A physiological memoir presented to the Literary and Philosophical Society of Liverpool, May 2d, 1828 / by John Bywater.

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FROM a perusal of the last memoir, as well as my physiological essay, which I had the pleasure to present to your notice, it will be evident that they do not possess that well-connected arrangement and regularity which is so highly necessary to the clear understanding of a subject like the one under our immediate consideration.

Perhaps the chief cause of this want of connection and regularity was the unexpected experimental results obtained at the commencement of the inquiry, which led me to adopt certain theoretic speculations, some of which I have since thought proper to abandon. Although I have

changed several of my early opinions on this subject, still it will be found that my chief object in pursuing this inquiry, is to establish this important conclusion, viz. that chemical and vital processes originate from the action of solar light, or some powerful influence that is derived from that agent. If we again consider the incomprehensible momentum of light, we shall almost be inevitably led to the persuasion, that a force like this which moves at the rate of nearly 200,000 miles in a second of time, must have something more about it than what belongs to mere matter; for this inconceivable velocity, and its well-known modifying influence over terrestrial matter approximate so strongly to the activity of some mental operations, that we can scarcely resist the idea that it has received such a special impress from the hand of Heaven as to constitute it that medium in the economy of nature upon which the will of the Deity more immediately operates, to bring about the most important physical purposes of his general providence.

That solar light is a promoter of vegetable and animal life is so obvious, that it will not require any long train of argument to establish the inference; but as it is highly probable that in producing these effects, it does not become equally attached

to all kinds of matter, it will form an interesting investigation to inquire to what species of terrestrial matter this agent becomes the most influentially united. By admitting that solar light is associated or endowed with a living principle which it imparts to the face of nature, it naturally directs our attention to oxygen, as the presence of this body is essentially necessary for the progress and continuance of vegetable and animal life. In pursuing this branch of the inquiry, we shall have to refer to two processes, which at first view seem to have little or no connexion with each other, but which will tend to establish the principle that chemical and vital energies originate from the same source. The processes here alluded to, are combustion and animal respiration: respecting the first, the well-known but simple process of a burning candle will answer our purpose; for the results attending this process are simply the union of the oxygen of the air with the carbon of the candle—the liberation of light and its consequent heat, and the formation of carbonic acid gas. Now the most important inference to be drawn from this statement is, that the oxygen of the atmosphere which shared in the combustible process, was associated with a living principle; for light, which was liberated from it during the process, must have retained a living

principle while in union with the oxygen of the air, for we know by a great variety of well established facts that a living power is uniformly associated with light. The idea, that a similar principle to that which gives birth to vital processes is concerned in the process of combustion, is supported by the circumstance that the two processes of respiration and combustion require to be placed under very similar situations with respect to atmospheric air. To put this to the test of experiment, let the air in a small vessel be exposed exclusively to the respiring process of a small animal until it die for want of fresh air; let another vessel be similarly exposed to the combustible process of a burning candle until the candle goes out; and then introduce a small animal into the air thus deteriorated by the candle, and it will immediately die; and if a lighted candle be introduced into the air deteriorated by the small animal, it will instantly go out: results which have induced several eminent physiologists to infer that respiration is a species of slow combustion. Perhaps a more specific reason than this may be given, why animal respiration ought to be called a slow combustible process, for we find that the carbon of the blood, like the carbon of the candle, forms a union with the oxygen of the atmosphere, and constitutes car-

bonic acid gas. Here, then, we are led, by a simple train of facts, to ask, what becomes of the living principle which was united to the oxygen of the air before it was respired; for it must have been separated from this oxygen at the time the latter entered into union with the carbon of the blood, agreeably to what has been stated respecting respiration; and, as it does not manifest itself, as in the decomposing process of the candle, by resuming its former character of light, we must conclude that it has entered into the animal system, and, in all probability, constitutes that living energy which invigorates the animal frame, and is every moment renewed by the act of respiration.

