond the natural power, and so violent as to baffle all muscular resistance. Dr. Ure concludes his experiments by stating his belief, that if blood had been present and properly arranged, he could have succeeded in establishing circulation.* We may not accede to his conjecture, since

* Ure's Chem. Dictionary.

more parts than he could command would require to be set in motion; but we cannot doubt about the galvanic influence being capable of exciting their actions. Many other conditions beside motion are requisite for life, and even this one might prove too imperfect for circulation, since it has been remarked by Bichat* and others that the *voluntary* muscles are thus excited, beyond comparison, much more than those which are not under the will. When persons are attacked with nervousness, one of the most singular symptoms is the erratic muscular motion; the fingers twitch irregularly, and the impulse shoots from part to part like the coursing of lightning. This, in effect, is what would result from electricity constantly accumulating and diffusing itself through multiplied conductors. Galvanism seems to act as a stimulus to the muscular fibre, and its effects are too manifest to require any further detail.

I shall now consider its agency in secretion.

Dr. Wilson Philip on this subject makes the following observation: "I cannot help regarding it as almost ascertained, that in those diseases in which the derangement is in the nervous power alone, where the sensorial functions are entire and the vessels healthy, and merely the power of secretion, which seems immediately to depend on the nervous system, is in fault, galvanism will often prove a valuable means of relief."† With this view he administered it in cases of habitual asthma, and, according to his own words, "it failed to give considerable relief only in about one tenth." It may, however, be supposed that such application only restored the muscular motions necessary for respiration without otherwise promoting the involved se-

* Treatise on Life.

† Philos. Trans. for 1817.

cretions. In other experiments, related by the same author,* digestion was accomplished by the galvanic influence; but, if we regard analogy from man, the extensive connection of the par vagum and fact that the cœliac plexus sends off branches to the stomach, render it uncertain whether the gastric secretion was *directly* effected by passing the galvanic influence through the par vagum or branch of the eighth pair. However, Dr. Philip as justly remarks, the "identity of galvanic electricity and nervous influence is established by these experiments." He divided the par vagum, which is distributed to the stomach and subservient to digestion, by incision in the necks of several rabbits. After the operation, it was found that the parsley, which they had previously eaten, remained in the stomach without alteration, and after a longer time the animals died apparently from suffocation. Other animals underwent a similar division of the par vagum; but the galvanic influence was applied to the portion *below* the division, or to that which was connected with the stomach. This was done by touching one wire to the divided end, and the other to a silver dish or plate, placed closely in contact with the skin of the animal opposite to its stomach. In this last case no difficulty of breathing took place, and after the galvanic influence had been continued twenty-six hours, the parsley was found to be as perfectly digested as that in healthy rabbits fed at the same time. Their stomach also gave the peculiar smell which those of healthy rabbits have during healthy digestion. Until a more definite knowledge is obtained concerning the destination of nerves connected with the stomach of a rabbit, these interesting experiments can only be considered as relating generally to the functions of the stomach, in-

* Inquiry into the Laws of Vital Functions.

cluding its muscular motions, (which seem much more considerable in herbiverous than carniverous animals,*) as well as its office of secretion, &c.

Experiments have been made upon blood and its components in order to imitate by galvanism the secreting process, but the range has hitherto been very limited. This is what might be expected when we consider how very unfavourable any arrangement must be. By subjecting blood to galvanism scarcely more than one product can result, since it is but reasonable to suppose that whatever compound is produced from any of its serum, the same must be produced from all of it. Probably, if any thing can promote a variety of products, it will be more likely to follow when that first formed from blood is taken and exposed by itself to the galvanic agency, repeating the same operation for all as they may occur.

Dr. Philip† states, that galvanism changes arterial blood to a dark venous colour, and prevents the formation of a coagulum, or at least dissolves it when formed. The same kind of blood at the same time, and under all similar circumstances, except that of galvanism, retained its florid colour, and coagulated. Galvanism also produces caloric, by its action upon *arterial* blood, but none when operating on *venous* blood. It is also remarked by the same writer, that *venous* blood suffers no visible alteration. Whether this be strictly correct or not, we should be inclined to suppose that arterial blood has much more matter to undergo changes than that found in veins ; and any such analogy between the galvanic and nervous agency is of the utmost importance to be known. When we consider their obvious similarity we feel inclined to illustrate one by the other. May it not, therefore, be supposed, that the gal-

* J. Bell's Anat. vol. 3.

† Inquiry into the Vital Functions.

vanic influence in the body over arterial blood, during the time of secretion, impoverished it agreeable to the galvanic analysis, giving out caloric, as Mr. Philip has shown it does, and changing its colour from florid to a dark one, leaving it thus characterized to enter the veins? The resemblance is certainly close, for, according to these experiments, galvanism could effect no *more* changes on the venous blood. It is to be observed, however, that Sir Everard Home, in his paper, entitled "Hints on the subject of animal secretions,"* details changes effected by galvanism or venous blood. Some of these I shall now mention. They were performed by Mr. William Brande.

He immersed the conductors of a four-inch double plate battery, into four ounces of fresh drawn *venous* blood, keeping up its natural temperature all the time. The bath was composed of a very weak solution of muriatic acid. The galvanic influence seemed to cease at the termination of a quarter of an hour. When examined, "the blood which had surrounded the negative wire, was of a deep red colour and extremely alcaline; that surrounding the positive wire, was slightly acid, and of a brighter hue. In this experiment, the coagulation of the blood was not materially affected by the electrical power alluded to." Dr. Philip, states, that venous blood undergoes no visible change; but Brande observed, that its colour became brighter. Hare, in his work on the stomach, mentions that electricity prevents the blood from coagulating after death; in the foregoing experiment, as well as in another performed by Mr. Brande on the venous blood of a deer *pithed* for the express purpose of preventing coagulation, we find that this property of blood manifested itself,

* Philos. Trans. for 1809.

although under the influence of galvanism. There is this difference however, that Hare alludes to a *shock* powerfully and rapidly pervading the system, as when struck by lightning, whereas the blood in Mr. Brande's experiments was exposed to a *current;* so that the fluid might by the latter mode manifest its property *previous* to any extensive changes.

One of the most interesting discoveries, by transmitting galvanism through the animal fluids, is that they all contain *albumen* which is *soluble*, when united to an *alkali*, and that their *coagulation* depends upon that union being destroyed. Mr. Brande in his paper on *albumen*,* has examined this property in several fluids; and finds that a very small galvanic power is sufficient to effect a perfect coagulation at the negative pole, even where the *albumen* is diluted with so large a quantity of water as not to be detected by the usual tests. By the experiments mentioned in Sir Everard Home's paper, before alluded to, it appears that galvanism has the power of separating *albumen* from the blood, or its serum; by one degree of power it is separated in a *solid* form, and by a less degree, in a *fluid* form. Hence then, there seems reasonable ground for presuming that this agent is extensively employed in producing the different animal solids and fluids from the blood, since according to Mr. Hachett's experiments, *albumen* is the principal material of which animal bodies are composed.† Mr. Home, remarks "that the structure of the nerves may fit them to have a low electrical power, which can be employed for that purpose, and as such low powers are not influenced by imperfect conductors, as animal fluids, the nerves will not be robbed of their electricity by surround-

*Philos. Trans. for 1809.

†Philos. Trans. for 1800.

ing parts." We have also noticed that a low power is best adapted for effecting the separation of *albumen.* This power will even be effectual when the most delicate electrometer is incapable of affording the least indication.* I have already remarked, that animated matter is occasionally formed where nothing like a nervous structure has been detected; (see commencement of this section;) there are instances also, when this structure seems too minute and imperfect, to perform such a function. All embryos are of this nature. In eggs the evanescent structure can hardly be supposed to work all the diversity of animated compounds, which are found to accumulate so very rapidly. Its condition is isolated, and without any more maternal assistance than can be obtained from a common baking oven; we find moreover, that the vital action is for a long time confined to a mere speck. The condition of embryos matured in the womb is scarcely better; they all have a rapid secretion of animated matter, while their most favourable connexion with the mother seems merely for the purpose of affording blood. Even if we suppose (as is most probable) that this blood does not circulate through both, but that the mother affords *nutriment* which enters elaborated into the fœtal circulation,† still all the peculiar products constituting true secretion must be effected, exclusively in the embryo. Plants of the most perfect nature are not supposed to have nerves; how much less reason, then, must there be for denying the existence of such a system in the circumscribed seed? yet the energy of an acorn sends forth the gigantic oak. We find the secreting power as prominent in the millet seed as in the garden bean, and limits far below the microsco-

* Mr. Home's paper on secretion.

† Chapman on fœtal circulation.

pic power, include hundreds of such systems. When we consider these facts, we must come to the conclusion, not only that secretions whether animated or not, can occur without a nervous structure, but that in the early stages of corporeal existence, there is a universal and diffusable agent employed for its advancement. Two reasons in particular induce us to consider this agent as electricity or galvanism. It is qualified to produce compounds of the most varied kind, and its supply is constant throughout nature; open to the minutest assemblage of organized substances, *without requiring any vital action on their part.* Dr. Philip, in his work on vital functions, suggests the agency of galvanism at such times. "If the nervous influence be galvanism," he remarks, "there may be some apparatus in the uterine system for collecting and applying this agent, which is every where diffused, till the brain and spinal marrow can perform their functions; and which may continue to supply their place where they never exist. We have seen that galvanism is capable of performing all the functions of the nervous system, properly so called. In combination with the powers of circulation, it can, therefore, perform all the functions essential to the life of the perfect animal, except respiration, for which, we have seen the sensorial power (residing almost entirely in the brain) is necessary." Elsewhere this writer continues: "we must regard the rudiments of life as confined to the circulation, from which, by the power of galvanism collected by some means *external* to the fœtus, all other parts are gradually evolved; till *within* the fœtus itself, a galvanic apparatus of sufficient power for the performance of the nervous functions is produced."* However we

* Page 242.

may revolt from terms and expressions which give the vital functions the appearance of depending upon combinations, which we can only accomplish by mechanism; we should always recollect that the principle is distinct from the workmanship; and, I must confess, I am aware of no illustration so apt on the present occasion as galvanism; no matter whether the womb be the apparatus or the embryo, or, indeed, the universe itself.

LIGHT.

The agency of this principle over the vital functions, and of course over the animated productions, is in a number of instances very obvious and important. It is probable, however, that its extensive influence depends upon its being a compound of two of the most active ones before mentioned. The solar light is the form alluded to in the present consideration; and we learn from the prismatic analysis, that the sunbeam is composed of rays of *colour, heat, and electricity.* The first does not seem capable of effecting chemical changes, and the two latter have already been noticed. But as the action of sunshine is very remarkable, and as, in the present state of knowledge, it is impossible to explain its peculiarities by the properties of any constituent alone, I have assigned a separate consideration for the agency of life.

Sir Humphry Davy* remarks, that, "in general, in nature the effects of the solar rays are very compounded. Healthy vegetation depends upon the presence of the solar beams, or of light; and whilst the heat gives fluidity and mobility to the vegetable juices, chemical effects likewise are occasioned, oxygen is separated from them, and

* Elements of Chem. Philos.

inflammable compounds formed. Plants deprived of light become white, and contain an excess of saccharine and aqueous particles; and flowers owe the variety of their hues to the influence of the solar beams. Even animals require the presence of the rays of the sun; and their colours seem materially to depend upon the chemical influence of these rays. A comparison between the polar and tropical animals, and between the parts of their bodies exposed, and those not exposed to light, shows the correctness of this opinion." In the animal creation, brilliancy of colour and gaudy plumage belong to the tropical climates; more sombrous tints distinguish the polar inhabitants; and dull colours characterize nocturnal animals, and those who chiefly abide below the surface.* In detailing the properties of light on the living system, I shall be compelled to neglect all arrangement or connexion; the subject does not admit of it. The effects of light are moreover of such a general nature, that it will be impossible to point out its immediate agency in the production of animated substances. Indeed, there is reason to suppose that it has none, since their formation generally takes place *within* the corporeal system. But its importance in many of the functions conducive to such formations, cannot be overlooked. The action of light on animals is not so well understood as upon vegetables. We find that oviparous animals generally deposit their eggs or spawns, where they will be exposed to the sunshine. One great source of vitality resulting from this arrangement is the warmth induced. Indeed, we may suppose this to be the prominent advantage, since we find birds, as the ostrich, deposit their eggs in sand banks, which as well as the egg shell itself has the power of reflecting light; and in the night time the agency

* Brande's Chem.

of light seems withdrawn, whereas that of warmth still remains. Besides, the hen and other birds which set on their eggs so great a portion of time, must prevent the access of light, while at the same time they accumulate the range of temperature. In vegetables the advantange of sunshine is very manifest. Plants growing in hot houses will expose their leaves to the sunshine, although the quality of the circumambient air cannot be materially altered, since the light enters by glass casements; neither does its temperature require any farther increase. This appetence is in some instances very remarkable. Light acts beneficently upon the upper surface of leaves and hurtfully upon the under side. This at least applies to most plants. Whatever be their situation, either nailed up against a north or south wall, impending, or in a hot house, they will invariably turn to light the side of the leaf that (in a perpendicular position of the plant) is uppermost; even when by such motion less heat comes to them, as in a hot house. So great is this power, that though repeatedly checked by forcible retrograde motion, the leaves will constantly turn back again, until the plant becomes weak as it were by exertion. The misletoe and some others, both sides of whose leaves are alike in appearance; or the upright sword-shaped leaves, both sides of which seem to perform the same function with light, are indifferently exposed, and do not alter in consequence of any variation of the light, or of the position among the stem and branches. A familiar example of leaves following the sun and its beams, may be observed in a clover field. The *Helia-anthus anneas*, or sun flower, turns with its blossom all day to follow the sun; and at night, retraces the same course to meet him as he emerges, in the morning, from the east. Calandrini found that vine leaves turned to the light when *separated from the stem* and suspended by a fine thread.* This last observation seems to show, that the important agency of light, though constituting a vital phenomenon, is effected upon physical principles.

