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No. 1---University Series.

ON THE

PHYSICAL BASIS OF LIFE.

BY T. H. HUXLEY, LL.D., F.R.S.



NEW HAVEN, CONN.:
CHARLES C. CHATFIELD.

1870. Price 25cts

Boyle

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T. A. Denwett
ON THE
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WITH ILLUSTRATIONS AND MAPS

SECOND EDITION.

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INTRODUCTION.

The following remarkable discourse was originally delivered in Edinburg, November 18th, 1868, as the first of a series of Sunday evening addresses, upon non-religious topics, instituted by the Rev. J. Cranbrook. It was subsequently published in London as the leading article in the *Fortnightly Review*, for February, 1869, and attracted so much attention that five editions of that number of the magazine have already been issued. It is now re-printed in this country, in permanent form, for the first time, and will doubtless prove of great interest to American readers. The author is Thomas Henry Huxley, of London, Professor of Natural History in the Royal School of Mines, and of Comparative Anatomy and Physiology in the Royal College of Surgeons. He is also President of the Geological Society of London. Although comparatively a young man, his numerous and valuable contributions to Natural Science entitle him to be considered one of the first of living Naturalists, especially in the departments of Zoölogy and Paleontology, to which he has mainly devoted himself. He is undoubtedly the ablest English advocate of Darwin's theory of the Origin of Species, particularly with reference to its application to the human race, which he believes to be nearly related to the higher apes. It is, indeed, through his discussion of this question that he is, perhaps, best known to the general public, as his late work entitled "Man's Place in Nature," and other writings on similar topics, have been very widely read in this country and in Europe. In the present lecture Professor Huxley discusses a kindred subject of no less interest and importance, and should have an equally candid hearing.

YALE COLLEGE, March 30th, 1869.

PUBLISHER'S NOTE.

The constant and increasing demand for this lecture, which has exhausted a very large edition, indicates the interest which it has awakened in this country. In presenting this second edition, a change has been made in the size and form, in order to make it uniform with a series of scientific and educational essays and lectures which it is proposed to publish under the name of the "University Series." This series will consist of the ablest lectures and essays of the best minds of Europe and America. It is the intention of the publisher to admit nothing into it that is not worthy of the careful thought of every educated person in America.

On the Physical Basis of Life.

In order to make the title of this discourse generally intelligible, I have translated the term "Protoplasm," which is the scientific name of the substance of which I am about to speak, by the words "the physical basis of life." I suppose that, to many, the idea that there is such a thing as a physical basis, or matter, of life may be novel—so widely spread is the conception of life as a something which works through matter, but is independent of it; and even those who are aware that matter and life are inseparably connected, may not be prepared for the conclusion plainly suggested by the phrase "the physical basis or matter of life," that there is some one kind of matter which is common to all living beings, and that their endless diversities are bound together by a physical, as well as an ideal, unity. In fact, when first apprehended, such a doctrine as this appears almost shocking to common sense. What, truly, can seem to be more obviously different from one another in faculty, in form, and in substance, than the various kinds of living beings? What community of faculty can there be between the brightly-colored lichen, which so nearly resembles a mere mineral incrustation of the bare rock on

which it grows, and the painter, to whom it is instinct with beauty, or the botanist, whom it feeds with knowledge?

Again, think of the microscopic fungus—a mere infinitesimal ovoid particle, which finds space and duration enough to multiply into countless millions in the body of a living fly; and then of the wealth of foliage, the luxuriance of flower and fruit, which lies between this bald sketch of a plant and the giant pine of California, towering to the dimensions of a cathedral spire, or the Indian fig, which covers acres with its profound shadow, and endures while nations and empires come and go around its vast circumference! Or, turning to the other half of the world of life, picture to yourselves the great finner whale, hugest of beasts that live, or have lived, disporting his eighty or ninety feet of bone, muscle and blubber, with easy roll, among waves in which the stoutest ship that ever left dockyard would founder hopelessly; and contrast him with the invisible animalcules—mere gelatinous specks, multitudes of which could, in fact, dance upon the point of a needle with the same ease as the angels of the schoolmen could, in imagination. With these images before your minds, you may well ask what community of form, or structure, is there between the animalcule and the whale, or between the fungus and fig-tree? And, *a fortiori*, between all four?

Finally, if we regard substance, or material composition, what hidden bond can connect the flower which a girl wears in her hair and the blood which courses through her youthful veins; or, what is there in common between the dense and resisting mass of the oak, or the strong fabric of the tortoise, and those broad disks of glassy

jelly which may be seen pulsating through the waters of a calm sea, but which drain away to mere films in the hand which raises them out of their element? Such objections as these must, I think, arise in the mind of every one who ponders, for the first time, upon the conception of a single physical basis of life underlying all the diversities of vital existence; but I propose to demonstrate to you that, notwithstanding these apparent difficulties, a threefold unity—namely, a unity of power or faculty, a unity of form, and a unity of substantial composition—does pervade the whole living world. No very abstruse argumentation is needed, in the first place, to prove that the powers, or faculties, of all kinds of living matter, diverse as they may be in degree, are substantially similar in kind. Goethe has condensed a survey of all the powers of mankind into the well-known epigram :

“ Warum treibt sich das Volk so und schreit ? Es will sich ernähren
Kinder zeugen, und sie nähren so gut es vermag.