By taking these two processes into consideration at the same time, we are furnished with more satisfactory evidence respecting the process of respiration than we could have obtained from either of them when separately considered. In the first place, we have noticed a result which has been obtained from both these processes, viz. that of carbonic acid gas being formed during combustion and respiration. Now we have ocular demonstration in the combustible process that light is liberated during the formation of this gas, which light we know possesses a vital power, consequently we

have a right to infer that a similar vital power is liberated during the unseen act of respiration, because the same chemical result is obtained, though the stimulating power has not escaped under the character of light as in the case of combustion. These conclusions are of such a palpable nature, that it will not be necessary to enforce them by any tedious process of reasoning, but allow them to conduct us to another interesting part of the animal economy, which, at present, is involved in much obscurity. The effects, to which I particularly refer, are muscular contractions, which I have before mentioned, though not in so satisfactory a manner as I think the present state of inquiry will now enable us to accomplish. Although we every moment witness the effects of muscular energy and feel its influence, and know that it is at the command of our will; yet so recondite is the operation, that physiologists, after the most minute attention to the subject, have only been enabled to form a very imperfect idea of the principle on which it depends. That the animal muscles retain within themselves a living or irritable principle, is a conclusion supported by a great variety of evidence; and the much doubted opinion of the celebrated John Hunter, viz. that the blood also partakes of a living or irritable principle, will receive a strong

corroboration from the view we are taking of the subject; for if the irritable power of the muscles is continually renewed, by the vivifying process of respiration, in the manner we have described, it is evident, that the blood must be the medium by which this principle is conveyed to the muscular system—an inference that tends to verify the doctrine of Mr. Hunter. From this statement, it appears evident, that the act of respiration imparts to the animal frame a regular supply of this vital or living energy, which in the muscular fibre may be recognized under the character of irritability, while that portion of the same energy which pervades the nervous system, may be considered as the nervous fluid—as it is along these conducting portions of the animal structure that its exciting influence is transfered from one part to another. That the nerves convey various sensible impressions to the sensorium, or tablet of the brain, can scarcely be doubted; and that the mind has the power, by reflection, to form new associations from this intellectual storehouse, and impart them to the nerves seem equally probable: but how it perceives and forms these new associations, or in what manner it communicates these mental determinations to the nervous system, so as to excite the muscular contractions intended, are questions

of such a dark and hidden character, that any attempt to draw aside the veil, which, at present, conceals them, would inevitably lead us into difficulties of a still more dark and perplexing nature. Although this inquiry may direct our attention to questions beyond the limits of any direct experimental investigation, yet it ought not to be forgotten, that it has brought together an assemblage of physiological facts, which are also of a peculiar interesting nature, and quite within the range of our comprehension. Admitting that the vital power of animals is continually expended by a number of voluntary and involuntary actions, and that it is as constantly renewed by the act of respiration, yet it would have been difficult for us to have conceived how the various tribes of animals which live and breathe in this elastic ocean of vitality, could have been supplied with this stimulating power, so as to have kept their involuntary actions in due order, without some such regulating contrivance as respiration; for if this stimulating power had been received into the animal structure without any regulating method, it would, like the unchecked spring of a watch, have had an uniform tendency to carry on the involuntary functions of the body with such rapidity as must have quickly destroyed the delicate mechanism of the animal

system. The act of respiration is not only subject to the involuntary actions of the animal frame, but is also under the control of the will when any great muscular effort is required—therefore renders this renewing process of the highest importance to the well-being of animal life. The mixed principle of action here alluded to, is most completely exemplified by the respiring action of the horse, for when stimulated by the power of the whip to make any long and violent muscular exertion, his respiration becomes more rapid, as if he instinctively knew that an increased respiration would supply him with that vital power which he is so rapidly expending, by the violent but voluntary action of his muscular system. By taking a retrospect of the physiological facts on which this train of reasoning is founded, we shall arrive at these plain but very important deductions, viz. that the appropriate action of all the animal functions chiefly depend on two processes, viz. digestion and respiration; for by the first process and its consequent secretions, carbon is continually added to the blood, while the latter process is continually extracting it from the system again; and that, during this change, light, under its vital character, is liberated from the air and enters into the animal frame, and constitutes that renovating source from

