THE

BIBLIOTHECA SACRA.

ARTICLE I.

THE PARADOXES OF SCIENCE.[1]

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THERE is a somewhat general impression abroad in the world, that whatever is scientific is clear and free from doubt and difficulty. But such an opinion is as far as possible from the truth. The mysteries of existence, though seeming to be progressively solved by science, are never more than partially solved. Indeed, in the strict sense of the word, they are never solved at all. The attempted explanations of science, instead of being real solutions of mystery, are merely substitutions of one mystery for another, or, what is more frequently the case, of several mysteries in place of one.

I. THE THEORY OF GRAVITATION.

The Newtonian theory of gravitation is far from being so simple as it seems, and this its author clearly saw and was free to acknowledge. Newton's law was merely a mathematical statement of facts established partly by observation, but more largely by inference, since observation is never absolutely exact, and is always limited in its

[1]The second lecture in Professor Wright's Lowell Institute course on "The Scientific Aspects of Christian Evidences," delivered in Boston, November 26, 1896.

range. The statement, therefore, that all material objects are attracted toward each other by a force which is directly as the product of the combined masses, and inversely as the square of the distance, is itself a theory incapable of absolute verification; while the acceptance of the theory impales us on one or other horn of a dilemma from which it is not easy to be extricated. We must either believe that bodies act upon each other from a distance through a vacuum, or that matter is continuous in space, so that there is no such thing as a vacuum. In his third letter to Bentley, Newton declared that it was to him "inconceivable that inanimate brute matter should, without the mediation of something else which is not material, operate upon and affect other matter, without mutual contact." And again, "that one body may act upon another at a distance, through a vacuum, without the mediation of anything else by and through which their action may be conveyed from one to another, is to me so great an absurdity that I believe no man, who has in philosophical matters a competent faculty of thinking, can ever fall into it. Gravity must be caused by an agent acting constantly according to certain laws; but whether this agent be material or immaterial, I have left to the consideration of my readers."

So keenly were the difficulties of this paradox felt, that many of Newton's eminent contemporaries, especially upon the Continent, refused to accept the theory of gravitation, thus delaying its final triumph for a century. Huygens declared the theory to be absurd; John Bernoulli, that it was "revolting to minds accustomed to receiving no principle in physics save those which are incontestable and evident"; while Leibnitz called gravitation "an incorporeal, an inexplicable power." To the contemporaries of Newton, and indeed as we have seen to Newton himself, that one material body should act upon another at a distance seemed not only inconceivable but absurd.

The philosophical statements of this difficulty are easily understood and incapable of refutation. A material body can no more act *where* it is not that when it is not. According to the Newtonian hypothesis, matter in itself is inert and motionless. Its sole office is to receive and transmit or transform such motion as is imparted to it from the outside. The impartation of motion to a mass of matter is always from behind: it is by a push, and not by a pull. With reason did Newton's contemporaries assert that his law of gravitation seemed to compel the readmission of occult forces to the realm of science; while it had been the great mission of scientific men up to that time to banish such conceptions from the universe.

Nor have the difficulties of Newton's theory disappeared since his day. The acceptance of the theory as a fact has taken place in spite of the paradoxes which it involves, and mathematicians and physicists are as much puzzled as ever to find any ultimate explanation of the law. Gravitation is unlike all other forces of which we are cognizant, and cannot therefore be brought into harmony with them.

First, gravitation acts instantaneously, while all other known forces occupy appreciable time in passing from one portion of space to another. The swiftest rate of transmission of force with which we are familiar is that of light, which speeds at the rate of 187,000 miles per second, and crosses the space separating the sun from the earth in eight and one-quarter minutes. But the astronomers have shown, that, if the force of gravitation be not transmitted instantaneously, it must certainly be at a rate which is fifty million times greater than that of light—that is, it cannot be more than $\frac{1}{1000000}$ of a second in passing from the earth to the sun.[1] If its rate were less than this, it would have been detected by the careful observations which astronomers have already made. From the nearest fixed star the

[1] Smithsonian Report, 1876, p. 212.

light reaches us, traveling at the rate of 187,000 miles a second, in three years; but the force of gravity, if it requires any time at all to cross that space, cannot take more than two seconds. Astronomical calculations are based upon the assumption that the action of gravitation is instantaneous across all distances of space.

Again, gravity is absolutely indifferent to all intervening objects, and is inexhaustible. A grain of sand exerts its gravitating influence upon another grain upon the opposite side of the globe. The intervention of the earth neither augments nor abates the action of the mysterious power. It would act with equal power upon any number of grains situated at equal distances. Indeed the attractive power of every particle of matter would seem to be unlimited in capacity. The force exerted by the sun to hold the planets in their orbits does not to any degree exhaust the sun's power. The planets might be multiplied indefinitely, and the sun would continue to attract each addition to the family with a power which is directly as the product of the two masses, and inversely as the square of their distance apart.