* * * * *

Weiter bringt es kein Mensch, stell' er sich, wie er auch will.”

In physiological language this means, that all the multifarious and complicated activities of man are comprehensible under three categories. Either they are immediately directed towards the maintenance and development of the body, or they effect transitory changes in the relative positions of parts of the body, or they tend towards the continuance of the species. Even those manifestations of intellect, of feeling, and of will, which we rightly name the higher faculties, are not excluded from this classification, inasmuch as to every one but the subject of them, they are known only as transit-

ory changes in the relative positions of parts of the body. Speech, gesture, and every other form of human action are, in the long run, resolvable into muscular contraction, and muscular contraction is but a transitory change in the relative positions of the parts of a muscle. But the scheme, which is large enough to embrace the activities of the highest form of life, covers all those of the lower creatures. The lowest plant, or animalcule, feeds, grows and reproduces its kind. In addition, all animals manifest those transitory changes of form which we class under irritability and contractility; and it is more than probable, that when the vegetable world is thoroughly explored, we shall find all plants in possession of the same powers, at one time or other of their existence. I am not now alluding to such phenomena, at once rare and conspicuous, as those exhibited by the leaflets of the sensitive plant, or the stamens of the barberry, but to much more widely-spread, and, at the same time, more subtle and hidden, manifestations of vegetable contractility. You are doubtless aware that the common nettle owes its stinging property to the innumerable stiff and needle-like, though exquisitely delicate, hairs which cover its surface. Each stinging-needle tapers from a broad base to a slender summit, which, though rounded at the end, is of such microscopic fineness that it readily penetrates, and breaks off in, the skin. The whole hair consists of a very delicate outer case of wood, closely applied to the inner surface of which is a layer of semi-fluid matter, full of innumerable granules of extreme minuteness. This semi-fluid lining is protoplasm, which thus constitutes a kind of bag, full of a limpid liquid,

and roughly corresponding in form with the interior of the hair which it fills. When viewed with a sufficiently high magnifying power, the protoplasmic layer of the nettle hair is seen to be in a condition of unceasing activity. Local contractions of the whole thickness of its substance pass slowly and gradually from point to point, and give rise to the appearance of progressive waves, just as the bending of successive stalks of corn by a breeze produces the apparent billows of a corn-field. But, in addition to these movements, and independently of them, the granules are driven, in relatively rapid streams, through channels in the protoplasm which seem to have a considerable amount of persistence. Most commonly, the currents in adjacent parts of the protoplasm take similar directions ; and, thus, there is a general stream up one side of the hair and down the other. But this does not prevent the existence of partial currents which take different routes ; and, sometimes, trains of granules may be seen coursing swiftly in opposite directions, within a twenty-thousandth of an inch of one another ; while, occasionally, opposite streams come into direct collision, and, after a longer or shorter struggle, one predominates. The cause of these currents seem to lie in contractions of the protoplasm which bounds the channels in which they flow, but which are so minute that the best microscopes show only their effects, and not themselves.

The spectacle afforded by the wonderful energies imprisoned within the compass of the microscopic hair of a plant, which we commonly regard as a merely passive organism, is not easily forgotten by one who has watched

its display continued hour after hour, without pause or sign of weakening. The possible complexity of many other organic forms, seemingly as simple as the protoplasm of the nettle, dawns upon one; and the comparison of such a protoplasm to a body with an internal circulation, which has been put forward by an eminent physiologist, loses much of its startling character. Currents similar to those of the hairs of the nettle have been observed in a great multitude of very different plants, and weighty authorities have suggested that they probably occur, in more or less perfection, in all young vegetable cells. If such be the case, the wonderful noonday silence of a tropical forest is, after all, due only to the dullness of our hearing; and could our ears catch the murmur of these tiny maelstroms, as they whirl in the innumerable myriads of living cells which constitute each tree, we should be stunned, as with the roar of a great city.

Among the lower plants, it is the rule rather than the exception, that contractility should be still more openly manifested at some periods of their existence. The protoplasm of *Algae* and *Fungi* becomes, under many circumstances, partially, or completely, freed from its woody case, and exhibits movements of its whole mass, or is propelled by the contractility of one or more hair-like prolongations of its body, which are called vibratile cilia. And, so far as the conditions of the manifestation of the phenomena of contractility have yet been studied, they are the same for the plant as for the animal. Heat and electric shocks influence both, and in the same way, though it may be in different degrees. It is by no means my intention to suggest that there is no