whence the vital powers of the body are supplied. The above conclusions are further supported by a variety of collateral circumstances, besides those already mentioned; for instance, when the respiration of a healthy person is quickened, the formation of carbonic acid gas is increased beyond its usual quantity, while in an exhausted or fatigued state of the animal frame, the usual quantity is diminished; therefore naturally lead us to infer, that the bodily fatigue we experience, after any great and continued muscular exertion, arises from the expenditure of carbon being greater than its natural supply; for if the formation of carbonic acid gas be the means by which a vital force is supplied to the body, our muscular energy must become feeble until this lost carbon is again replaced by a fresh supply of food or muscular rest. There is another circumstance which also deserves our notice, as it has a strong tendency to establish the conclusion, that light is the source whence vital energies are derived. It is a well-known fact, that combustion is carried on more rapidly, and that much more light is given out, when the process takes place in oxygen gas instead of atmospheric air; and it is equally well known, that when oxygen gas is respired instead of atmospheric air, the action of the vital functions are

increased in a similar proportion, clearly indicating that oxygen is the medium by which the vitality of light is conveyed to the animal system. Although this short sketch of respiration and muscular action may not be strictly correct in detail, yet I am strongly inclined to believe that it is so in principle, and that it supports the idea that vital processes depend on a directing power which has been specifically imparted to living organized structures, for the purpose of controlling the force of an universal agent, and adorning the terrestrial face of nature with an everchanging variety.

Having had occasion to refer, in a special manner, to the process of combustion, and show the probability that it arises from an active principle derived from light, it may not be altogether uninteresting to make a few general remarks on the nature of heat, as its source and real character are still disputed questions among physiologists. The idea, entertained by some writers, that heat originates and depends on the action of a subtile fluid, termed caloric, which is indifferent to motion, except that of keeping up an equilibrium among the various bodies through which it is diffused; or, as others have contended, that it entirely depends on a vibratory motion which obtains among the par-

ticles of the heated body; are opinions opposed to a number of well-established facts, and incompatible with the general process of combustion.—By considering the combustible process agreeably to the calorific hypothesis, how can we account for that excessive rush of caloric to the point where combustion takes place, when the principle of equalization is the grand law by which caloric is regulated?—Nor shall we be exempt from difficulties, by adopting the vibrating hypothesis; for we can only form an imperfect idea how any vibrations, which are imparted by a mechanical force to the particles of a small body, can be transfered to other bodies, and generate that immense vibrating power which must obtain in every extensive combustible process. In taking a general view of those processes which produce heat, we shall not fail to be impressed with a conviction, that some active agent, besides the particles of mere inert matter, is concerned in producing and carrying forward these processes. Hence, in all probability, has arisen the doctrine of caloric; but why should we encumber our theoretic views with the admission of caloric, or any agent whose existence has never been distinctly proved, when we know that solar light will, by its own direct influence, induce the strongest combustible or chemical effects. In

most common cases of combustion, such as take place in the production and progress of our ordinary fires, the particles of a small portion of combustible matter are generally first put into a violent agitation by a mechanical force, which inevitably weakens their cohesion, and so far prepares them, that they readily enter into combination with the oxygen of the atmosphere; and this union, no doubt, is most actively promoted by the light with which oxygen is combined, and which again becomes liberated by the conflict. The violent agitation into which the particles of this first portion of combustible matter are thrown by a mechanical force, is imparted to the exterior particles of the materials of which the fire is to be formed; and they, also, by having their cohesion weakened by these vibrations, become prepared to enter into a new combination with the oxygen of the air; and that, during this changing conflict, a wider range of particles become agitated and their cohesion lessened; consequently allow the oxygen of the air to enter into union with them by a similar principle; and thus the work of decomposition goes on till all the active materials which constitute the fire have been liberated, or have formed new combinations, and then the combustible process ends. Here, then, we see the probability that heat, under its most

active character, does not originate exclusively from the supposed agent termed caloric, or the vibrations of the particles of the combustible body, but from the mechanical vibrations of one series of particles being communicated to another which inevitably weakens their cohesion; and the uniform tendency which the light that is combined with the atmosphere has to promote new combinations between the combustible body and oxygen when thus situated.