This apparently unlimited capacity of the attractive force of gravitation perplexed and confounded Faraday to such an extent that he thought it to be in flat contradiction to the important and well-established modern doctrine of the conservation of energy. To Faraday, indeed, it seemed that a gravitating body possessed the mysterious power both of annihilating and of creating force. If, for example, a ball be projected to a height of ten miles from the center of gravity of another body, the attraction at the point at which the projectile force was overcome by the force of gravitation is only $\frac{1}{100}$ as great as it was at the distance of one mile, while, in returning again, the force of the gravitation in the mass increases a hundredfold.

To Faraday this seemed like an alternate annihilation and creation of force. When the bodies are removed from each other by ten units of distance, their mutual force exerted upon each other is only $\frac{1}{100}$ of what it was at the distance of one diameter. But it possesses now, what the physicists call, an energy of position one hundred times greater than before. When the bodies are permitted to fall through this space and collide, this potential energy manifests itself, first, in augmenting the velocity of the fall, and, finally, in the transformation of its energy of position into an energy of heat, which dissipates in space, and is lost, never to return again. The mass becomes cold when the heat is all radiated, but it does not lose any of its attractive power. Unlike heat, the power of attraction is indestructible by radiation. It continues its activity forever in its new position, reaching out its mysterious arms of influence instantaneously, and through all time, to the remotest realms of space.

Ever since the days of Newton, unceasing efforts have been made to explain gravitation by some theory of the impact of material elements upon each other, and by that means to avoid the absurdity of supposing action at a distance, or the action of a body where it is not. Newton himself at times cherished the theory that, as gravitation is merely constant stress, it was produced by the steady pressure of ethereal matter filling all space, but being much rarer in the dense bodies of the stars and planets than it is in the empty celestial spaces, growing denser and denser perpetually, in passing from them to greater distances, "thereby causing the gravity of those great bodies toward one another, and of their parts toward bodies; every body endeavoring to go from the denser part of the medium toward the rarer." [1] But as this involves an increase of density up to the point of infinity in the outer circles, it could scarcely be entertained; while, as it would also tend

[1] Optics, Bk. iii., appendix. Query 21.

to retard the planetary movements, he concludes that, as "there is no evidence for its existence, therefore it ought to be rejected. And if it be rejected, the hypothesis that light consists in pression, or motion, propagated through such a medium, are rejected with it."[1]

So great are the difficulties of this theory, that Newton at last came back to accept the position which, twenty-four years before, he had declared to be so absurd that no competent thinker could ever fall into it; and despairingly asks, "Have not the small particles of bodies certain powers, virtues, or forces, by which *they act at a distance?* . . . What I call attraction *may* be performed by impulse, or by some other means unknown to me. I use that word here to signify only in general any force by which bodies tend toward one another, whatsoever be the cause."[2]

In 1692, in Newton's third letter to Bentley, he had expressed himself similarly to this effect, averring that "gravity must be caused by an agent acting constantly according to certain laws; but whether this agent be material or immaterial, I have left to the consideration of my readers." Again, in the "Principia," at the conclusion of the third book, he writes: "Hitherto I have not been able to discover the cause of those properties of gravity from phenomena, and I frame no hypothesis; for whatever is not deduced from the phenomena is to be called an hypothesis. . . . To us it is enough that gravity does really exist, and act according to the laws which we have explained."

The recognition of this paradox by John Stuart Mill, and his confident acceptance of the facts which involve it, is even more remarkable than in the case of Sir Isaac Newton. Where the great discoverer halted and wavered, the logician marches boldly forward and cheerfully impales himself on one horn of the destructive dilemma. "No one now feels," says Mill, "any difficulty in conceiv-

[1] Optics, Bk. iii., appendix. Query 28. [2] *Ibid.*, Query 31.

ing gravity to be, as much as any other property is, 'innate, inherent, and essential to matter,' nor finds the comprehension of it facilitated in the smallest degree by the supposition of an ether; nor thinks it at all incredible that the celestial bodies can and do act, where they, in actual bodily presence, are not. To us it is not more wonderful that bodies should act upon one another 'without mutual contact,' than that they should do so when in contact; we are familiar with both these facts, and we find them equally inexplicable and equally easy to believe."[1]