difference in faculty between the lowest plant and the highest, or between plants and animals. But the difference between the powers of the lowest plant, or animal, and those of the highest is one of degree, not of kind, and depends, as Milne-Edwards long ago so well pointed out, upon the extent to which the principle of the division of labor is carried out in the living economy. In the lowest organism all parts are competent to perform all functions, and one and the same portion of protoplasm may successively take on the function of feeding, moving, or reproducing apparatus. In the highest, on the contrary, a great number of parts combine to perform each function, each part doing its allotted share of the work with great accuracy and efficiency, but being useless for any other purpose. On the other hand, notwithstanding all the fundamental resemblances which exist between the powers of the protoplasm in plants and in animals, they present a striking difference (to which I shall advert more at length presently,) in the fact that plants can manufacture fresh protoplasm out of mineral compounds, whereas animals are obliged to procure it ready made, and hence, in the long run, depend upon plants. Upon what condition this difference in the powers of the two great divisions of the world of life depends, nothing is at present known.

With such qualification as arises out of the last-mentioned fact, it may be truly said that the acts of all living things are fundamentally one. Is any such unity predictable of their forms? Let us seek in easily verified facts for a reply to this question. If a drop of blood be drawn by pricking one's finger, and viewed with proper

precautions and under a sufficiently high microscopic power, there will be seen, among the innumerable multitude of little, circular, discoidal bodies, or corpuscles, which float in it and give it its color, a comparatively small number of colorless corpuscles, of somewhat larger size and very irregular shape. If the drop of blood be kept at the temperature of the body, these colorless corpuscles will be seen to exhibit a marvelous activity, changing their forms with great rapidity, drawing in and thrusting out prolongations of their substance, and creeping about as if they were independent organisms. The substance which is thus active is a mass of protoplasm, and its activity differs in detail, rather than in principle, from that of the protoplasm of the nettle. Under sundry circumstances the corpuscle dies and becomes distended into a round mass, in the midst of which is seen a smaller spherical body, which existed, but was more or less hidden, in the living corpuscle, and is called its *nucleus*. Corpuscles of essentially similar structure are to be found in the skin, in the lining of the mouth, and scattered through the whole frame work of the body. Nay, more; in the earliest condition of the human organism, in that state in which it has just become distinguishable from the egg in which it arises, it is nothing but an aggregation of such corpuscles, and every organ of the body was, once, no more than such an aggregation. Thus a nucleated mass of protoplasm turns out to be what may be termed the structural unit of the human body. As a matter of fact, the body, in its earliest state, is a mere multiple of such units; and, in its perfect condition, it is a multiple of such units, variously

modified. But does the formula which expresses the essential structural character of the highest animal cover all the rest, as the statement of its powers and faculties covered that of all others? Very nearly. Beast and fowl, reptile and fish, mollusk, worm, and polype, are all composed of structural units of the same character, namely, masses of protoplasm with a nucleus. There are sundry very low animals, each of which, structurally, is a mere colorless blood-corpuscle, leading an independent life. But, at the very bottom of the animal scale, even this simplicity becomes simplified, and all the phenomena of life are manifested by a particle of protoplasm without a nucleus. Nor are such organisms insignificant by reason of their want of complexity. It is a fair question whether the protoplasm of those simplest forms of life, which people an immense extent of the bottom of the sea, would not outweigh that of all the higher living beings which inhabit the land, put together. And in ancient times, no less than at the present day, such living beings as these have been the greatest of rock builders.

What has been said of the animal world is no less true of plants. Imbedded in the protoplasm at the broad, or attached, end of the nettle hair, there lies a spheroidal nucleus. Careful examination further proves that the whole substance of the nettle is made up of a repetition of such masses of nucleated protoplasm, each contained in a wooden case, which is modified in form, sometimes into a woody fibre, sometimes into a duct or spiral vessel, sometimes into a pollen grain, or an ovule. Traced back to its earliest state, the nettle arises

as the man does, in a particle of nucleated protoplasm. And in the lowest plants, as in the lowest animals, a single mass of such protoplasm may constitute the whole plant, or the protoplasm may exist without a nucleus. Under these circumstances it may well be asked, how is one mass of non-nucleated protoplasm to be distinguished from another? why call one "plant" and the other "animal?" The only reply is that, so far as form is concerned, plants and animals are not separable, and that, in many cases, it is a mere matter of convention whether we call a given organism an animal or a plant.

There is a living body called *Æthalium septicum*, which appears upon decaying vegetable substances, and in one of its forms, is common upon the surface of tan pits. In this condition it is, to all intents and purposes, a fungus, and formerly was always regarded as such; but the remarkable investigations of De Bary have shown that, in another condition, the *Æthalium* is an actively locomotive creature, and takes in solid matters, upon which, apparently, it feeds, thus exhibiting the most characteristic feature of animality. Is this a plant, or is it an animal? Is it both, or is it neither? Some decide in favor of the last supposition, and establish an intermediate kingdom, a sort of biological No Man's Land for all these questionable forms. But, as it is admittedly impossible to draw any distinct boundary line between this no man's land and the vegetable world on the one hand, or the animal, on the other, it appears to me that this proceeding merely doubles the difficulty which, before, was single. Protoplasm, simple or nucleated, is the formal basis of all life. It is the clay of the potter;

which, bake it and paint it as he will, remains clay, separated by artifice, and not by nature, from the commonest brick or sun-dried clod. Thus it becomes clear that all living powers are cognate, and that all living forms are fundamentally of one character.