I shall now examine what are the changes effected. Priestley, in 1778, observed that plants, under certain circumstances, emitted oxygen gas.† Ingenhausz afterwards determined, that the *leaves* performed this function and only at such times as the sun's light shines full upon them. Thus it was found that when the leaves of a plant were made to pass under into a glass receiver, inverted and full of water, that the upper surfaces gave bubbles of oxygen gas, as long as the sun shone on them.‡ This effect seems to follow chiefly from the agency of light. Subsequent experiments proved, that it was not the water which became decomposed; since no bubbles appear when that fluid has been boiled; but that they depended upon *carbonic acid gas*, dissolved by the water, and that their number will be in proportion to the quantity of that gas.§ Hence then from these data we learn the agency of sunshine. Water is not decomposed to any extent, whereas oxygen gas is liberated, therefore the carbonic acid must. The plant retains one of the constituents (carbon) for its nourishment; while the other (oxygen) is set at liberty and rises in the bell. In the *dark* it is found that plants reverse this operation; that is, they give out carbon and absorb oxygen. But the extent at this time is very trifling. Otherwise the carbon taken in for nourishment during the day would be lost during night, (particularly in those sections of the earth where the night nearly equals the day,) and the plants ultimately decline. This result would be contrary to observation; and as it is, we perceive how plants, upon the

Smith's Botany. † On air. ‡ On vegetation. § Encyc. Method. Physiol.

whole, conduce to the general economy by subtracting carbon from the carbonic acid of the atmosphere, and replacing it by oxygen gas, which is so essential to the life of all animals. Sunlight has a very considerable deoxidizing power, as may be seen by exposing nitrate of silver to it for a short time. The salt will be decomposed, and this results in consequence of the light subtracting oxygen. But carbonic acid is not so easily decomposed by this single power, so that we may consider the above to be effected by two affinities, depending both upon the plant and light. The nature of the agency of light is shown by another experiment. When plants are exposed to hydrogen in the *dark*, they still remain green; though without this gas the absence of light would occasion that green to become a faded white colour.* Hydrogen gas has its most powerful affinity for oxygen; and the similarity of effects intimates that light also exerts the same kind of agency. From this experiment we might be led to suppose that the *green* colour depends in some manner upon the supply of carbon. We find that when the sun shines upon a plant carbon is readily obtained from atmospheric carbonic acid, and the colour becomes fresh and green. The presence of hydrogen is able to produce the same effect,† apparently, because it takes the oxygen of carbonic acid and leaves the carbon to unite to the plant. But in the dark no carbon is furnished, since there is no effectual agent present, and the plant loses its green colour, and fades to a whitish one. With these remarks I shall conclude the subject of light; since, as has before been observed the range of experiment is by far too limited to give much information upon the peculiarities of its agency.

* Smith's Botany. † Thompson's Chem. vol. 4.

ATMOSPHERIC AIR. (*Oxygen.*)

It is well known that the vital functions cannot long continue without the assistance of this air. It follows, therefore, that the formation of animated matter absolutely depends upon it or some other possessed of similar properties. It will not, therefore, be necessary to dwell long on this point; as the nature of its agency is of most importance. The experiments of Ray, Boyle, Muschenbroeck, and Boerhaave, all prove, beyond a doubt, that no plant vegetates in the vacuum of the air pump. It follows, therefore, that no seed will germinate unless atmospherical air, or some air having similar properties, have access to it; and it is for this reason that seeds will not germinate at a certain depth below the surface of the earth.* Guided by similar phenomena, the agriculturist finds that ploughing the soil is the surest way to destroy weeds and grasses; by which process the sod is turned over on them, and they become hid from the air in consequence of being hid in the furrow. It is now determined that it is the *oxygen* in atmospheric air which is of such importance; and that no seed will germinate in any other gas unless mixed with it. An experiment of Mr. Humboldt corroborates this very beautifully. This gentleman found that seeds vegetate more rapidly when steeped in a solution of chlorine; and it is the distinguished property of this substance to liberate *oxygen* by decomposing water. At Vienna, seeds which had been long kept, and which had constantly refused to germinate, grew readily when treated with it.† In the commencement of germination, if under favourable circumstances, carbonic acid is given off *for a*

* Ann. de Chim. iii. 57. † Thompson's Chem. vol. 4.

time, even when no oxygen gas is present. This, therefore, seems to result from an internal chemical action converting the farrinaceous matter of the cotyledons into saccharine and other nutritive matter. We see a similar phenomenon in the malting of grain. It seems, from experiment, that the water at such times is not decomposed, since neither oxygen nor hydrogen is liberated. But when the cotyledons have afforded their substance for support, the presence of oxygen becomes absolutely necessary; and as much carbonic acid (in bulk) is found as there is oxygen. This seems nearly all the use of oxygen gas at such times, because as the carbonic acid is just sufficient to require the whole quantity, none can be imbibed by the seeds. They, on the contrary, by such a process, lose carbon. Saussure determined that wheat and barley consumed oxygen in this manner between $\frac{1}{1000}$ and $\frac{1}{2000}$ of their weight; whereas beans required as much as $\frac{1}{100}$. Hence we see plainly that the quantity varies to a great extent according to the kind of seed. In these instances beans seem to require, at least, ten times as much oxygen as wheat and barley. A comparison of the experiments here detailed, with those mentioned when treating of light, point out a singular difference between the economy of a seed and that of a plant. The former (seed) seems to require the *emission* of carbonic acid, while the latter decomposes carbonic acid and *retains* its carbon. It is true they are under very different circumstances, since the plant effects these changes by the agency of light, whereas the seed is deprived of it. It is true, also, that plants themselves, when in the shade, seem to emit carbonic acid.* But under the circumstances most advantageous to each this difference evidently exists. It

* Ingenhausz on Vegetation.

has been shown that plants cannot thrive without oxygen; and Saussure, in his researches on vegetation, discovered that in the day time they give it out, (chiefly taken from the carbonic acid which is absorbed by them for the purpose of subtracting its carbon,) and in the night they take in a fresh supply. It would be useless to detail all such peculiarities; those already noticed are sufficient to show the general agency of oxygen gas or atmospheric air; and almost all the important facts on this subject may be found amply noticed by Dr. Thompson, in his system of chemistry, vol. 4.

The presence of oxygen gas, *after* respiration has commenced, is justly considered as indispensable; but its utility during all the previous changes of animal existence, is as yet very much overlooked. I think there can be no doubt but that one general principle governs both vegetable and animal formation, and that whenever such operations take place, whether in the adult or embryo, the same agents are directly or indirectly employed. Dr. Ewell,* made experiments which show the importance of oxygen gas at this early period of animal existence. He ascertained, that the semen of man owes its fluidity to oxygen; or rather that it absorbs this gas, and then becomes fluid. He remarks that "after making several experiments, and reflecting on the subject, he is convinced that the presence of pure vital air, or oxygen gas, is necessary to give the *first* animation to the embryo formed in the uterus. That it is only after this union, with a little oxygen, that the embryo is enabled to receive nutriment from the mother, and that, consequently, coition will always be unfruitful unless it takes place in pure air." Whatever may be the agency of oxygen gas upon the embryo in the womb, it is manifest that

* Letters on Generation, Med. Repos. No. 38.

its supply, *per vaginam*, must be very limited. Dr. Ewell, states another of his experiments, which may be considered, however, as relating more to the changes necessary for nourishment, than as proving the nature of incipient animation. "Two frogs *engaged* in copulation, were taken and *held in vessels* containing pure distilled water; one vessel of water was impregnated with nitrogen gas, another with carbonic acid gas, a third with atmospheric air, and a fourth with oxygen gas. In each of these, the frogs deposited their filaments which was carefully attended to, for several days. It was found that only the filaments in the vessels containing oxygen and atmospheric air, had the least appearance of tadpoles." Other facts are stated, by Dr. Ewell, appertaining to propagation. They may be seen in his letter to Dr. Miller.* Bird's eggs are constructed so as to be supplied with atmospheric air or its constituent oxygen gas. They have all at the but or large end a pouch called the folliculus æris, for the purpose of containing the air. The vitellus or yolk, as appears by the hen's egg, is so poised by thin menbranes, that the cicatricula (very near which the *functum saliens*, or first point of animation is observed) may always face upwards. This is effected by the organization, which makes that portion of the vitellus, which is *opposite* the cicatricula and outside the line of suspension, the heaviest; and it has two prominent advantages. It always keeps the neighbourhood of the *functum saliens* (in every position of the egg) *nearest* to the two great chemical agents, *caloric* and *vital air*. The first is furnished by the hen bird, and the last by the follicle or air bag. Whatever be the shape or kind of egg, this arrangement will occasion such approximation; generally the air is collected in the but, because this end is the highest. During incubation

*Med. Repos. No. 38.

there is a still closer approach of the vitellus to the folliculus æris. It is not necessary to attribute this phenomenon to a vital power; since it takes place in consequence of chemical changes rendering the yolk specifically *lighter.* Indeed, it extends the truth that nature makes a liberal use of her physical laws even in the very foundation of life; and it is even proved that when the egg is kept upright on its but, the vitellus will rise to the point, and thus leave the follicule.* By the natural position, however, it is manifest, that though still guided by the same laws they must approach each other.

Dr. Paris, in his memoir on the physiology of the egg,† gives the following description. "The external shell and the internal membrane with which it is lined, constitute the varieties of the folliculus æris; its extent in the recent egg is extremely small, and before its exclusion from the uterus, it does not appear to exist. It would seem to commence at the moment the egg is deposited by the bird. A small portion of the watery contents of the egg transpire through the shell, and the air then rushes through the obtuse end, and inflates the follicule," &c. "Its size and subsequent increase are to be explained upon the same principle; which they establish an important relation between the diminution of the bulk, of the ovular contents and the extent of this preumatic apparatus. During the progress of incubation, it is dilated to a very considerable magnitude." A few days after incubation, blood vessels are observed to "extend and multiply their ramifications on the yolk and white, by which, the blood is exposed to the action of the air in the follicle, oxygenated and returned to the embryon." This use, Dr. Paris re-

* Barr's Buffon, vol. 3. page 24.

† Ann. Philos. for 1821.

marks, is manifested by the position of the blood vessels, as well as by the air itself, which, before incubation, is atmospheric, but which afterwards becomes contaminated with *carbonic acid gas.* The increase which this air at the but of a hen's egg obtains by incubation, is, according to Dr. Paris, as nearly ten to one. Whatever obstructs the inflation of this follicle and the renewal of its air destroys the embryo. The experiments of Reaumur offer abundant proof of this truth. In his attempts to develope the egg by the heat of dung, they, for a long time, failed, owing as the subsequently discovered, to the impurity of the atmosphere. He also varnished eggs, so as to prevent the access of air; and found that when such were placed under the hen, they invariably perished. Spallanzani instituted many experiments with the same view. "I have often," says he, "placed the eggs of terrestrial and aquatic insects under the receiver of an air pump; but none ever hatched in this situation, although in every other respect in a condition to do so." Boerhave also remarks, that "*ovula quorum cunque insectorum, in vitris accurate clausis, non producunt.*" It is a fact well known in the farm yard, that turkeys frequently destroy or smother their eggs by a too constant and assiduous attention.

Dr. Paris then proceeds to notice that the air follicule may also have a secondary office to perform, namely, that of producing by its air a part of those necessary chemical changes which the albumen and vitellus are found to undergo. It will not be necessary to extend this inquiry; we see plainly the importance of oxygen gas, or atmospheric air for all kinds of embryos; and the animal as well as vegetable one seems to require the supply for the purpose of getting rid of *carbon.* The *adult* animal still displays the same economy; but plants seem to give out carbon only in the night or shade, and then in exceedingly small quantity.* When treating of respiration as a part of the process of sanguification, I shall take up the consideration of oxygen; also, subsequently when examining irritability as a property of animated matter. For the present it will be sufficient to remark, that oxygen gas is intimately concerned in every vital function, both animal and vegetable, wherever assimilation or secretion is performed.

AGENTS IN GENERAL.

I have been led to include atmospheric air among chemical agents; because its presence, which is almost universal, always promotes changes of composition. But upon an examination it will be perceived that its influence depends merely upon presenting a substance, (oxygen) which has a strong chemical affinity for most other organic substances. It certainly has no power of itself to dispose bodies to union; which is the strict signification of an agent. On the contrary, it may be considered in the very opposite point of view; for it is evident, that if the atmospheric pressure were taken off from all bodies there would be more æriform states, and therefore more chemical combinations. In noticing the vital function, we are often led to consider bodies as agents, when in truth their influence depends upon presenting materials with strong chemical affinities. The gastric juice is most generally called an agent; but if it is at all so, it must depend upon being a solvent, or upon possessing some of those mentioned pre-

* Thompson's Chem. vol. iv. Vegetation.

viously to atmospheric air. So also we might regard exercise, appetite, disease or violent injuries, as agents, since they all predispose the body to a new series of chemical changes. Guided by such considerations, it is evident that the number of agents would be unreasonably and infinitely extended. I shall therefore pass over their consideration, and treat of alteratives, which are the most notable of the kind.