But, notwithstanding the ease with which Mill disposes of the paradox, it still remains true that the greatest leaders in modern science are perplexed by it as much as Newton was, and efforts to explain gravitation by some theory of impact or of pressure, and thus to avoid the apparent absurdity of an attraction which is felt at a distance and through a vacuum, are as prevalent at the close of the nineteenth century as they were in the latter part of the seventeenth. Professor Tait[2] still maintains that the theory of Lesage is "the only even apparently hopeful attempt which has yet been made to explain the mechanism of gravitation." Lesage's theory was that all space is frequented by innumerable minute particles of matter moving with great velocity in every possible direction, and that the onward motion of a portion of these particles is intercepted by the masses of matter with which they come in contact. But where the course is free in both directions, the effect of these impacts is neutralized by the impact of those from an opposite direction. When, however, two bodies are in line, each would protect the other from a certain number of impacts upon the sides which are facing each other, and so give rise to a mutual attraction; in other words, two bodies produce between them a shadow of pro-

[1] Logic, Harper's ed., N. Y., 1867, pp. 461, 462.

[2] Lectures before the British Association, 1876, at Glasgow.

tection from the impinging molecules as they do from rays of light.

But, ingenious as this theory is, it involves more than one apparent absurdity as great as that which Newton perceived in action at a distance. The most patent of these is that urged by Clerk Maxwell, who shows that the impact of molecules which would suffice to produce gravitation would generate such an amount of heat that they would in a few seconds raise not only the body, but the whole material universe, to the melting-point.[1]

The other direction in which physicists have been looking for a rational conception of the force of gravitation is to the possible effects of waves of transmission through an all-prevalent ether, such as is hypothecated to account for the phenomena of light. The most carefully wrought out theory of this class is that of Professor James Challis,[2] an eminent mathematician of Cambridge, Eng., who assumes that the universe is pervaded by an ether which is defined to be "a uniform, elastic fluid medium pervading all space not occupied by atoms, and varying in pressure proportionally to the variations of its density. The theory recognizes no other kinds of force than these two, the one an active force resident in the ether, and the other a passive reaction of the atoms."[3]

This ether is supposed to be all-tremulous with vibratory waves of different lengths, each order of length giving rise to various exhibitions of force,—waves of a certain length producing heat; those of another length, light; those of

[1] Encyc. Brit., art. "atoms."

[2] Smithsonian Rep., 1876, pp. 247–254; Principles of Mathematics and Physics (Cambridge, 1869, pp. 750). A theory somewhat resembling this has been carefully wrought out by Mr. J. H. Kedzie in his interesting volume on Solar Heat, Gravitation, and Sun Spots (Chicago, 1886, pp. 304).

[3] Smithsonian Report, 1876, p. 247.

other lengths molecular attraction; and of still another length, gravity.

But, as heat manifests itself as a repulsive force, separating the particles from each other, while gravity is an attractive force, drawing the particles together, we have ethereal vibrations producing exactly opposite results; that is, while some of the vibrations are forcing the particles of matter toward each other, other vibrations are separating them from each other. Professor Challis undertakes to solve the difficulty by supposing that waves of different magnitude may produce opposite results,—those of large length producing attraction, and those of extremely small length producing repulsion.

Some of the most interesting paradoxes involved in this supposition will appear later, in connection with remarks upon the atomic theory of matter. But here it is sufficient to say, that the ceaseless vibrations of the all-pervading ether involve an omnipresent activity which is absolutely without any scientific explanation, and is flatly in contradiction to the modern doctrine of the conservation of energy. Professor Challis's carefully elaborated theory makes the atoms themselves the cause of those indefinitely minute vibrations involving repulsion; while the vibrations cf greater wave length, producing gravitation, must come from the outside, and be produced from some independent and inexhaustible source of energy. In short, this theory, like all others, in its attempt to account for gravitation, ends in a paradox. It is, scientifically speaking, absurd. But the facts, nevertheless, remain to warn us against making the limit of our conceptions the measure of the truth.

II. THE ATOMIC CONSTITUTION OF MATTER.

In close connection with these difficulties concerning the Newtonian theory of gravitation are those of the modern scientific conception of the constitution of matter. By numerous well-established scientific methods of proof, matter, according to the new chemistry, consists of sixty or seventy kinds of minute atoms which are collected into molecules and masses, or volumes, and held together by the mysterious force of molecular attraction, and kept apart to various degrees of distance by certain repulsive forces connected with the vibrations of an all-pervading ether. Under this view, a molecule, like a solar system, is simply a body of atoms in motion, like a swarm of gnats in the air; while the larger masses of matter represent more comprehensive systems of motion compounded with centripetal and centrifugal forces of mysterious origin.