The researches of the chemist have revealed a no less striking uniformity of material composition in living matter. In perfect strictness, it is true that chemical investigation can tell us little or nothing, directly, of the composition of living matter, inasmuch as such matter must needs die in the act of analysis, and upon this very obvious ground, objections, which I confess seem to me to be somewhat frivolous, have been raised to the drawing of any conclusions whatever respecting the composition of actually living matter from that of the dead matter of life, which alone is accessible to us. But objectors of this class do not seem to reflect that it is also, in strictness, true that we know nothing about the composition of any body whatever, as it is. The statement that a crystal of calc-spar consists of carbonate of lime, is quite true, if we only mean that, by appropriate processes, it may be resolved into carbonic acid and quicklime. If you pass the same carbonic acid over the very quicklime thus obtained, you will obtain carbonate of lime again ; but it will not be calc-spar, nor anything like it. Can it, therefore, be said that chemical analysis teaches nothing about the chemical composition of calc-spar ? Such a statement would be absurd ; but it is hardly more so than the talk one occasionally hears about the uselessness of applying the results of chemical analysis to the living bodies which have yielded them. One fact, at

any rate, is out of reach of such refinements, and this is, that all the forms of protoplasm which have yet been examined contain the four elements, carbon, hydrogen, oxygen, and nitrogen, in very complex union, and that they behave similarly towards several re-agents. To this complex combination, the nature of which has never been determined with exactness, the name of Protein has been applied. And if we use this term with such caution as may properly arise out of our comparative ignorance of the things for which it stands, it may be truly said, that all protoplasm is proteinaceous ; or, as the white, or albumen, of an egg is one of the commonest examples of a nearly pure proteine matter, we may say that all living matter is more or less albuminoid. Perhaps it would not yet be safe to say that all forms of protoplasm are affected by the direct action of electric shocks ; and yet the number of cases in which the contraction of protoplasm is shown to be affected by this agency increases, every day. Nor can it be affirmed with perfect confidence that all forms of protoplasm are liable to undergo that peculiar coagulation at the temperature of 40 degrees—50 degrees centigrade, which has been called “heat-stiffening,” though Kühne’s beautiful researches have proved this occurrence to take place in so many and such diverse living beings, that it is hardly rash to expect that the law holds good for all. Enough has, perhaps, been said to prove the existence of a general uniformity in the character of the protoplasm, or physical basis of life, in whatever group of living beings it may be studied. But it will be understood that this general uniformity by no means excludes any amount of

special modifications of the fundamental substance. The mineral, carbonate of lime, assumes an immense diversity of characters, though no one doubts that under all these Protean changes it is one and the same thing.

And now, what is the ultimate fate, and what the origin of the matter of life? Is it, as some of the older naturalists supposed, diffused throughout the universe in molecules, which are indestructible and unchangeable in themselves; but, in endless transmigration, unite in innumerable permutations, into the diversified forms of life we know? Or, is the matter of life composed of ordinary matter, differing from it only in the manner in which its atoms are aggregated? Is it built up of ordinary matter, and again resolved into ordinary matter when its work is done? Modern science does not hesitate a moment between these alternatives. Physiology writes over the portals of life,

“*Debemur morti nos nostraque,*”

with a profounder meaning than the Roman poet attached to that melancholy line. Under whatever disguise it takes refuge, whether fungus or oak, worm or man, the living protoplasm not only ultimately dies and is resolved into its mineral and lifeless constituents, but is always dying, and, strange as the paradox may sound, could not live unless it died. In the wonderful story of the “*Peau de Chagrin*,” the hero becomes possessed of a magical wild ass’s skin, which yields him the means of gratifying all his wishes. But its surface represents the duration of the proprietor’s life; and for every satisfied desire the skin shrinks in proportion to the intensity of fruition, until at length life and the last handbreadth of the

"Peau de Chagrin," disappear with the gratification of a last wish. Balzac's studies had led him over a wide range of thought and speculation, and his shadowing forth of physiological truth in this strange story may have been intentional. At any rate, the matter of life is a veritable "Peau de Chagrin," and for every vital act it is somewhat the smaller. All work implies waste, and the work of life results, directly or indirectly, in the waste of protoplasm. Every word uttered by a speaker costs him some physical loss ; and, in the strictest sense, he burns that others may have light—so much eloquence, so much of his body resolved into carbonic acid, water and urea. It is clear that this process of expenditure cannot go on forever. But, happily, the protoplasmic *peau de chagrin* differs from Balzac's in its capacity of being repaired, and brought back to its full size, after every exertion. For example, this present lecture, whatever its intellectual worth to you, has a certain physical value to me, which is, conceivably, expressible by the number of grains of protoplasm and other bodily substance wasted in maintaining my vital processes during its delivery. My *peau de chagrin* will be distinctly smaller at the end of the discourse than it was at the beginning. By-and-by, I shall probably have recourse to the substance commonly called mutton, for the purpose of stretching it back to its original size. Now this mutton was once the living protoplasm, more or less modified, of another animal—a sheep. As I shall eat it, it is the same matter altered, not only by death, but by exposure to sundry artificial operations in the process of cooking. But these changes, whatever be their extent,