ALTERATIVES.

By this term, I mean all such substances as have the power of producing an *alteration* in the irritable action of animated matter. There is no name expressive of such a class of bodies, unless it be this one. I shall not, therefore, dwell on its merits, but proceed with its present application. Alteratives are either mechanical or chemical; but the nature of my subject leads me to the consideration of the latter. I must remark, however, that the former kind act a highly important part in the animated body. All distensions of the heart, womb, bladder, and other viscera, appear of this nature. Mechanical alteratives, by their size, figure, or weight, may lead almost directly to chemical decomposition.

Chemical alteratives consist of such bodies as affect irritability by their peculiarity of *composition*. Arsenious acid (white arsenic) will illustrate the distinction. By its weight, size, or irregularity of shape, it is always, in the first instance, a *mechanical* alterative; but, by its qualities of composition, which are evidently unconnected with the foregoing properties, it acts as a *chemical* alterative.

Chemical alteratives are divided into *sedatives* and *stimuli*. The former are supposed always to diminish the extent of irritable action, and the latter to augment it. This distinction arises from their ultimate effects; but the method by which these are brought about, leads to another subdivision of both. They may alter the amount of irritability, by acting either on the *composition* (in the chemical sense) or on the structure. As agents, it is not necessary that they should always effect chemical changes. Indeed, by doing so they very frequently prove injurious. The influence of such substances as do not *sensibly* change the *composition* of animated matter, is extremely obscure. Many have accounted for it, by supposing, that physical properties were displayed by the constituting particles; hence arose the terms *sharp*, *dull*, or *rough* taste. When we consider, that every body has a *peculiar* taste, no matter what its composition may be, and that the effect of *tasting* does not seem to alter such chemical composition, we might be lead to suppose, that such properties depend upon some configuration characterising the smallest sensible particles. But this explanation is, at present, generally abandoned, for several reasons. Either the properties of astringents or antispasmodics must be in opposition to those which we should expect to follow from the above explanation. If it be supposed that atomic *figure* can *contract* the irritable fibre, then it will be hardly possible to suppose that the same can produce a *relaxation*. We know, moreover, that such properties result from the chemical composition, and that the body possessed of them never loses them by any mechanical change. Dr. Park* observes, that " the various kinds and degrees of sensation which arise from the application of different substances to our organs may be referred to their perculiar modes of

* On the Laws of Sensation, Journal of Sciences and Arts, No. 2.

action; and, accordingly, they are as various as the nature of the substances." This gentleman considers, that sensations are produced by chemical agents, and remarks, that they "are more durable in their impression, as they are dissolved in the fluids on the sentient surface, and require more time for the changes they produce, to be again obliterated; and, accordingly, until this has been effected, the organ may be considered as having its susceptibility for that particular impression partially suspended. Or, the substances applied, no longer producing the same *changes*, no longer excites the same sensation. Thus, substances kept long applied to our organs of taste, lose their power of exciting sensible impressions; as, wine, long held in the mouth, loses the flavour peculiar to it, and if several kinds of wine be tasted in quick succession, it soon becomes difficult or impossible to distinguish them." I confess, when these effects are confined to a short space of time, it is impossible to perceive any thing sufficiently definite to be considered chemical; but, by extending the review, there seems reason for supporting the opinion. Nerves are so extremely irritable, that the most limited and evanescent changes of structure may cause sensation. We know, for instance, that alcohol has the property of coagulating albumen in the animal fluids, by uniting to the alkali which renders it soluble.* This is a perfect decomposition. When flesh, or almost any animal solid, is steeped in alcohol, the albumen coagulates, and forms those flakes which render the fluid turbid, and turns the whole substance, after some time, into a *white* mass. Now, it can readily be supposed, that such a change which subtracts both the *alkali* and *albumen* from the substance of an ir-

* Brande's Paper, Phil. Trans. for 1809.

ritable nerve, will, at its commencement, be able to excite *sensation*. All the alteratives need not act precisely by this decomposition; but, the instance will show, that they may occasion changes capable of altering the extent of irritability. Besides, we should recollect, that such substances, by acting only on a *single* constituent, may prove very effectual without our being able to perceive the least evidence. Escharotics are known to destroy nearly the *whole* texture, as well as composition, and, therefore, we feel less hesitation in asserting that the change is chemical. Many of these substances produce similar effects on the dead and living matter; and, in such cases, we have a direct proof of their nature. Astringents and antiseptics are of this kind. The agency of the first is not distinctly understood; but we know that it does not depend upon vitality, since the same takes place with the dead fibre. Antiseptics, on the other hand, must act chemically, during life, on the putrid portion, in order to change its fetid smell, and therefore we may extend its power over the others which are nearly in the same state; particularly since we find, that it checks or destroys their tendency. Even light, which is a stimulus to the optic nerve, and which is known to convey with itself, through the dense texture of glass prism, its *caloric* and *electricity*, may, when it enters the eye, occasion a tendency to decomposition, or its incipient form. Herschel, in making his observations on the sun, found that the irritation proceeded from the red rays, which are known to produce *heat* in the greatest degree; and the experiments of Mr. Brande (before noticed) show, that a very small power of electricity is capable of affecting albumen. We need not suppose that such incipient changes would be inconsistent with the permanent character of irritability; the same power which removes the nervous matter after its inevitable and incessant waste, without our being conscious of the change, can provide for both cases. When we consider the structure of a nerve, we will be aware of the number of variations to which it is liable. The true medullary filaments are surrounded by a vascular texture which follows closely in contact, through all their irregularity, and is replete with blood vessels analogous to the pia mater, then this is cased within two membranous coats exteriorly. It is evident, that whatever substance causes these membranes to contract, will diminish the circulation of blood through the nerve; for whether the medullary matter is in mass, and incapable of contraction, or as Mr. J. Bell* supposed, in zig-zag filaments, or, as has lately appeared, in globules, still compression or elongation of the whole nerve must *shorten* its diameter, and they crowd the blood vessels. Now, as Mr. Bell remarks, "pressure by impeding the circulation of the blood in these vessels, soon effects *the sensibility* of the nerve; for, however the function of the nerve may directly result from its organization, yet the life and vital energy is received from the blood in the circulation through it, and cannot long continue if that blood be interrupted in its course." Such a substance as has the least power to occasion membranous contraction, will, therefore, have a tendency to lessen sensibility, or in other words, to act as a *sedative;* though before such contraction takes place, its presence may stimulate or increase sensation. Such seems the nature of cold applications, and, perhaps, such sedatives as opium, which have been supposed in the first instance to stimulate. When we immerse a hand in very cold water, at first the sensation

* Anat. vol. 2.

amounts to pain, but after a while this feeling completely subsides, or is at least lessened very nearly to that extent; yet this is not owing to the subtraction of caloric, for if the other hand be immersed in water of the *same* temperature as the first at the time sensation ceased, we will again be effected with a feeling of coldness. Cold air contracts the skin when it occasions numbness, and therefore may effect the membranous coats of nerves in the same way. But it is useless to be throwing away even conjectures; the subject is certainly a very unsatisfactory one, and the names by which we indicate the bodies under consideration may be the least likely to throw light on their true nature. If relaxation of habit leads to an excess of sensibility, then astringents, producing an opposite action, may appear to have some claims for the character of a sedative. There is reason to suppose that the irritability, or, as it is generally called, sensibility of a nerve is intimately connected with the degree of circulation through its substance; yet the principle upon which its existence, as well as transmission depends, is so completely obscure as to warrant our being satisfied with the knowledge of the mere fact. I shall, therefore, pass over all these substances which, acting as alteratives, either to stimulate or allay the irritable fibre. It is sufficient to remark, that if these effects do not depend upon chemical action, they certainly do upon qualities immediately and exclusively resulting from the chemical composition of bodies.

The next subject to be considered is the formation of animated matter.

THIRD DIVISION.

PRODUCTION OF ANIMATED MATTER.

SANGUIFICATION.

When we consider the complex structure of the living body, as well as the routine of motions constituting its functions, we cannot be surprised at its continual decay. Admonished by appetite, all animals endowed with the power of locomotion seek nourishment, which by an operation of constitutional changes, obtains the power of vitality, and takes the place of parts no longer fit for vital functions. Necessity does not always however dictate hunger or thirst; like sleep these seem to follow some laws of muscular motion. Man generally feels his periodical return of appetite every three or four hours; (excluding the time of sleep, where there is little or no active sensation;) this is the term occupied by the *gastric* operation, and certainly does not imply any *corporeal* necessity, since we know that a fresh supply has passed on to minister to its wants. But it shows, beside the force of habit, that *incessant* support is requisite for our consumptive fabric; all its laws are selfish as well as imperious. Whatever may be the form of habit, we find that the effect for which it is intended, always is more perfect when it occurs with regularity. Hence the uniform return of appetite always tends to give better sustenance than when more nutricious food is taken at short and irregular periods. In the animal functions there are two principal causes of destruction—motion and chemical affinity. The first is always augmented by health and muscular exercise, and gives rise to the necessity of more food at one time than another; chemical affinity, on the contrary, is generally speaking a permanent cause, since the matter, which always regulates its extent, is similar from one period to another. Plants have no locomotion; so that they require a less amount of food, as well as a more uniform supply. Assimilation with them is nearly one uninterrupted process, until circulation ceases in the autumn.

In the following remarks I shall confine myself to the assimilating operations of mankind chiefly; and shall divide the subject into *the formation* of *blood* and the formation of the *animated structure.*

DIGESTION.

As all the corporeal structure proceeds from the blood, we cannot conceive the long continuance of life without this fluid, or something analogous to it. Plants have a sap which is capable of furnishing all the solid parts during summer; and at the opening of spring (during which time it is little else than water) it meets with nutriment deposited in the autumn, so as to become enriched early in its ascension. Animals which are called cold blooded, have this fluid with all its qualities except colour. In short, we find its importance manifested in every form and stage of life.

The source of blood in the embryo is very little understood. But the most probable opinion seems to be that there is no continuity of circulation from the maternal vessels.* We see this fact illustrated in eggs and seeds. The chick must have its system independent of the hen; consequently, we must suppose that it fabricates its own

* Dr. Chapman on Fœtal Circulation.

blood; the same, therefore, may take place in the uterine embryo. How this is effected leads to a very obscure but interesting inquiry. In the chick the blood is observed long before the solid structure, and therefore can hardly be supposed to have its origin from any extent of organic functions. We certainly form an overrated opinion of the sanguiferous process when we confine our views of it to that performed by the adult. Even in the fœtal state we must cut off *digestion* and *respiration*, and in the early stages of existence the agency of vascular connection. How much less reason, then, is there for supposing a vital origin of blood at the time when it is confined to the punctum saliens or *irritated* speck in the yolk of a hen's egg. If on the other hand we consider the *materials* as well as the vessels of a limited circulation, as being furnished by the mother, then the blood may originate from the external application of chemical agents, as heat, light, &c.; influenced by these, the male semen may also combine in the formation of blood. It is as rational to suppose that the embryo should be irritable as any other part of the female body which results from assimilated nutriment. But I shall abandon a subject which is so manifestly conjectural, and proceed to notice the process by which blood is formed in the adult system, and which will be found to give strong evidence of having a chemical origin. The food is masticated in the mouth, mixed with the saliva, and transferred, by swallowing, into the stomach; here it undergoes changes of composition and becomes *chyme*. This chyme passes through the stomach into the duodenum, where it meets with the bile and pancreatic juice, and by their chemical action becomes *chyle* and *excrement*. As these substances proceed through the intestines they pass by a system of absorbents, called lacteals, which gradually take off the chyle, while the excrement, unfit for nutriment from the beginning, or rendered so in consequence of the changes of digestion, continues to proceed through the intestines, and is finally evacuated. The lacteals, by their ramifications, convey the chyle into the common reservoir of all absorbents, called the thoracic duct; this duct opens (in man) into the angle formed by the union of the left subclavian and jugular veins; and thus the chyle enters the blood. It is then carried by the circulation to the lungs, where it meets with changes which convert it into *red*, and, apparently, *perfect* blood. From this outline we perceive three important changes; namely, from food to chyme, from chyme to chyle and excrement, and from chyle to blood. These are certainly the leading ones; but there are various others which are not so notable. We shall now notice the foregoing more particularly.

It has been contended by many physiologists, that digestion begins in the mouth. In some animals, whose appetite seems too great for the capacity of their stomach, we find that the portions which they swallow (but which are unable to enter lower than the bottom of the œsophagus) become digested; it is probable that the saliva then performs the principal operation, since it possesses so strong an affinity for oxygen as to become charged with it before it mixes with the food. But whether this opinion be correct matters very little; we know it acts as a solvent, and all changes which it could produce previous to entering the stomach must be very limited. The quantity of saliva secreted during the ordinary meal of a healthy man has been estimated at six ounces.