In those cases of combustion where the combustible substances are so prepared by art, or situated by nature, that the whole of their particles when excited by a change of position or a slight mechanical force rush into an instantaneous union with the oxygen of the atmosphere, the effect is termed an explosion; but when heat simply expands bodies without producing any chemical change, it originates from the vibrations into which the particles of the heated body are thrown by a mechanical force.

That the processes of combustion and respiration are not only illustrative of each other, but they are also illustrative of what are called chemical affinities; for, if light which is combined with

oxygen is the source of vital and combustible changes, there can be little doubt, but it is under different modifications, the source of every species of chemical action, as combustible effects are some of the strongest manifestations of chemical energies. The energetic and elective character of chemical affinities but ill accord with any well-known property of matter ; but instead of ascribing this extraordinary power of election to an unknown and imaginary influence, let us refer it to the modifying influence of slightly oxygenated solar light, whose universal circulation has been established by the directing polarity of the compass needle, and we shall find ourselves in possession of a power exactly suited for the purpose. To take all the advantages which this circulating agent offers for our consideration, let us bear in mind, that in all those cases of chemical change which we ascribe to chemical affinities, the different particles of the bodies, before they are chemically changed, must be so situated that they will readily move one amongst another, and then take into the account that this circulating fluid agent is perpetually passing through them in every direction as proved by magnetical experiments, and we shall discover how well calculated it is to produce the chemical changes under consideration. The fact, that solar

light, when simply brought to a focus by a powerful lens, will, by its own energy, supersede the necessity of a mechanical force in the production of the most violent chemical changes; and, the circumstance, that vegetable processes, which may fairly be considered as chemical processes under the control of organized structures, are most decidedly promoted by its presence irresistibly lead us to this obvious conclusion, that chemical affinities, under all their various forms and characters, depend on the influence of solar light, whose action is modified by the organized or unorganized particles of matter on which it operates. That this agency is also the real cause of electrical energies, might be shown from a variety of experimental facts; but as it would carry our remarks beyond the proposed limits of this memoir, I shall briefly conclude by saying, that electricity is nothing more than light united to highly attenuated terrestrial matter, either through a mechanical or chemical operation, which it carries along the surface of conducting bodies by its extreme activity, and from which it is again liberated by an explosion. That the electric fluid or fluids are highly attenuated terrestrial matter united to light, is strongly corroborated by the fact, that a stream of electricity viewed in the dark has all the appearance of a body of

agent, agreeably to what has been already stated, will carry this matter through the various masses of earth, it has to pass by the irresistible force of its own circulation, consequently produce in its progress those undulations we term earthquakes. Another circumstance that gives a support to these opinions is, that compass needles, particularly in South America, become agitated and irregular in their polar action at the approach and during an earthquake. By embracing the electrical views just brought forward, we shall not require any negative or positive state of the earth and atmosphere to enable us to comprehend the effects in question, but simply to suppose that earthquakes originate from the action of highly attenuated terrestrial matter which this agent carries along with it in its circulation.

Although the early part of this inquiry did not obtain that regular and systematic character which the high interest of the subject demands, still I trust the investigation has now assumed such a connected arrangement as will allow the following general conclusions to be drawn from the papers I have already published :—

1. That terrestrial phenomena, or physical

changes in general, are produced and depend on a stimulating energy which originates from solar light.

2. That in the unorganized part of nature this power operates upon the particles of different kinds of matter and produces what are termed chemical affinities; but when this agency becomes specifically connected with living organized structures, it produces what are termed vital effects, and is the active promoter of every living process.

3. That solar light becomes united to different portions of terrestrial matter (particularly oxygen) and circulates through the earth and atmosphere under some one of its varieties, is rendered highly probable by the phenomena of polar magnetism.

THE END.