have not rendered it incompetent to resume its old functions as matter of life. A singular inward laboratory, which I possess, will dissolve a certain portion of the modified protoplasm, the solution so formed will pass into my veins ; and the subtle influences to which it will then be subjected will convert the dead protoplasm into living protoplasm, and transubstantiate sheep into man. Nor is this all. If digestion were a thing to be trifled with, I might sup upon lobster, and the matter of life of the crustacean would undergo the same wonderful metamorphosis into humanity. And were I to return to my own place by sea, and undergo shipwreck, the crustacea might, and probably would, return the compliment, and demonstrate our common nature by turning my protoplasm into living lobster. Or, if nothing better were to be had, I might supply my wants with mere bread, and I should find the protoplasm of the wheat-plant to be convertible into man, with no more trouble than that of the sheep, and with far less, I fancy, than that of the lobster. Hence it appears to be a matter of no great moment what animal, or what plant, I lay under contribution for protoplasm, and the fact speaks volumes for the general identity of that substance in all living beings. I share this catholicity of assimilation with other animals, all of which, so far as we know, could thrive equally well on the protoplasm of any of their fellows, or of any plant ; but here the assimilative powers of the animal world cease.

A solution of smelling-salts in water with an infinitesimal proportion of some other saline matters, contains all the elementary bodies which enter into the composition of protoplasm ; but, as I need hardly say, a hogs-

head of that fluid would not keep a hungry man from starving, nor would it save any animal whatever from a like fate. An animal cannot make protoplasm, but must take it ready-made from some other animal, or some plant—the animal's highest feat of constructive chemistry being to convert dead protoplasm into that living matter of life which is appropriate to itself. Therefore, in seeking for the origin of protoplasm, we must eventually turn to the vegetable world. The fluid containing carbonic acid, water, and ammonia, which offers such a barmecide feast to the animal, is a table richly spread to multitudes of plants ; and with a due supply of only such materials, many a plant will not only maintain itself in vigor, but grow and multiply until it has increased a million-fold, or a million million-fold, the quantity of protoplasm which it originally possessed ; in this way building up the matter of life, to an indefinite extent, from the common matter of the universe. Thus the animal can only raise the complex substance of dead protoplasm to the higher power, as one may say, of living protoplasm ; while the plant can raise the less complex substances—carbonic acid, water, and ammonia—to the same stage of living protoplasm, if not to the same level. But the plant also has its limitations. Some of the fungi, for example, appear to need higher compounds to start with, and no known plant can live upon the uncompounded elements of protoplasm. A plant supplied with pure carbon, hydrogen, oxygen, and nitrogen, phosphorus, sulphur, and the like, would as infallibly die as the animal in his bath of smelling-salts, though it would be surrounded by all the constituents of protoplasm. Nor,

indeed, need the process of simplification of vegetable food be carried so far as this, in order to arrive at the limit of the plant's thaumaturgy.

Let water, carbonic acid, and all the other needful constituents, be supplied without ammonia, and an ordinary plant will still be unable to manufacture protoplasm. Thus the matter of life, so far as we know it (and we have no right to speculate on any other) breaks up in consequence of that continual death which is the condition of its manifesting vitality, into carbonic acid, water, and ammonia, which certainly possess no properties but those of ordinary matter ; and out of these same forms of ordinary matter and from none which are simpler, the vegetable world builds up all the protoplasm which keeps the animal world agoing. Plants are the accumulators of the power which animals distribute and disperse.

But it will be observed, that the existence of the matter of life depends on the preëxistence of certain compounds, namely, carbonic acid, water, and ammonia. Withdraw any one of these three from the world and all vital phenomena come to an end. They are related to the protoplasm of the plant, as the protoplasm of the plant is to that of the animal. Carbon, hydrogen, oxygen, and nitrogen are all lifeless bodies. Of these, carbon and oxygen unite in certain proportions and under certain conditions, to give rise to carbonic acid ; hydrogen and oxygen produce water ; nitrogen and hydrogen give rise to ammonia. These new compounds, like the elementary bodies of which they are composed, are lifeless. But when they are brought together, under certain