It has been concluded, from the experiments of Stevens, Reaumur, Spallanzani, Scopoli, Brugnatelli, Carimini, &c., that the formation of *chyme* is brought about by the action of a particular liquid secreted by the stomach, and therefore called the *gastric juice.* It seems that this operation depends upon a fluid; for when food is shut up close in balls, and swallowed, no important change takes place; but when these balls have holes, the food becomes chyme. The process terminates in three or four hours. The case of the woman in the clinical ward of La Charité, and who had a fistulous opening through her stomach, illustrates the regularity of this period. In common description it has been said, that the gastric juice converts *all* substances into chyme, and that this chyme is a *homogenous* substance. We are to consider that such a definition of the power peculiar to gastric juice, is far too vague and extensive.

When the usual food has been suddenly laid aside for other of a different kind, we know that bad digestion often takes place. Dr. Adam's experiments go to prove that the gastric juice is always the same;* and therefore we may consider the deficiency to arise from the properties alone. We know, further, that the husks of grain, woody fibres, and a thousand other substances in food, never become chyme, but exist as mixtures. This fact shows, that chyme is not a homogenous mass; but that it is made up by a compound resulting from the decomposition of substances which undergo changes readily, as well as of such other parts whose texture and composition are too powerfully constituted. Richerand justly remarks, that a substance to be fit for our nourishment should be capable of decomposition and fermentation; or, in other words, capable of undergoing an inward and spontaneous change,

* On Morbid Poisons.

so that its elements and relations may be altered.* This necessity entitles us to consider that digestion is of a chemical nature. Where would be the *necessity* of this tendency to chemical changes, if they were to be opposed by the vital influence? If the chyme were always to be of a *similar* composition, it would not be in opposition to the opinion. The ultimate constituents of all animal food are always the same, and but three or four in number: carbon, hydrogen, nitrogen and oxygen; when of a vegetable nature, the only difference will be in the absence of nitrogen. This is not all; the *proximate principles* of food resemble each other so much that an analysis can, in some instances, scarcely make out the difference; and those which are entirely without this general resemblance, pass off to constitute the *fœces*. Thus, a dog cannot digest the whole bone; his gastric power cannot assimilate the phosphate of lime which differs from the gelatine in its chemical constituents, and not in texture, since mastication and the muscular motion of his stomach reduce both to an impalpable consistence. This process gives the appearance of assimilation to the whole mass; but when the gelatine, which is the truly digested constituent, becomes absorbed by the lacteals, we find the earthy salt unaltered, and constituting the excrement called *album grœcum*. I shall pass over the gastric juice itself, since all the methods hitherto made use of to procure it are not only objectionable themselves, but they have led to unsettled disputes about its properties. The resemblance that the chyme bears to a homogenous substance, and the facility with which all variety of food enters into such a constitution, have led physiologysts, in general, to deny that di-

* Physiology.

gestion is a chemical process; it shall, therefore, be my present object, to examine the solidity of this opinion.

In the first place, where shall we look for limited vital influence, if not in the *canals* and *cavities* of the body? Is it not absurd even to suppose any? As I have before remarked, this property depends upon *matter*, and no reason should induce us to suppose that it may exist where there is none. It follows, unequivocally, that where inanimate substances of a complex nature fill up, or are passing through such spaces, that their tendencies to decomposition will be as strong as any where else in nature under similar chemical advantages. The true *vital economy* is, therefore, in taking advantage of such tendency, by furnishing chemical agents which, by their affinity, shall give rise to the compounds observable throughout the body. Of such a nature seem the gastric and pancreatic juices, the bile, and a number of others.

The most inconceivable distinctions have been adopted to make the principles of life as little understood as possible. The gastric juice has been endowed with a vital influence;* but what can be more absurd, when we reflect, that this fluid while separated in the stomach and mixed with the food, must also be supposed to have intelligence of what is good or what is bad for the body at large? It is ridiculous to think of such an agent; the gastric juice *must* produce its effect, as all other substances do, by chemical or physical qualities in general. Surely the vital functions are wonderful enough by furnishing *this* fluid, rather than any other ineffectual one, without making all its agents conjurors. But it is begging the question, when no proof can be offered. Have we not abundant proof, that the vital power is nothing when unconnected

* J. Bell Anat. vol. 3. page 214.

with the general system? There is not a single part of the body, even the most highly endowed, which can when unconnected, either communicate the living power to an inanimate body in contact, or withstand by its own strength of vitality the tendency to decomposition. How then can we consistently suppose, that the gastric juice, which is sent from the living texture, can alone possess the power of making the food *resist* chemical changes, or of obtaining, without such changes, the vital property? We might as well maintain that the bile, pancreatic juice, and other agents for decomposition, operated by inherent vitality. The distinction is indeed, since the most important change seems to be effected by these fluids. On general principles, there should be as great an antichemical vitality in the intestines and bladder, as in the stomach; but such an opinion would be contradicted by the most superficial observation. Mr. John Bell, because he was informed that a cow can digest her secundines or membranes, gives up his faith in the chemical agency of the gastric juice: "This throws us back," he remarks, "from the simple idea which we should be apt to entertain of the nature of the change produced by digestion, viz. that it is chemical. For we see that the *nature* of the solvent thrown out from the stomach, and its chemical properties, may be changed by an alteration in the action of the coats of the stomach." It remains, however, to be proved that the *nature* of the gastric juice is changed; Dr. Adam's experiments show the contrary. And even if such were the case, it would only prove, what is already well known, that one body acts with more chemical energy than another. But surely we cannot overlook the fact, that the gastric juice is emitted, like the saliva and other secretions, by an action of the solid texture. There is nothing more strange in the gastric fluid being thrown into the stomach more profusely by the presence of one kind of food than another, than that the saliva should be secreted more plentifully by savoury meats than by a chip of wood. Until we are better acquainted with the peculiarity of stimuli, we cannot say that such is not the case, when the usual diet has been changed. But after all, is the digestion of meat by a cow or horse stranger than that by man, the dog or cat? Habit makes the same substance be secreted more profusely at one time than another, and the irritability of the organ itself is always intimately concerned; since less nutritious food may become suited to the stomach, and its bulk as well as indigestible constituents even promote the operation. By this principle gramnivorous animals may be brought to live on animal food; and after being accustomed to this their stomachs will become incapable of digesting vegetables, and *vice versa;* even man whose power seems most general from habit, may by living long on vegetable food be rendered unfit for the digestion of flesh. I am far from maintaining that this process is independent of the vital influence. Whatever may be the nature of such an existence, whether really dependent on physical properties or not, we must still consider its phenomena as vital. The object in view is to show that laws which have belonged to matter since creation are not destroyed by life; and that the nature of our conformation directs them by agents which they would obey any where else; just as we see a river still flowing through all its natural and artificial embankments. We must be aware, that even in the midst of the most vital substance, decomposition can take place from the presence of a chemical agent; no one surely can pretend that it is the vitality of that part itself which makes amends for those changes. The connexions with blood vessels, nerves, &c. accomplish this; principally from being themselves irritated by the injury. It is totally unsupported by analogy to give this multiplied power to the gastric juice, even though of an irritable nature; it is totally devested of connecting organs, as nerves, &c. Much less can we diffuse it through cavities; particularly when matter with the strongest tendency to decomposition, is passing through them; and some of which, as the intestines, are found not to be able to prevent the usual chemical changes of putrefaction, when there are no substances furnished with the power of causing a new play of affinities.

I shall now notice some further chemical parts of the process. The gastric juice is said to be antiseptic, and this has been considered by many as a proof of its vital agency. There is not, however, a single one of its characters so decidedly chemical as this; besides, it is no property of life that one *isolated* substance should protect another and prevent decay. The analogy is probably drawn from an injured limb recovering its strength; but, again, it must be repeated, that the limb does nothing but *receive* the changes. Its irritable structure prompts the action which propels the new supply; but cannot alone protect the limb. So it is with every detached production of the body, though endowed with the most delicate irritability, unless possessed also of an independent circulating system, its operation of defending itself, or any other body in contact, by that property, is no stronger than that of inanimate matter.

The operation in the stomach of rabbits, as stated by Dr. Wilson Philip,* shows, that digestion takes place on the

* On the Vital Functions.

surface of the food where it lies in contact with the stomach, which is the source of the gastric fluid. For this purpose we see the utility of a fact stated by that author, namely, that after a short time, these surfaces of food change, and are carried by muscular motion to the pyloric extremity, until the central portions are brought in contact with the stomach. There is also a property of the stomach, particularly that of a calf, whereby milk and the serum of blood are coagulated immediately.* This, very probably, acts an important part of digestion; but, if so, it must be by its chemical properties alone, since Dr. Young's experiments in particular show that the operation goes on as well out of the body. This gentleman found that *seven grains* of the inner coat of a calf's stomach, infused in water, gave a liquid which coagulated more than a *hundred ounces* of milk; that is to say, more than 6,857 times its own weight.† Is it, therefore, so remarkable, that with such an agent as this, the food should be made to enter into other chemical compounds than those of fermentation or putrefaction? As to its utility, our imperfect knowledge of coagulation prevents a decided opinion; it evidently separates the albumen of food with great readiness, and, therefore, may be the means employed to furnish that highly important material to the system without requiring its *reformation*. It is to be remarked, however, that other offices would have to combine; and there is no experimental foundation for the opinion. It need not now be urged as an objection to the chemical character of digestion, that, unless in disordered health, there is no complete fermentation or putrefaction. The very phenomena of dyspepsia show, that the *tendency* is

* Hunter's Animal Economy. † Thomson's Chem. vol. iv.

never extinct; and facts well established all go to prove, that the nature of the process consists not only in a series of active chemical changes, but in a muscular arrangement to discharge the food *before* its natural tendencies, even out of the body, could be developed. After undergoing *imposed* changes in the stomach, and remaining there only for the short space of three or four hours, it is evacuated into the duodenum, there *immediately* to undergo others. Now, where I would ask is the *time* or opportunity for *spontaneous* changes? Nay, beside these now mentioned, it can be shown, by another arrangement, that nature designs that they should occur as little as possible. Dr. Philip* states, that the food which is in the *pyloric* portion of the stomach is always most perfectly digested, and is *quite dry* in comparison to the *undigested* food at the cardiac extremity, which is mixed with a *large proportion of fluid.* What more obvious deduction can we draw from this singular fact than that the pyloric portion of food, since it has undergone all the imposed changes which should occur in the stomach, is rendered comparatively *dry*, in order to diminish its lasting tendency to *spontaneous* decomposition; while, on the other hand, that at the cardiac portion is mixed with *fluid* to promote more rapidly the action of the gastric juice, &c. I shall now, in a general manner, bring to view the circumstances which induce chemical action in the stomach; and by keeping in view the foregoing remarks, we will be enabled to conclude correctly as to their nature.

1st. The saliva is a fluid with a strong affinity for oxygen; the general agency of solution is also augmented by the gastric juice. The importance of this state of consis-

* Vital Functions.

tency has led to the axiom "corpora non agunt nisi sint soluta," and its truth has scarcely met with a contradiction. Our conformation bears testimony of its importance during digestion. Teeth, or something analogous, are always requisite to grind down the food. When these do not perform their office, the ill effects are manifest; very old persons without teeth, or such persons who eat in haste, or bolt their food, are generally troubled with indigestion.

2d. There is an elevation of temperature during digestion. This circumstance conduces to chemical action, whether it is furnished for the purpose, or exists as a consequent. Cold-blooded animals are known to digest much slower than hot-blooded ones; and Spallanzani has shown, that the gastric juice, at a temperature below seven degrees Reaumur, or about 48 degrees Fahrenheit, is no more effectual in softening or dissolving food, than plain water.* If we consider this elevation of temperature as a *consequent* of digestion, then there will be more reason for supposing that true chemical changes occasion it.

3d. The properties of such food, as have undergone perfect digestion, are completely changed, both as to taste, smell, and colour. These changes begin so soon that after the food has remained a few minutes in the stomach, they can be easily noticed. This fact, as Speer† justly remarks, shows that chemical action is the first to take place in the stomach, since no other power could have operated in so short a time.

4th. The digestion generally takes place best in such food as most readily undergoes chemical decomposition.

5th. The gastric juice acts on the stomach itself after life. Mr. Hunter long ago noticed this fact on the hu-

* Richerand's Physiol. † On the Stomach.

man stomach. (Phil. Trans. for 1772.) This gentleman supposed it necessary that the animal should be in health, immediately preceding death, in order that the secretion of the gastric juice may be natural, and capable of dissolving the dead stomach; but Mr. John Bell remarks, that he found the stomach of children, who had died after a long illness, digested by the secretion of the stomach.* Dr. Wilson Philip states that the gastric juice of rabbits can so completely digest its own stomach, after death, as to leave no trace of former structure. (Enquiry into the Vital Functions.) Now, it may be asked why the gastric juice does not produce the same effect during life, provided its agency is chemical? To this it may be answered, that like all other changes in the living body, even if it does take place, we may be so constituted as not to be aware of it. But the best reason seems to be that the living stomach is always covered with its peculiar fluids, which by interposition defend the living structure, and which must be thrown out on its surface by every irritating material. In the stomach there exists an abundance of what Mr. Bell calls the "general vascular secretion" mixed with its glandular secretions;† these must evidently be decomposed even before the organization, furnishing the gastric juice, can be acted upon; and during life such changes are prevented from extending by a constant absorption and fresh secretion. *After* life, this vascular secretion can only serve as a protection while it remains unaffected; but after decomposition takes place it even acts injuriously by the absence of *absorption*. The protecting effect of fluids, which apparently for this purpose cover the smallest fibres, may be noticed among fishes; where it is remarked that those which can throw out on

* Anat. vol. 3. † Anat. vol. 3.

their bodies the most of that thick mucous fluid which characterises all of them, more or less, can remain longest alive when exposed to the action of the air.