conditions they give rise to the still more complex body, protoplasm, and this protoplasm exhibits the phenomena of life. I see no break in this series of steps in molecular complication, and I am unable to understand why the language which is applicable to any one term of the series may not be used to any of the others. We think fit to call different kinds of matter carbon, oxygen, hydrogen, and nitrogen, and to speak of the various powers and activities of these substances as the properties of the matter of which they are composed. When hydrogen and oxygen are mixed in a certain proportion, and the electric spark is passed through them, they disappear and a quantity of water, equal in weight to the sum of their weights, appears in their place. There is not the slightest parity between the passive and active powers of the water and those of the oxygen and hydrogen which have given rise to it. At 32 degrees Fahrenheit, and far below that temperature, oxygen and hydrogen are elastic gaseous bodies, whose particles tend to rush away from one another with great force. Water, at the same temperature, is a strong though brittle solid, whose particles tend to cohere into definite geometrical shapes, and sometimes build up frosty imitations of the most complex forms of vegetable foliage. Nevertheless we call these, and many other strange phenomena, the properties of the water, and we do not hesitate to believe that, in some way or another, they result from the properties of the component elements of the water. We do not assume that a something called "aquosity" entered into and took possession of the oxide of hydrogen as soon as it was formed, and then guided the aqueous

particles to their places in the facets of the crystal, or amongst the leaflets of the hoar-frost. On the contrary, we live in the hope and in the faith that, by the advance of molecular physics, we shall by-and-by be able to see our way as clearly from the constituents of water to the properties of water, as we are now able to deduce the operations of a watch from the form of its parts and the manner in which they are put together. Is the case in any way changed when carbonic acid, water and ammonia disappear, and in their place, under the influence of preexisting living protoplasm, an equivalent weight of the matter of life makes its appearance? It is true that there is no sort of parity between the properties of the components and the properties of the resultant, but neither was there in the case of the water. It is also true that what I have spoken of as the influence of preexisting living matter is something quite unintelligible; but does any body quite comprehend the *modus operandi* of an electric spark, which traverses a mixture of oxygen and hydrogen? What justification is there, then, for the assumption of the existence in the living matter of a something which has no representative or correlative in the not living matter which gave rise to it? What better philosophical status has "vitality" than "aquosity?" And why should "vitality" hope for a better fate than the other "itys" which have disappeared since Martinus Scriblerus accounted for the operation of the meat-jack by its inherent "meat roasting quality," and scorned the "materialism" of those who explained the turning of the spit by a certain mechanism worked by the draught of the chimney? If scientific language is to possess a definite and

constant signification whenever it is employed, it seems to me that we are logically bound to apply to the protoplasm, or physical basis of life, the same conceptions as those which are held to be legitimate elsewhere. If the phenomena exhibited by water are its properties, so are those presented by protoplasm, living or dead, its properties. If the properties of water may be properly said to result from the nature and disposition of its component molecules, I can find no intelligible ground for refusing to say that the properties of protoplasm result from the nature and disposition of its molecules. But I bid you beware that, in accepting these conclusions, you are placing your feet on the first rung of a ladder which, in most people's estimation, is the reverse of Jacob's, and leads to the antipodes of heaven. It may seem a small thing to admit that the dull vital actions of a fungus, or a foraminifer, are the properties of their protoplasm, and are the direct results of the nature of the matter of which they are composed.

But if, as I have endeavored to prove to you, their protoplasm is essentially identical with, and most readily converted into, that of any animal, I can discover no logical halting place between the admission that such is the case, and the further concession that all vital action may, with equal propriety, be said to be the result of the molecular forces of the protoplasm which displays it. And if so, it must be true, in the same sense and to the same extent, that the thoughts to which I am now giving utterance, and your thoughts regarding them, are the expression of molecular changes in that matter of life which is the source of our other vital phenomena. Past

experience leads me to be tolerably certain that, when the propositions I have just placed before you are accessible to public comment and criticism, they will be condemned by many zealous persons, and perhaps by some few of the wise and thoughtful. I should not wonder if "gross and brutal materialism" were the mildest phrase applied to them in certain quarters. And most undoubtedly the terms of the propositions are distinctly materialistic. Nevertheless, two things are certain : the one, that I hold the statements to be substantially true ; the other, that I, individually, am no materialist, but, on the contrary, believe materialism to involve grave philosophical error.

This union of materialistic terminology with the repudiation of materialistic philosophy I share with some of the most thoughtful men with whom I am acquainted. And, when I first undertook to deliver the present discourse, it appeared to me to be a fitting opportunity to explain how such an union is not only consistent with, but necessitated by sound logic. I purposed to lead you through the territory of vital phenomena to the materialistic slough in which you find yourselves now plunged, and then to point out to you the sole path by which, in my judgment, extrication is possible. An occurrence, of which I was unaware until my arrival here last night, renders this line of argument singularly opportune. I found in your papers the eloquent address "On the Limits of Philosophical Inquiry," which a distinguished prelate of the English Church delivered before the members of the Philosophical Institution on the previous day. My argument, also, turns upon this very point of

limits of philosophical inquiry ; and I cannot bring out my own views better than by contrasting them with those so plainly, and, in the main, fairly stated by the Archbishop of York. But I may be permitted to make a preliminary comment upon an occurrence that greatly astonished me. Applying the name of "the New Philosophy" to that estimate of the limits of philosophical inquiry which I, in common with many other men of science, hold to be just, the Archbishop opens his address by identifying this "new philosophy" with the positive philosophy of M. Comte (of whom he speaks as its "founder") ; and then proceeds to attack that philosopher and his doctrine vigorously. Now, so far as I am concerned, the most Reverend prelate might dialectically hew M. Comte in pieces, as a modern Agag, and I should not attempt to stay his hand. In so far as my study of what specially characterizes the Positive Philosophy has led me, I find therein little or nothing of any scientific value, and a great deal which is as thoroughly antagonistic to the very essence of science as anything in ultramontane Catholicism. In fact, M. Comte's philosophy in practice might be compendiously described as Catholicism *minus* Christianity. But what has Comptism to do with the "New Philosophy," as the Archbishop defines it in the following passage ?

" Let me briefly remind you of the leading principles of this new philosophy.

" All knowledge is experience of facts acquired by the senses. The traditions of older philosophies have obscured our experience by mixing with it much that the senses cannot observe, and until these additions are dis-

carded our knowledge is impure. Thus, metaphysics tells us that one fact which we observe is a cause, and another is the effect of that cause ; but upon a rigid analysis we find that our senses observe nothing of cause or effect ; they observe, first, that one fact succeeds another, and, after some opportunity, that this fact has never failed to follow—that for cause and effect we should substitute invariable succession. An older philosophy teaches us to define an object by distinguishing its essential from its accidental qualities ; but experience knows nothing of essential and accidental ; she sees only that certain marks attach to an object, and, after many observations, that some of them attach invariably, whilst others may at times be absent. * * * * * As all knowledge is relative, the notion of anything being necessary must be banished with other traditions."

There is much here that expresses the spirit of the "New Philosophy," if by that term be meant the spirit of modern science ; but I cannot but marvel that the assembled wisdom and learning of Edinburg should have uttered no sign of dissent, when Comte was declared to be the founder of these doctrines. No one will accuse Scotchmen of habitually forgetting their great countrymen ; but it was enough to make David Hume turn in his grave, that here, almost within ear-shot of his house, an instructed audience should have listened, without a murmur, while his most characteristic doctrines were attributed to a French writer of fifty years later date, in whose dreary and verbose pages we miss alike the vigor of thought and the exquisite clearness of the style of the man whom I make bold to term the most acute thinker

of the eighteenth century—even though that century produced Kant. But I did not come to Scotland to vindicate the honor of one of the greatest men she has ever produced. My business is to point out to you that the only way of escape out of the crass materialism in which we just now landed is the adoption and strict working out of the very principles which the Archbishop holds up to reprobation.

Let us suppose that knowledge is absolute, and not relative, and therefore, that our conception of matter represents that which it really is. Let us suppose, further, that we do know more of cause and effect than a certain definite order of succession among facts, and that we have a knowledge of the necessity of that succession—and hence, of necessary laws—and I, for my part, do not see what escape there is from utter materialism and necessarianism. For it is obvious that our knowledge of what we call the material world is, to begin with, at least as certain and definite as that of the spiritual world, and that our acquaintance with the law is of as old a date as our knowledge of spontaneity.

Further, I take it to be demonstrable that it is utterly impossible to prove that anything whatever may not be the effect of a material and necessary cause, and that human logic is equally incompetent to prove that any act is really spontaneous. A really spontaneous act is one which, by the assumption, has no cause; and the attempt to prove such a negative as this is, on the face of the matter, absurd. And while it is thus a philosophical impossibility to demonstrate that any given phenomenon is not the effect of a material cause, any

one who is acquainted with the history of science will admit, that its progress has, in all ages, meant, and now more than ever means, the extension of the province of what we call matter and causation, and the concomitant gradual banishment from all regions of human thought of what we call spirit and spontaneity.

I have endeavored, in the first part of this discourse, to give you a conception of the direction towards which modern physiology is tending ; and I ask you, what is the difference between the conception of life as the product of a certain disposition of material molecules, and the old notion of an Archæus governing and directing blind matter within each living body, except this—that here, as elsewhere, matter and law have devoured spirit and spontaneity ? And as surely as every future grows out of past and present, so will the physiology of the future gradually extend the realm of matter and law until it is coëxtensive with knowledge, with feeling, and with action. The consciousness of this great truth weighs like a nightmare, I believe, upon many of the best minds of these days. They watch what they conceive to be the progress of materialism, in such fear and powerless anger as a savage feels, when, during an eclipse, the great shadow creeps over the face of the sun. The advancing tide of matter threatens to drown their souls ; the tightening grasp of law impedes their freedom ; they are alarmed lest man's moral nature be debased by the increase of his wisdom.