Now, does it not seem unreasonable to suppose that *all* these chemical agents should be crowded together in one process, and that the *most natural*, without that process being chemical? If only one were observable we might hesitate; but I cannot see how we can overlook the presence of so many. It has been said that gases should result from chemical changes in the stomach. This undoubtedly would be the case if the decomposition depended upon the internal action of the nutritious particles; provided, also, they remained a *sufficient time* under such circumstances, which is found not to be the case. It by no means follows that the same result should take place, where the decomposition is effected by *one* agent, as the gastric juice. But I shall show, that with all this arrangement the most unequivocal signs of spontaneous decomposition do actually exist in a limited degree. Dr. Prout, whose authority stands high on this subject, observes, that " a gaseous product is usually evolved" during the action of the gastric, pancreatic, and biliary fluids.* By other authorities it seems, also, that the gases formed through the alimentary canal (including the stomach) have a fixed ratio and relation to each other. " From the experiments of Magendie and Chevreul, it appears that the oxygen gas which *usually* exists in the stomach in a considerable proportion when compared with the other gases, gradually diminishes, and at last disappears as we proceed along the course of the alimentary canal; while at the same time the proportion of carbonic acid and hydrogen gas increases."† The following gives a view of their results.

* Ann. Philos. for 1819.

† Thompson's Chem. book 5.

	Oxyg.	Carb. acid	Hydrog.	Nitrog.	Carb. hyd.	
Stomach,	11 00	14 00	3 55	71 45	00 00	=100.
Cœcum,	00 00	12 50	7 40	67 58	12 50	
Rectum,	00 00	42 86	0 00	45 96	11 18	

In the small and large intestines these gases were also found to exist in variable and considerable quantities, but with less regularity. These gentlemen examined the bodies of four criminals executed in Paris, very soon after death. Their results may be seen more particularly in the Ann. de Chim. et Phys. ii. 292.

We learn from Dr. Prout's paper on sanguification,* before alluded to, that the chyme itself gives no traces of an albuminous principle; (in which term Dr. Prout includes the perfect albumen, fibrine and colouring principle of the blood;) but that its formation takes place in the duodenum, and some distance down in the intestines. The most important change must, therefore, take place after the chyme leaves the stomach, and unites to the bile and pancreatic juice.* This gentleman is of opinion, that the blood begins to be formed from the food, in all its parts, from the first moment of its entrance into the duodenum.

As to the action of the bile and pancreatic juice, little is distinctly known except their importance; though even this point has been questioned. Berzelius has shown that the bile becomes decomposed by its union with the chyme; and Dr. Prout, in his paper on sanguification, states, that he always found that the acidity of the chyme, *which was almost invariable*, became *neutralized* by its addition. Now, these facts show the importance of bile; notwithstanding the remark, that when the ductus communus choledicus is obstructed, no manifest deficiency of chyle is observable. Probably the truth would not be so favourable were the fact better established.

* Ann. Philos. for 1819.

† Thompson's Chem. book v.

I have but a few remarks to offer on the chyle. While in the intestines, or mouths of the lacteals, its true character is hardly perceptible; it undergoes coagulation very slowly and imperfectly, and does not assume a reddish colour when exposed to the air. Hence, Dr. Prout supposes, that it then contains a very small proportion only of a principle analogous to fibrine, "or at least this principle exists, as yet, in a very imperfect state, and no colouring matter." When the chyle is found in the thoracic duct, (where the absorbents empty their contents from the body at large,) it bears a close resemblance to blood, and seems only to differ in its colour. To a certain degree it also has the last quality; for its white particles become pinkish when exposed to the air.* This perfection of chyle, without any manifest progress, may result from a tendency to inward changes, first established in the duodenum and intestines. The absorption by lacteals seems, as Dr. Prout remarks, to be merely a mechanical process. One of the most singular phenomena that occur during the process of *vegetable* digestion, is the formation of nitrogen. The flesh and other parts of an animal confined altogether to this kind of food, contains nitrogen gas as a constituent, although vegetables are almost all without it. This is very singular, inasmuch as nitrogen has not yet been decomposed, while no doubt can be entertained but that it occurs from digestion. Its compound nature has been suspected, however, by several chemists, and Mr. Miers published a number of ingenious experiments in order to show that it is a compound of oxygen and hydrogen† Berzelius maintained that it is not a simple substance.‡ When we consider that it must have been produced by the pro-

* Prout. † Ann. Philos. iii. and iv. ‡ Ann. Philos. ii.

cess of digestion, we will form a better opinion of its nature by suspecting the correctness of our knowledge, or at least the deficiency of the means which are possessed to detect its composition. During the respiration of *nearly pure* oxygen gas, a portion of it disappears, and an equal bulk of *nitrogen* appears in its place. The substitution is greatest at the commencement, and amounts at an average to near 80 cubic inches. This curious fact was established by Messrs. Allen and Pepys, whose experiments on respiration were conducted on a very large scale. Yet, in the ordinary process, no nitrogen seems to be formed. So, also, when a mixture of 79 hydrogen, and 21 oxygen gas, is breathed, nitrogen appears among the products. The experiment seems to confirm Mr. Miers's idea not only of the compound nature of nitrogen, but of its constituents. Indeed, when we consider how *instantaneously* carbon unites to oxygen during respiration, we will be less surprised that hydrogen should also combine with oxygen, and form a compound not to be imitated easily in the laboratory.

RESPIRATION.

I shall finish this view of the sanguiferous process by continuing the remarks on respiration. It is remarkable that this process so universally imperious upon all kinds of animals, never has manifested more than two offices; that of giving colour and fibrine to the chyle, and that of subtracting carbon from the system. I cannot but think, that the extent of its importance is highly undervalued. All the labours of philosophers, for years past, have been concentrated in the few gases effected by respiration; and all the changes produced both on the chyle and blood, have been limited to the subtraction of carbon. It appears to me, that more important and definite knowledge would arise were the investigation confined to the blood itself, than to the external characters of respiration; the true changes must exist in the blood of the *pulmonary veins*, and more solid information might accrue, by comparing this with the blood of the *pulmonary arteries*, which is replete with the matter about to be changed. It is not so important to know, that carbon is given off as to know in what state such a change has left the circulating materials. We have yet to learn why it is, that carbon seems in such profusion and waste, whereas the oxygen, hydrogen, and nitrogen, never make their appearance as separate secretions. The supply of all is daily continued from the nutriment; and carbon is generally found in the compound secretions, as well as the others. This substance must result chiefly from the waste of all the organic texture, (since the chyle is but a trifling interference both from quantity and quality ;) what then becomes of the other constituents? the absorbents which take up one must take up all, if the decomposition be effectual, and convey them into the circulation ; yet here they have not been found in a *separate* state ; but if they form soluble combinations, the blood seems best adapted to display them. As it is, respiration consists in the evolution of carbon, and in the *negative* effect of giving the venous blood a florid colour, (since it is the absence of carbon which seems to cause this phenomenon.) During this process there is a separation of moisture, which arises principally from the substance of the lungs; experiments show that little or none of the atmospheric oxygen goes for its formation. Crawford has also determined that venous blood has less specific caloric than arterial blood, in the proportion of 8.9, to 10.3. and therefore, the latent caloric of the former, as it becomes liberated during respiration, enters into union with the arterial blood, as fast as it is formed, and thus leaves the lungs at their original temperature. During circulation, the arterial blood is gradually converted into venous; consequently, its specific caloric diminishes, and it must *give out* heat. This is the reason that the temperature of the extremities does not *diminish*, or that of the lungs *increase*. Dr. Davy has since proved, that Crawford's estimate is by far too high; since he found that the specific caloric of arterial blood is but 0.913, when that of other is 0.903. Dr. Crawford also adopted the theory of Dr. Black; by supposing that a great quantity of caloric is given out by the union of oxygen and carbon, which he considered sufficient, not only to carry off the newly formed water in the state of vapour, and to raise considerably the temperature of the air respired, but to support the temperature of the body. This has also met with a contradiction from the examination of Delaroche and Berard, who have shown that the specific caloric of oxygen and carbonic acid differ much less than Crawford supposed; that of the first being but 0.8848, when the last is 0.828. The theory of Dr. Crawford displays unusual elegance, but we must look elesewhere than on respiration to discover the true sources of animal heat. Chemical changes no doubt contribute largely, but they are not those in the lungs. Thus then, though unwillingly, we are obliged to curtail the function of respiration to its power of subtracting carbon. Its operation on the chyle is thus described by Dr. Thompson;* "It appears from the most accurate observations hitherto made, that neither chyle nor lymph contain fibrine, which forms a conspicuous part of the blood. This fibrine is employed to supply the waste of the muscles, the most active

* Chem. book 5.

parts of the body, and therefore in all probability requiring the most frequent supply. Nor can it be doubted that it is employed for other useful purposes. The quantity of fibrine in the blood, then, must be constantly diminishing, and therefore, new fibrine must be constantly formed. But the only substances out of which it can be formed are the chyle and lymph, neither of which contain it. There must, therefore, be a continual decomposition of the chyle and lymph going on in the blood vessels, and a continual new formation of fibrine. Other substances also, may be formed; but we are certain this *must* be formed there, because it does not exist previously. Now, one great end of respiration must undoubtedly be to assist this decomposition of chyle, and complete formation of blood. In what manner the chyle, or a part of it, is converted into fibrine, it is impossible to say; we are not sufficiently acquainted with the subject to be able to explain the process. But we can see, at least, that carbon must be abstracted from that part of the chyle which is to be converted into fibrine. Hence, as the process of blood making advances, there must be a greater and greater redundance of carbon in the liquid. Unless this redundance were removed, the process could not go on, and probably the whole would run into putrefaction. We may conclude, then, that one great use of respiration is to abstract this carbon, by forming with it carbonic acid. How this is performed, indeed, it is impossible at present to explain; but the fact is undoubted." Messrs. Allen and Pepys have shown, by their experiments, that the body of a healthy full-sized man, gives off daily, by respiration, an average of eleven troy ounces of solid carbon. This must evidently be infinitely more than what proceeds from chyle, since chyle is but an exceedingly small proportion of the food eaten. One year of such respiration would make a man give off from his lungs near 335 pounds troy of solid carbon, a weight which almost equals *twice* the body itself. Dr. Prout* has shown that the carbon they evolved is different in different periods of the day. At noon it is near its maximum, and at its minimum about midnight; and at morning twilight it begins to increase. This gentleman also found, that alcohol and all fermented liquors diminished the proportion, and likewise that when the constitution is affected by mercury the same takes place. Dr. Fyfe remarked the same phenomena, and observed further, that a course of nitric acid and vegetable diet produced the same effect.† Fishes require but little atmospheric air: it appears that a man consumes fifty thousand times as much oxygen gas as a trench.‡ Yet the presence of this principle is equally necessary for the existence of both and for all other animals. These are the principle facts of respiration; with which I shall close this subject. There is no function more purely chemical as far as it is at present understood; for a full and impartial detail I cannot refer to a better work than that of Dr. Bostock.

FOURTH DIVISION.

ASSIMILATION.

Before entering on this intricate consideration, it will be but justice to remark, that speculation constitutes its great features. We know the materials and the product, but know little positively of the agents *proximately* concerned, or of their connexion during the progress of assimilation. Wherever, however, experiments appear, I

* Ann. Philos. 2. and 4. † Ibid 4. ‡ Thompson's Chem. book 5.

shall give them place, if sufficiently authentic, no matter what opinion they may contradict, or what unpleasant conclusion they may lead to. This is absolutely necessary if truth is at all to be regarded upon the subject of our existence; and when they are as fairly impeached as they have been established, and by the same *experimental* method, it will be the only time to overlook them or throw them aside.

COMPOSITION AND FIGURE.

I have before remarked, that the blood of animals and the sap of vegetables furnish the materials for assimilation. The formation of these fluids should also be included within this process; but I have already noticed that operation, and there seems naturally to be a distinction. My first examination will be of the blood itself. When the blood has been drawn from an animal, and allowed to stand, it coagulates, and by this process becomes divided into two parts. The coagulum itself (which has also been called cruor, because it alone retains the red colour peculiar to blood) constitutes one part, and the other consists of a limpid straw-coloured fluid, which is called *serum.* Diseases, and a variety of different other circumstances have the power of altering the proportion of these constituents; but that most usual is about *one* part of cruor to *three* of serum.* Blood by the same process gives out vapour with a peculiar smell as well as some carbonic acid gas which was formed and dissolved previous to coagulation. This spontaneous decomposition of the blood is not retarded or promoted by external agents, such

* Thomson's Chem. book v.

as air or its absence, temperature or dilution with water; electricity when given in large shocks through the body has been said to prevent the coagulation; such is also the effect of violent and fatal passions.* The cause seems confined to the blood itself; and the peculiarities of its operation led Mr. Hunter to suppose that the blood has vital properties: Dr. Gordon has rendered it probable that heat is thus evolved.†

The *serum* is found to contain either a free or carbonated *alkali*, since it turns the syrup of violets to a green colour. Rouelle and Dr. Marcet determined that the alkali is soda, whereas Dr. Pearson very plausibly considers the alkali in the animal fluids to be potassa. It is probably of little consequence either way, as both have the power of dissolving albumen, which seems their most extensive use in the animal economy. Serum also contains *albumen* in a considerable quantity, also a very large proportion of *water*. Lactate of soda, and the muriates of soda and potassa to a very trifling amount, as well as different phospates. Berzelius is of opinion that phosphorus sulphur, and the bases of lime and magnesia, exist as constituents of *albumen*, and are only produced as salts, &c. by incineration.

The cruor, when carefully washed by a gentle stream of cold water, is separated into a white, solid, and elastic substance, having all the properties of *fibrine*, and into the *colouring* matter which the water dissolves. Berzelius and Brande have shown that the cruor also contains albumen; but, as Dr. Thomson remarks, it is impossible to separate the *serum* completely from the *cruor*, and, therefore, the albumen they noticed may belong to the serum. When

* Ann. Philos. iv. 139.

† Hunter on Blood.

the colouring matter of the blood is incinerated, about one third per cent., oxyde of iron may be extracted from its ashes; and to this oxyde has been attributed the colour of the blood. When, however, we consider its very small proportion, and the fact of its being denied to exist in blood by different chemists, there will appear but little reason to suppose we know the true cause. Berzelius found the ashes to amount to only one eightieth of the colouring matter, and of this there is not more than one half oxyde of iron; he is also of opinion, that it is the iron itself, and not its *oxyde* which exists in the blood.* Fourcroy analyzed the blood of a human *fœtus*, and found that it differed from the blood of the adult in three things: 1. Its colouring matter is darker, and apparently more abundant; 2. It contains *no fibrine*, but probably a greater proportion of gelatine than the blood of adults; 3. It contains no phosphoric acid.† The absence of fibrine may be owing to the rapid formation of muscular matter at this time of life; the other differences must also depend upon fœtal peculiarities.

Thus we have a view of the materials in blood.

Like all animal substances, albumen is capable of existing in various states, both when coagulated and uncoagulated, and of forming a number of distinct species; such as the curds of milk, white of eggs, and that in the blood. Coagulated albumen forms an essential part of *bone* and *muscle; brain* may be considered as a species of it, and so may the lens of the eye. *Cartilage*, *nails*, *horns*, and *hair*, are almost *entirely* composed of it. It forms the *membranous* parts of many shells, sponges, &c. and is, in short,

* Ann. Philos. ii. 202.

† Ann. de Chim. vii. 162.

one of the most general and important of the animal substances.* Mr. Hachett has shown that *albumen* may be converted into *gelatine*, another important animal production. Nitric acid has this power, and although we are not to suppose that the same operation takes place in the body, we learn that if it can result from chemical affinity, there is nothing to prevent production on similar principles in the body. Their resemblance is more strongly pointed out by analysis.

	Carbon.	Oxygen.	Hydrog.	Nitrog.	
Gelatin,	47 8	27 2	7 9	16 9	= 100 parts.
Albumen,	52 8	23 87	7 5	15 7	

By applying the atomic theory to these results, it appears that *albumen* differs from *gelatine*, by having two additional atoms of carbon, and one atom less of hydrogen. Now, we know that respiration has the power of subtracting carbon, and the hydrogen exists in every animal compound.

The fibrine has also its varieties, and constitutes the basis of all muscles. For this purpose it seems to require no further change from the state in which it exists as a constituent of blood, than to become more firm by deposition. We cannot undertake to show how a muscle gets its shape, but the texture of fibrine is not unlike that of the muscle when well washed in water. We may even conceive in a general manner how its structure arises; for, in every instance, the smallest faciculus of fibrine is enclosed in a covering of cellular matter, which is principally composed of the other constituent of blood; namely, albumen. When

* Thomson's Chem.

they are both thrown out by the arteries, the influence of some of the agents (as galvanism) might *coagulate* the latter around the fibrine, and they multiply the facicule.* In short, when we examine the muscular structure, these two constituents of blood will be found to occupy almost the entire substance including blood vessels and nerves. The last seems to be nearly constituted by albumen, and I shall, subsequently, show, that the blood vessels have their origin from the foregoing ingredients. It would occupy too much time to notice all the animal productions, or their shades of difference; I shall, therefore, designedly omit doing so, and refer to Dr. Thomson's system of chemistry for a collected account.

As to the principle by which such productions are effected, although it is not in our power to offer experimental proof, we know that it must be of a chemical nature. No other agent has the property of altering chemical composition; and some of these very animal productions have been imitated by operating chemically on others. But the vegetable kingdom offers the greatest variety of examples; several of which I shall now mention. 1. *Oxalic acid* may be found by treating sugar with nitric acid. 2. *Camphor;* by treating oil of turpentine with muriatic acid. 3. *Tannin;* imitated by digesting charcoal in nitric acid. 4. *Sugar;* by boiling almost any animal or vegetable substance for several hours in a weak solution of sulphuric acid. 5. *Gum;* may be formed from starch. 6. *Citric acid;* from the same substance by chlorine. 7. *Saclactic acid;* and 8. *Malic acid;* from gum by nitric. 9. *Bitter principle of quassia* may be imitated by digesting alcohol some

* Sir E. Home is of opinion that muscular fibre is formed by the serous globules. (See page 107.)

months on wheat flour. 10. *Bird lime*, by fermenting the middle bark of holly, and then boiling the residue to dryness. 11. *Resin*, by treating bitumen with nitric acid. 12. *Extractive*, by treating guaiacum with the same acid,* &c. &c. These are considered as vital productions, and their imitations are either identical in external and chemical characters, or so nearly so, that very little doubt can be left of their chemical formation by secretion. It may, however, be said, that this conclusion is not correct, because chemistry has not produced each of these imitations from the flood of plants, which seems to be done when they result from secretion, and it may be denied that one secretion is at any time formed from another. To that objection it may be answered, that in all human probability it will never be in the power of the objector to prove, that nature is not thus imitated; and therefore, why should mere doubt on that subject prevent our adopting a position which is strengthed by collateral proof? My object in this essay is to prove by phenomena, facts and analogy, that the same power which is so astonishingly active in searching, as it were, through matter infinitely more compact and penetrable than organised substances, can and does operate in the different changes of life. If life were sufficient to perfect our structure, why should so much of it be hourly cast off? What renders such rejected parts unfit? No agency of life, most surely; it is the action of substance on substance, even in the midst of life. It is true, that the vital phenomena do not depend upon the mechanical action of organs alone, but it is equally true, that they are not confined, independent of all other natural agency, to a vital principle.

* Thomson's Chem. vol. iv. passim.

There are true chemical phenomena, as Fourcroy remarks, in the bodies of all animals. Products and changes result from the intimate attraction which governs the different particles composing the organic tissue. "Liquids solidify and concrete, while solids become dissolved by the invariable laws of solution; salts chrystalize and are united one to the other; elastic bodies form and expand in the midst of cavities and dilatable reservoirs. In the most tortuous ducts, or tubes mucous fluids thicken or become more fluid; insipid and colourless bodies acquire both the opposite qualities; oily matter is produced or saponified; precipitations are formed and prevented; salts change their bases and become mutually decomposed; others are constituted, while acids are formed and alkaline or metallic oxides liberated."* These are facts which no one of the least observation can doubt, and are absolutely demonstrative of chemical changes. But further, we find compounds formed in the living body precisely of the same nature as invariably results from chemical union. A fair deduction therefore it would seem must be, that this principle of composition guided them in the living body; thus we find iron, mercury and other metallic substances converted into the same oxydes, within the sphere of vitality as they are when exposed to chemical action without it; they will unite to acids just as well in either situation. So also as to gases salts and acids. The ammonia of the body is the same as that of the laboratory; and if we analyze the carbonic acid, carburetted and sulphuretted hydrogen, nitrogen, and its compounds, the phosphates, muriates, carbonates, &c., the uncombined acids so manifestly and frequently resulting from the principles of life, we must be

* Connaiss. Chim.

convinced that they were formed under the operation of the most perfect as well as active chemical laws. There are other substances as madder, indigo, garlic, &c., which pass into the circulation, and may be found unaltered in the different secretions. A theory has been broached to account for these facts, by one whose ardour in favour of *sympathy* seems to have carried him beyond fair reasoning or probability in support of his speculations. Dr. Chapman, in his notes to Richerand's physiology, styles the humoral pathology "an absurd system;" and in his zeal for alteration hazards the idea "that the process of assimilation, whether performed by the chylopoietic viscera or by the absorbent apparatus, completely decomposes all substances subjected to its influence; and however various in their principles, reduces them to one homogeneous fluid, bland and inoperative in its nature, or in other words, renders them fit for the purposes of nutrition. But in the excretions and secretions, beyond the sphere of vital powers, chemical action takes place; by which those substances are in part, or entirely *regenerated*." A few remarks will show how very little is gained by this substitute. In the first place, chemistry is allowed to exercise its power in the *secretions*, which is really more than could have been expected. In the next place, we are told that these secretions are "removed beyond the sphere of vital functions;" and this situation may, of course, be in the very substance of a gland. It is in these shrines of life, then, that Dr. Chapman supposes chemical action can best succeed. Would it not be fair (though the contrary was meant to be implied) to conclude, therefore, that chemical union must take place in *every other part* of the living body? But we are further informed that a *regeneration* of the *same* substances, as were received into the stomach, takes place in the secretions, which we are in the habit of considering as only *parts* of the assimilated food. And yet, though at first thoroughly decomposed, the original substances can be regenerated after their constituents have circulated through the body, and, in all human probability, become incorporated in the most *remote extremities.* This does not seem much short of a miracle. If I did not fear being thought disrespectful, I should say it could only be accomplished by a *convention* of all the secreting organs, in which it was agreed that *common stock* should again be made. But even then a few delinquent organs might be found to spoil the harmony intended, by permitting the whole of their share of matter or workmanship to *slip out of the body.* Any one who is devested of prejudice can hardly deny that the humoral pathology has some claims to attention; and to abuse the whole as an absurdity because somewhat of this may be traced in particular *expressions,* is doing the greatest injustice to the *principle.* It is a fact, that where any change of composition takes place it must be proximately effected by the *inanimate* qualities of matter. I do not deny that the vital structure renders it more definite of a final end; but it is by the difference of its chemical agents that it does so. How much less, then, have we reson to detract from the character of chemical action in tubes and cavities ? All glands are composed of tortuous tubes, and within those the changes take place; the length and conformation of such vessels show the intention to be, that the substances shall act by their chemical power, aided by those which they meet on their way. The muscular structure, on the other hand, seems thrown out directly from the delicate extremities of arteries, because as the fibrine, albumen, &c.,

exist already formed in the blood they require little else than a deposition and coagulation; and certainly are not in need of further changes of composition by being compelled to react in tortuous tubes and under a most retarded circulation. Another circumstance we should keep in mind, since it shows the existence of chemical affinities in these situations. Disease, which always implies *debility* in the vital functions, leads to the *greatest* variety in the secretions, and often changes the character of any one so as not to leave a doubt. Now if such secretions depended upon a vital power alone, its deficiency would be more likely to lessen their amount than change their ordinary qualities; but chemical compounds always occur in the greatest variety when the substances are more numerous. In disease, not only the composition of the blood becomes altered, but during its disordered circulation materials are crowded together which otherwise would have been located in various parts of the system. Under such circumstances the chemical character of the secretions becomes more remote from those which depend upon the regulated function. During that disease, known by the name of diabetes, in which the urine is excessive in quantity, the serum of blood often assumes the appearance of whey; and Dr. Wollaston has shown that it contains no perceptible quantity of sugar, even when the urine is loaded with it.* These remarks must suffice, since little definite information can be offered; but I apprehend that whatever may be the peculiarity of the vital arrangement, its material productions must invariably result from true chemical affinity, promoted by some or all of the agents mentioned in the former part of this essay.

* Thomson's Chem. book 5.

FIGURE.

Upon this subject the late experiments of Sir Everard Home will be found more curious and important than any of which I am at present aware; they must also constitute the entire subject, since I am desirous of confining this essay to as limited a form as possible. It is well known among the numerous original ideas of Mr. Hunter, that he maintains that the blood formed its own vessels independent of any communication with those already existing; or, in his own words, that "the blood moves in the living solids which it both *forms* and *supports*," and that "when new vessels are formed, they are not always elongations from the original ones, but vessels newly formed, which *afterwards* open a communication with the original." Now, although we may suppose the blood to have irritability, (which is what the author implies, and which in my opinion is perfectly reasonable,) without conceding to the ironical language of Mr. John Bell, that, therefore, "it should have the privilege of *knowing* when to exert itself," or "that it should have some kind of *intelligence* or consciousness, by means of which it could understand when it were within and when without the body; and whether in certain circumstances, it were fit that such vessels should be formed." Intelligence can only exist in complete living *systems;* and there are thousands apparently without it which have both irritability and definite functions. This quality is never a character of detached parts, even of the brain, which is its seat. The irritability of a finger *just cut off* is as great as before the operation, and its organization is infinitely better adapted for the exercise of sensibility, (since it possesses nerves) than the blood; yet we cannot be so forgetful of this property as to suppose that the disjointed finger possesses the least extent of it. The following experiments will show that the blood does produce its own vessels, and that too by the agency of its chemical and physical properties.