If the “New Philosophy” be worthy of the reprobation with which it is visited, I confess their fears seem to me to be well founded. While, on the contrary, could

David Hume be consulted, I think he would smile at their perplexities, and chide them for doing even as the heathen, and falling down in terror before the hideous idols their own hands have raised. For, after all, what do we know of this terrible "matter," except as a name for the unknown and hypothetical cause of states of our own consciousness? And what do we know of that "spirit" over whose threatened extinction by matter a great lamentation is arising, like that which was heard at the death of Pan, except that it is also a name for an unknown and hypothetical cause, or condition, of states of consciousness? In other words, matter and spirit are but names for the imaginary substrata of groups of natural phenomena. And what is the dire necessity and "iron" law under which men groan? Truly, most gratuitously invented bugbears. I suppose if there be an "iron" law, it is that of gravitation; and if there be a physical necessity, it is that a stone, unsupported, must fall to the ground. But what is all we really know and can know about the latter phenomenon? Simply, that, in all human experience, stones have fallen to the ground under these conditions; that we have not the smallest reason for believing that any stone so circumstanced will not fall to the ground, and that we have, on the contrary, every reason to believe that it will so fall. It is very convenient to indicate that all the conditions of belief have been fulfilled in this case, by calling the statement that unsupported stones will fall to the ground, "a law of nature." But when, as commonly happens, we change will into must, we introduce an idea of necessity which most assuredly does not lie in the observed facts, and has no

warranty that I can discover elsewhere. For my part, I utterly repudiate and anathematize the intruder. Fact, I know ; and Law I know ; but what is this Necessity, save an empty shadow of my own mind's throwing? But, if it is certain that we can have no knowledge of the nature of either matter or spirit, and that the notion of necessity is something illegitimately thrust into the perfectly legitimate conception of law, the materialistic position that there is nothing in the world but matter, force, and necessity, is as utterly devoid of justification as the most baseless of theological dogmas.

The fundamental doctrines of materialism, like those of spiritualism, and most other "isms," lie outside "the limits of philosophical inquiry," and David Hume's great service to humanity is his irrefragable demonstration of what these limits are. Hume called himself a sceptic, and therefore others cannot be blamed if they apply the same title to him ; but that does not alter the fact that the name, with its existing implications, does him gross injustice. If a man asks me what the politics of the inhabitants of the moon are, and I reply that I do not know ; that neither I, nor any one else have any means of knowing ; and that, under these circumstances I decline to trouble myself about the subject at all, I do not think he has any right to call me a sceptic. On the contrary, in replying thus, I conceive that I am simply honest and truthful, and show a proper regard for the economy of time. So Hume's strong and subtle intellect takes up a great many problems about which we are naturally curious, and shows us that they are essentially questions of lunar politics, in their essence incap-

pable of being answered, and therefore not worth the attention of men who have work to do in the world. And thus ends one of his essays :

" If we take in hand any volume of Divinity, or school metaphysics, for instance, let us ask, *Does it contain any abstract reasoning concerning quantity or number?* No. *Does it contain any experimental reasoning concerning matter of fact and existence?* No. Commit it then to the flames ; for it can contain nothing but sophistry and illusion."

Permit me to enforce this most wise advice. Why trouble ourselves about matters of which, however important they may be, we do know nothing, and can know nothing ? We live in a world which is full of misery and ignorance, and the plain duty of each and all of us is to try to make the little corner he can influence somewhat less miserable and somewhat less ignorant than it was before he entered it. To do this effectually it is necessary to be fully possessed of only two beliefs : the first, that the order of nature is ascertainable by our faculties to an extent which is practically unlimited ; the second, that our volition counts for something as a condition of the course of events. Each of these beliefs can be verified experimentally, as often as we like to try. Each, therefore, stands upon the strongest foundation upon which any belief can rest ; and forms one of our highest truths.

If we find that the ascertainment of the order of nature is facilitated by using one terminology, or one set of symbols, rather than another, it is our clear duty to use the former, and no harm can accrue so long as we bear in mind that we are dealing merely with terms and symbols.

In itself it is of little moment whether we express the phenomena of matter in terms of spirit, or the phenomena of spirit in terms of matter ; matter may be regarded as a form of thought, thought may be regarded as a property of matter—each statement has a certain relative truth. But with a view to the progress of science, the materialistic terminology is in every way to be preferred. For it connects thought with the other phenomena of the universe, and suggests inquiry into the nature of those physical conditions or concomitants of thought, which are more or less accessible to us, and a knowledge of which may, in future, help us to exercise the same kind of control over the world of thought as we already possess in respect of the material world ; whereas, the alternative, or spiritualistic, terminology is utterly barren, and leads to nothing but obscurity and confusion of ideas. Thus there can be little doubt that the further science advances, the more extensively and consistently will all the phenomena of nature be represented by materialistic formulæ and symbols. But the man of science, who, forgetting the limits of philosophical inquiry, slides from these formulæ and symbols into what is commonly understood by materialism, seems to me to place himself on a level with the mathematician, who should mistake the *x's* and *y's*, with which he works his problems, for real entities—and with this further disadvantage as compared with the mathematician, that the blunders of the latter are of no practical consequence, while the errors of systematic materialism may paralyze the energies and destroy the beauty of a life.

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