In Sir Everard Home's paper upon coagulation (croonian lecture*) we find the following account of blood taken from his own arm. " In about five minutes something was seen to be disengaged in different parts of the coagulum, (beginning to show itself where the greatest number of globules were collected ;) and from thence passing in every direction with considerable rapidity through the serum, but not at all interfering with the globules themselves, which had all discharged their colouring matter. Whereever this *extricated matter* was carried, a net-work immediately formed, anastimosing with itself on every side, and through every part of the coagulum. When the parts became dry, the appearance of a net work remained unaltered. In some instances, bubbles were seen to burst through the *upper surface* of the coagulum ; this, however, *did not prevent* the ramifications that have been described, from taking place. These changes were observed with strict attention through a microscope. Sir Everard Home has presented engravings of their appearance, and it is absolutely impossible to overlook the strong resemblance which they bear to designs of organized substances. This gentleman further remarks, that " if the blood is cold when it is exposed in the microscope, and there is a large quantity of serum on the glass, the net work is only formed in those parts where clusters of globules are collected," and further, that " when clear serum,

* Phil. Trans. for 1818.

without any globules is put upon the glass, nothing is extricated. In this paper it is also shown that after blood had remained extravasated, and become vascular, a short time was sufficient to make them become regular *tubes*, having *distinct and separable coats.* From these facts we learn that a gas forms the blood vessels with their ramifications, and that it originates from the serous globules. This shows that these globules undergo *chemical changes;* not accidentally or in a limited number, since the passage formed by some of the gas through the upper surface of the coagulum, did not put a stop to the tubular formation. This gas was determined to be carbonic acid; which whether it was derived from the serous globules or from different parts of the body during circulation, is always, in organic matter, a proof of chemical changes. Their utility in the production of blood is made manifest by an experiment of Sir E. Home, instituted for the purpose; he " placed a vessel nearly filled with blood drawn from the arm, under the receiver of an air pump, and by exhaustion, extracted the gas contained in the blood. This blood deprived of its gas, when coagulated, exhibiting *no appearance* of net work. In that part which had coagulated *before* the exhaustion was completed, the net work was beautifully distinct." This gentleman injected these vessels, and concludes, that " as the injection could only fill the spaces from which the carbonic acid gas was *extracted*, it cannot be doubted that the channels were formed by the gas." Sir Everard Home also mentions the previous experiments of Mr. Bauer, which confirm the foregoing rationale by showing a similar process for vegetable formation. " In his close attention to the changes that took place, he was very much struck with the rapid increase of the tubular hair of the root of a young plant of wheat, in its earliest stage of vegetation; and fixing his whole attention upon that part of the plant, he observed small pustules of a slimy substance arising under the epidermis, on the surface of the young root. In a few seconds, a small bubble of gas burst from the root into the slimy matter, which it extended, in a moment, to the length the hair was to acquire; and the slimy matter, surrounding the gas, immediately *coagulated*, and formed a canal. He repeated his observations on another plant, whose pubescence consisted of a *jointed* hair, and observed the same effect to take place; a bubble issued from the young stalk, and extended the slimy mucus to a short distance, forming the first joint, which immediately coagulated and became transparent: at *its* extremity, a new pustule, of the slimy mucus, accumulated, into which, in a short time, the gas *from the first joint* rushed, and then in a moment a *second* joint was formed. In the same manner he observed the formation of ten or twelve joints to take place." It now only remains to show that the analogy is as manifest in *pus* which is known to be secreted for the object of *granulation*. For which purpose I shall continue Sir Everard Home's experiments as he describes them.* "As the globules of pus are similar to those of the blood, I made experiments upon the fluid in which they are suspended, and found inspissation to produce the same effect on it as coagulation does on the other; that a similar net-work is formed, and apparently by the same means (since, if pus is deprived of its carbonic acid gas, of which it contains a large quantity, by exhaustion in the air pump, no such net-work takes place.) This is a fact of considerable importance in practical surgery; for as

* Phil. Trans. for 1819.

we know that inspissated pus can become vascular, similar to coagulated blood, we have arrived at the *principle* on which granulations depend, and from whence they derive the power of contraction which is found to be inherent in them. We also can account for the great advantage of compression on the surface of sores; since, by that means, all the superfluous pus is removed, leaving only enough for inspissation, in which state the carbonic acid gas is extricated, forming channels so as to admit of its becoming afterwards vascular, and then taking on the form of healthy granulations. Sir Everard Home concludes that the pus is turned into *new flesh*, and offers the following facts. A healthy sore, when examined with a microscope, had the eminences on its surface (these were apparently composed of small clusters of tortuous blood-vessels ;) the hollows were filled with pus. After five or ten minutes' exposure, a very thin transparent pellicle covered the whole surface, while *bubbles of gas* were seen to make their appearance in different places. In a few minutes, more blood entered and diffused itself through the net-work of vessels, (formed by the gas,) which at this time were so weak, that putting the foot with the sore, to the ground, ruptured them. These canals, however, though so weak on the first day, were found on the *second* to have become *permanent tubes*, covered over by *cuticle*. The degree of *coagulation* determines the extent of *vascularity*; this fact was proved by the addition of muriate of ammonia as well as cold water, which have the property of producing coagulation much more speedily than atmospheric air. Sir Everard Home supposes that the blood (having a strong affinity) absorbs the carbonic acid gas as it enters these newly formed vessels. This gentleman shows the following reasons for supposing that the muscular fibre is made from the globules of the blood.*

1. The fibre can be separated until it appears, by microscopic measurement, not larger in diameter than those globules of blood. 2. Muscular fibre, when thus dissected, appears, through the microscope, as composed of *globules* so as to form a line. 3. The globules of blood, when deprived of their colouring matter, (which envelops them, and is three times as great,) while floating in the serum, are seen to have an attraction toward one another, and to unite; but "that while the globules are enveloped in their colouring matter, they are not seen to run together and coalesce with one another in the field of the microscope. It is, therefore, probable, that the attraction by which this effect is produced only takes place between globules deprived of their colour."

Thus have we seen that the agents, the matter, and the productions of life, are chiefly referible to the phenomena of chemistry. This ascendancy is not confined to the beginning or end; we *must* notice its progress through every stage, even from the first dawn of animated existence. Regulated by the most inconceivable wisdom, life is sustained by the universal laws of nature; and if our pride fondly gazes at the mystery of generation let us also learn to be instructed by the extinction of life; and instead of overrating our own conformation, let us reverence the wisdom which can cause life to arise, and be guided by the universal laws of matter!

I shall now enter upon an inquiry into life itself; and in doing so the truth shall alone be sought after, without reference to opinion or prejudice.

* Phil. Trans. for 1818.

ANIMATION.

In collecting together the phenomena of assimilation, numerous obstacles must ever oppose themselves. The first combinations of matter are so extremely minute that, in all human probability, the commencement of organization will never be perceptible. All that the eye can do is to observe its growth ; and, at the earliest period of this advantage, life is found already to exist. It is for this reason chiefly, that the origin of vitality lies so deeply obscured. Our conclusions, at present, must be governed by analogy and general views ; and although the evidence which thus results is not of the highest degree, it is certainly entitled to be next. By such means, though with more certainty, the existence of a Supreme Director is demonstrated when the works of nature are surveyed.

The inquiry whether animation can result from any possible modification in the composition of inanimate matter, has frequently entered into metaphysical discussions.

I must confess it has often astonished me how very easily satisfied some inquirers have been. A view limited to three or four properties of matter, such as dimension, figure, or weight, have been twisted into every form, and when these failed to give life, the subject has been considered as examined But who has ever investigated the chemical laws to their full extent, or brought to view the incalculable variety of its products? These surely can never be overlooked when we are surveying the property of matter ; and ages will roll by before any mortal can experimentally deny their power. But it appears to me that the solution can never result from a consideration of the properties of matter alone ; other circumstances full as imperious must be thoroughly understood, and these are so numerous as to render general reasoning unfounded. We are in the habit of saying one body has the power of uniting to another, but we speak incorrectly, or rather presuppose other agents. A familiar example will illustrate my meaning. Sulphuret of iron is well known to be a material product, or, in other words, *proximately* formed by the laws of matter; yet with all this certainty we cannot suppose that it invariably results from these laws alone. Although the constituents possess a perfect affinity for each other, they have no *inherent* power sufficiently strong to *bring them together* when outside of the least perceptible distance. The same circumstance takes place in all chemical compounds. Let the power for union be ever so strong, their *presence* is also requisite, and this never proceeds from their *material* properties; they also depend on agents, such as temperature, solution, trituration, and a thousand others emanating from the laws of the *universe*. Hence then though animation should proceed from the proximate influence of material properties, we cannot limit it to these alone. If conclusions are to be drawn, they should be founded upon the phenomena of vitality, which are daily passing before our eyes, and speak true knowledge to the understanding. We ought ever to be guided by what we know, and that range is too limited to attempt to draw general conclusions from the properties of matter. It is impossible, at present, to demonstrate undeniably the correctness of either opinion; the object of this essay is to bring forward facts which have a *tendency* to show the connexion of chemistry with animated matter.

The remarks of Buffon "that the *reproduction* of an animal or vegetable cannot be explained in a satisfactory manner, if a clear idea of the operation of *nutrition* is not obtained," seem to me, to be forcibly true. Nothing can be more analogous to the production of life than its subsequent support; I shall accordingly commence with this view. Buffon,* founded his theory of nutrition upon the idea, "that there exists an infinity of *living* organic particles in nature; that their production is of little expense to nature, since their existence is constant and invariable; and that the causes of death only *separate* without destroying them. Therefore the matter which an animal or vegetable assimilates, is an organic matter of the same nature as the animal or vegetable itself." This observation is undoubtedly true with one exception. It is impossible to admit the "constant and invariable" existence of any *living* particle; the supposition is directly contradicted by the most superficial view of matter. But on the other hand we must admit that the particles of *assimilated* nutriment are endowed with as much vitality as any which constitute the body itself. Hence this naturalist drew a correct conclusion when he remarked that "the matter which an animal or vegetable assimilates, is an organic matter of the same nature, as the animal or vegetable itself." This however is very far from the view which he wished to inculcate. But what can be more inconsistent with observation than to suppose that the generation of an animal or vegetable depends upon the union of living particles, which existed with this characteristic *since creation began*, and that death only separates them without *destroying their vitality?* Such a theory, though endowing matter so profusely, could not reserve for itself one living particle to sustain its own existence, and has not been able to survive the author whose brain was the most congenial

* Natural History.

hot bed that it ever had. We may presume therefore that an absolute extincton of life does take place; let us now apply this fact.

The *nutriment* which supports the body by adding *living* matter, was previous to its changes during assimilation perfectly inanimate. How can we consistently account for the acquisition of this vital property, without attributing it to the *changes of composition* occurring during that process? These we have already shown to be of a chemical nature; and we are not justified in doubting, until at least as strong evidence of contrary nature shall point an explanation of the phenomena. But let us examine the subject closer. There is not the slightest proof that nutriment can be thus endowed by mere contact with living matter, independent of such changes of composition; and, if we rely upon general reasoning, we must be convinced that it *does* not. In the first place, the existence of the phenomena decidedly points out the necessity of such changes; and in the next, it is perfectly in contradiction to our knowledge, to maintain that life can be transferred from substance to substance, by simple juxtaposition. Irritability, which is all the life we can suppose, when characterising a substance, may impart *motion* to a foreign body in conjunction, while that situation remains; but to endow this last with *its own properties* is far different. It is absurd to suppose that this property which depends upon, and is *limited to*, the matter possessing it, can act beyond that matter. But let us entertain a proper idea of irritability, or even its more complicated forms constituting the *living system*. Has it any existence without the application of a stimulus? Not the slightest. When we take a muscle and excite its contractions, we are correctly satisfied that it is *then* alive. Without an exciter we never could suppose it, and when that exciter is removed we have no right to do so, for it is unequivocally dead. Hence, then, we learn, that life is *an effect* depending upon at least two *inanimate* substances having a peculiar chemical and physical composition. Hence, also, we learn, that irritability has no influence beyond these limits, and that when it can be manifested in adjoining matter, it must originate upon the same principles, independent of any *connexion*. We are, therefore, I think, entitled to consider that irritability does arise in the assimilated nutriment, by mere contact with the living solids. But there is a degree of evidence that this property is acquired *before* any such union takes place. The substance of the blood is undoubtedly derived from the nutriment; therefore, all Mr. Hunter's arguments for its vitality, (and which an eminent writer considers as "the best established doctrine of modern physiology," must confirm the origin of this property. The fibrine has also been found irritable by the experiments of Circaud and Delametherie;* which seems to prove that this property is acquired *during circulation*. After this shall it be denied that assimilation is of a chemical nature? This would indeed be contending for argument sake. There is not only direct evidence that the blood undergoes true chemical changes; (see respiration;) but the total difference in composition, between chyle and the food, leaves scarcely a doubt. (See digestion.) If the property of irritability does not proceed from chemical changes in our food, why should the *rejection* of any be *necessary?* Why should this excess of matter so manifestly useless, be at any time the result of a vital process? The most rational answer seems to be, that vitality is de-

* See page 13. ante.

pendent upon a peculiarity of chemical composition, and that such substances as are formed by too powerful an affinity to admit of decomposition in the body, can never, by any vital process, residing in that body, be rendered susceptible of animation. The fœtal blood is allowed not to be coeval with the first organization which is the rudiment of the *original* vital foundation; hence this blood. as well as its irritability, must be generated by chemical changes effected in the matter constituting nourishment at this early period of imperfect existence. Lastly; Sir Everard Home's paper shows, that granulation and the formation of blood vessels, which cannot be excluded from vitality, depend upon a combination of the *physical* and *chemical* properties of the blood, or pus in animals, and the sap in plants.* Irritability, like a chemical property, depends upon composition more than dimension or figure; if the substance capable of exhibiting it be divided into pieces, the property is not extinguished; but when treated with a *chemical agent* it is destroyed in proportion to the extent and perfection of its power. Thus we have exhibited an instance where *vital matter* originates independent of the *generative* process; and have shown reason for supposing that it depends upon chemical composition. Let us point out a few more important considerations.

John Hunter supposes that the blood forms its own vessels;† all practical observation must lead us to the same conclusion. When a piece is cut out from a nerve, we know that it becomes filled up so as to render that nerve complete or nearly so, "by means of the blood forming a union of *coagulum;* and that the coagulum becomes more and more of the texture;" but what assimilating or secreting vessels are there *in this coagulum* to effect such a

* See page 103. ante. † On the Blood.

change, unless those formed of itself? Those that belong to the sound portions may even send proper matter; but if these are supposed to have no power of *extension*, as Mr. Hunter remarks, we must suppose that all vascular apparatus which afterwards gives this coagulum the property of a nerve, is formed by the coagulum. But this I shall not consider important to establish, since the polypus and other animals, the umbilical chord as well as all the vegetable kingdom show that *animation* may exist *without nerves*. Sir Everard Home's experiments on blood and pus prove that *blood vessels* are formed by the blood, independent of nerves or any necessary connexion with the body. His experiments also led him to suppose that flesh is formed by pus. If these facts be extended what do they lead to? Why, that all the other parts contained therein have a similar origin, and that granulation is in the end but a process of union by the first intention, since new vessels are united to the old ones by contact. We have seen that pus forms the blood vessels and flesh for such a breach; what more vital or important parts can any structure have than these? Surely we can have but little doubt concerning the origin of the minor apparatus such as absorbents. One other consideration strongly confirms the foregoing. If any system of vessels is always necessary to form another, how is the first set supported? if by another, how is this last supported? we must introduce another and another set, until they are brought to atomic magnitude, and even then nothing will be gained since the very last must have its system of supporting vessels. We shall inevitably come to the conclusion that one *whole set* origininates from the blood without any vascular apparatus. This may seem too extensive for admission; but the reason is that we confine our view to the most complex stage.

All that we now gaze at with wonder, was once simple and limited; where mutual assistance was either feeble or extinct. Can we then hesitate in believing that when such a limited vascular system originates independently of any other, it can become complex and extensive by a continuation of arrangement? Hence then we learn that the blood or something similar is qualified to form all the parts of a complex system; how much more qualified, then, must it be to form the *simplest* circulating apparatus, without nerves, and conducing to the support of the most *limited animation?* Let us now examine of what nature blood must be for this purpose.

We have seen that *changes of composition* in inanimate matter (during digestion, respiration, &c.) give rise to the formation of blood; therefore wherever these exist, under such circumstances (which are undoubtedly dependent upon chemical affinity) life *may* result. We are too much in the habit of confining our attention to the origin of blood in adults; let us, therefore, turn to the human embryo or the chick in ovo. The embryo has been supposed to have an *independent* circulation;* and this opinion is supported by direct analogy from the egg or seed. How then does it even *accumulate* its blood, since it performs neither *digestion* nor *respiration?* Certainly not by the process of an adult. But if the human embryo be supposed to receive its nourishment, assimilated, from the mother, we will abandon the instance and bring forward the chick in ovo, where no connexion whatever exists. In this no material assimilation, no digestion or respiration seem to take place when the blood appears at the punctum saliens; its origin, or at least accumulation, must be from beginning to end, from the egg

* Dr. Chapman on fœtal nourishment.

substance, and that too without any vital apparatus, (in appearance) sufficiently vigorous to have an agency. To this instance I will add the seal in which we must suppose the power of life infinitely more simple. From such considerations we should be inclined to believe, that blood may originate without the aid (in the commencement) of a vital structure. It is not necessary that this should be blood of our bodies, or even the same as first becomes visible in the chick. The fluid which originates in the *seed* or *plant* is totally dissimilar and yet it produces vessels and all the *vital structure;* neither is pus or serum exactly the same though possessed of such a power. Hence we learn that a vital structure may be formed by other than the complete blood, and life exist or be supported. To recapitulate: All the foregoing observations intimate that a fluid (analogous to blood) of *variable nature,* may be formed, (to appearance, without a vital agency, and principally from combinations of inanimate matter,) which shall have the power of forming a vital apparatus, provided, always, that circumstances which are not *peculiar* to life shall be favourable. It will now be my object to bring forward instances which have been considered favourable to such opinion; and it is to be remarked that, throughout, nothing but the very *simplest organization* will be found to exist. When parts of plants or animals (which undergo ready decomposition) are infused in water and well corked up in a phial, animalculæ invariably appear after a few days.* This experiment is easy of success, and the following facts have been found to follow: That it makes little or no difference whether the organic matter be infused in its *natural* state; or whether, *boiled,*

* Needham on Infusions.

roasted, or otherwise exposed to an elevation of temperature sufficient to *destroy* all the forms of life, with which we are acquainted: The animalculæ still appear during corruption.

That this generation takes place, particularly in jelly, (even after having been roasted or boiled,) though transfered as rapidly and guardedly as possible.

That it *only* takes place in such matter as can undergo what is considered spontaneous decomposition.

That the animalculæ are always *multiplied* in proportion to the extent of that decomposition.

That they are generated *throughout* the matter; even in parts which have not been *exposed* to the air; as when a mass of jelly is thrown into *boiling* water, to make the infusion.

That chemical agents are always necessary, &c. &c.

In opposition to the apparent deduction of these facts, it has been supposed that eggs, conveyed through the medium of the air or water, are always deposited on the organized matter previous to corruption; and that chemical combinations, though absolutely essential, do not give rise to animation, (which, however, seems to consist of little more than irritable motion.) This supposition, it is to be remarked, has no solid foundation; no eye has ever seen such eggs either in the air, water, or the corrupted matter, which is considered as a mere nidus. Neither can it be presumed that such eggs are of *greater* magnitude than the animalculæ; many of which are only visible during motion. Even Leuwenhock's statement is more rational, when he contended that he could distinguish the sexes of the animalculæ, for he actually saw *something*. But allowing (for the sake of investigating truth) that there are eggs thus deposited, can we indulge the belief that they will be able to survive roasting or boiling? They certainly cannot have more vitality than the animalculæ themselves, which are found to perish by the slightest change or exposure. And admitting, further, that such eggs might be deposited while the organic matter was transferring to the phial, why do they generate in such swarms *throughout* the matter? Or how is their vitality preserved after that matter has been thrown into a vessel of *boiling* water and immediately corked up? These circumstances should be well refuted; for they bear heavy against the egg system. Leuwenhock, when he observed animalculæ in the sordes, which accumulates about teeth, resorted to the opinion that they themselves are transferred through the air, water, &c. There is the same objection in this case as in the foregoing; and this naturalist was not guided by experimental conviction at the time he advanced the opinion. The fact turns out, when we examine the subject, that his head was turned about, proving that the animalculæ, in male semen, were the true *offspring in miniature;* and therefore he could not leave it to be thought by the world that his favourite theory qualified the *mouth* for fœtal generation. He accordingly maintained, that in the last case, animalculæ were conveyed by eating or drinking rain water, &c. But it is well known that persons who do not eat cheese have them also, (or the reverse) and that nothing similar to them is found to exist in rain water.* It has also been noticed, as a proof that regular generation takes place among animalculæ, that the paste-eel, (a species,) when cut in the abdomen, frequently gives birth to numerous young eels. This fact, however, does not in the least account for *their first* appearance in paste under the circumstances before noticed. All that

* Barr's Buffon p. 189. vol. 3.

seems proved, is, that such animalculæ have also the *power* of regular generation; and that, being thus more perfect, there is a *greater* opening for the equivocal origin of vitality.

Buffon observes that when blighted corn is examined numerous animalculæ are observed to inhabit its substance; and seem to be confined altogether in their *production* to the *rotten* farina. These he states "may be made to *live* and *die* alternately, and as often as we please." And further, that "there are still others, even in great quantities, which are at first kinds of *vegetables*, afterwards become species of *animals*, then return again to vegetables, and so alternately." This naturalist also remarks that "there are, perhaps, as many beings, either *living* or *vegetating*, which are produced by the *fortuitous assemblage* of organic molecules, as by a constant and successive *generation*."* Yet Buffon supposed that he thus proved generation never to be equivocal; because he considered what others call animalculæ or small animals, to be nothing more than *moving machines*, or his own living organic particles which death never destroyed. But his experiments may be viewed in a very different light, even though marshalled to support a very improbable theory; for whether he *supposes* these animalculæ to be mere *moving machines* or not, they have every appearance of animation. Besides, the proof given by assimilation, that inanimate matter becomes vital, (apparently in consequence of chemical changes, and certainly without the regular process of generation,) we may add that from the presence of worms in the stomach and intestines. It has been *supposed* that these are conveyed in without

*Idem, vol. 3. p. 222.

food; but is not this as badly supported as any? Independent of the implied admission by medical practitioners when they give directions not to consider such worms as the *cause*, but altogether as symptomatic (which is literally nothing else than the *effect*) of disordered digestion, their origin seems proved to be in the stomach and intestines, by the fact that no such worms are known to exist out of the body, and instantly perish when exposed. They are always distinct from the body, and only appear at such times and places as indicate the greatest latitude to chemical combinations. Why do they not oftener manifest themselves when the same food is eaten daily? Particularly as digestion is found not to *destroy* their vitality. In the pustules of psora (itch) there are animalculæ as well as in other eruptions; in the secretions (as semen) and in almost all animal or vegetable fluids, after remaining some time at rest in the living structure. To leave animals, and descend: we meet with a very common occurrence which passes unnoticed from its familiar appearance; I mean the formation of mould in a dirty tea pot; or on the margin of vessels holding infusions. We can hardly suppose that this is a species of tea, or that it came from China; yet it is an animated production, in appearance similar to that examined by Sir Joseph Banks. But it is needless to examine the subject further. There are chemical changes always antecedent to the appearance of these animated productions; so there are in assimilation. The materials are the same, as well as most of the agents; regular generation seems throughout to be but a process of assimilation; first, in the ovaria, to form the embryo, (as other living and definite structure of the female is formed,) then in the uterus, aided still by the female; or independently of all connexion, as in eggs and seeds. The great obstacle to fortuitous generation must, therefore, be the process of assimilation; for when this succeeds, a fluid will be produced capable of forming a vital circulating structure, (as blood vessels,) particularly as there appears no necessity for a complex system to support animation. Plants, seeds, embryos, and the imperfect classes of animals show, that the process is not always the same; and that it is equally effectual when curtailed of the principle features which characterize it in adults. The generating fluid (similar to blood) is manifestly proved by these examples to be of *different* natures; so that it is impossible to foresay what its origin must always be in a living body. As to the objection of final ends, we are as much at a loss in one case as the other. The animalculæ and worms seem equally useless in the living fluids, whether brought to life by regular or fortuitous generation; and the fact is well known, that as we descend and examine the power and process of generation in the lower classes of animals, we find the most astonishing deviations from the common form. Sexes do not appear necessary for the procreation of a polypus, which gives birth to new ones by simple division; or to those animated creatures who generate by shedding a *limb*. In these cases *living systems* are formed, (independently of any connexion) in parts, which previously seemed dependent members; and they prove that the simplest structure is sufficient to support such system. Further, we should reflect that animation is founded upon irritabillity, which seems nothing more than a property of matter depending upon the action or influence of stimuli, on an *indefinite* structure and composition. Before the application of a stimulus we have not the slighest evidence of irritability, (and indeed it seems impossible by any other means to prove it;) hence it is the matter which qualifies the existence of animation more than the process of generation. Other circumstances in the regular process do undoubtedly exist, for which it would be presumption (at the present imperfect state of knowledge) to give such a rationale ; but the object is merely to examine the outline or rather the nature of one of its principles. In the pursuit of truth we should rely upon facts more than opinion ; for the last never can unfold the works of God, or manifest His wisdom, whereas the first are *always* illustrative. The ancients admitted the fact of fortuitous generation, and quietly established the maxim, "*corruptio* unius, *generatio* alterius ;" but after the discovery of animalculæ in serum, by Leuwenhock, philosophers became warm with contention. This naturalist, after several times retracting his opinions, maintained them to be *embryos in miniature*. Buffon on the other hand opposed Leuwenhock, by contending that they were nothing less than his immutable but fanciful, " living organic particles ;" while Needham had the boldness to suppose their origin to be equivocal, or resulting from material laws, independent of regular generation. These opinions had a fashionable existence, and then subsided, leaving but little taste for further inquiry. But notwithstanding such opposite views, the facts noticed by these philosophers became the more confirmed, and must still continue to exist, unless nature forgets herself so far as to overturn her present regulations. I shall close this essay without drawing a single conclusion, persuaded that the facts must answer for themselves.

FINIS.