According to the well-established results of modern science, the difference between the three forms of any particular kind of matter, namely, the solid, the fluid, and the gaseous, is produced by the presence of heat, which is a mode of wave motion in the all-pervading ether. As a result of an increased intensity of heat, the molecules of matter are separated from each other and thrown into larger orbits of revolution. We are familiar with this fact in the innumerable instances in which heat is transformed into motion, as in the cylinder of the steam-engine, and in the contrary process, where visible heat is produced by the arrest of motion. A few smart blows from the blacksmith's hammer, for example, will raise a slim bar of Swedish iron to a red heat. Water, however, furnishes us the most familiar illustration of the three forms of matter in their relations to heat. By the addition of a certain amount of heat, water is changed to a gas, in which condition the particles become so separated that they are invisible, and any amount of tension can be produced by confining them in an inclosed space, and subjecting the volume to increased degrees of heat. The theory of the steam-engine is that the heat applied to the boiler produces tension by increasing the vibratory motion of the ether in which the gaseous atoms are floating, thus imparting increased velocity to the ultimate particles of water confined in the piston. It is the impact of these infinitesimal atoms against the head of the cylinder, which pushes it along. It is the law of all gases that the volume is increased proportionally with the increase of temperature; but, as already said, this increased volume is merely increased activity of motion on the part of the ultimate atoms. With twice the temperature the motion of the inclosed atoms is twice as rapid. In other words, the application of twice the amount of heat to a gas doubles the orbit of atomic revolution in each instant of time.

But in connection with this theory several paradoxes arise. Newton supposed that the ultimate particles of matter were impenetrable and inelastic, that is, that they were absolutely hard. To use his own words, "These primitive particles, being solids, are incomparably harder than any porous bodies compounded of them; even so very hard as never to wear or break in pieces; no ordinary power being able to divide what God himself made one in the first creation."[1] But this supposition of the impenetrability and consequent inelasticity of the ultimate atoms involves a paradox. On this supposition the collision of atoms which is constantly supposed to take place in gaseous bodies would produce a loss of motion where we know there is perpetual motion; for nothing is more certain than that a volume of gas confined within definite limits, in a room of constant temperature, maintains its character without change. The molecular energy of gas does not become dissipated in space; its machinery does not run down by reason of the friction of its parts.

To escape this paradox of the perpetual motion and collision of absolutely solid atoms, a class of physicists (of

[1] Optics, 4th ed., p. 375; quoted in Stallo's Modern Physics, p. 41.

whom Lord Kelvin and the late Clerk Maxwell are most eminent representatives) have invented atoms which are absolutely elastic. These atoms can collide indefinitely without losing any motion. When followed out to its full length, this conception leads us back again to the Cartesian theory, which so long withstood Newton, and delayed the acceptance of gravitation, namely, that there is no such thing as vacuous space, but that all space is full of a fluid which is absolutely continuous, and whose particles, if we can speak of particles, are infinitely divisible. In this inconceivable fluid, possessing qualities which in any form of statement are absolutely contradictory to each other, there are supposed to be an indefinite number of inconceivable and self-contradictory vortices or whirlpools of force producing the phenomena which on the other theory are thought of as impenetrable atoms. Maxwell's treatise on the dynamical theory of gases is in large part a discussion of the "motions and collisions of perfectly elastic spheres"; while Lord Kelvin says, "We are forbidden by the modern theory of the conservation of energy to assume inelasticity or anything short of perfect elasticity of the ultimate molecules, whether of ultra-mundane or mundane matter."[1] Thus, upon this theory, we have the absolute creation of something out of nothing. The whirling motion of particles of fluid which are no particles, and from which inertia is by the very definition ruled out, produce all the effects of the indestructible atom of definite weight and of all the properties which are supposed upon the other theory. This, however, is but a single illustration of the readiness of scientific men to accept self-contradictory statements of facts revealed to them by experience and mathematical calculation.

III. THE MYSTERY OF LIFE.

So far we have dealt with facts and theories of a purely

[1] Stallo's Modern Physics, p. 42.

physical character. The forces of animate nature are even more perplexing, recondite, and paradoxical, if indeed it is proper to speak of more or less degrees of inconceivability where all is absolutely mysterious. The Darwinian theory of evolution, for example, is based upon the observed fact that in general the progeny is like the parent. This is the law of heredity, without which there could be no such thing as species. If the progeny was not in general like the parent, utter confusion would everywhere prevail in the animate world, and we could form no calculation of what the harvest would be from the seed which had been sown. Without this law there would be no warrant that hen's eggs would produce chickens, or that grapeseed would not produce thorns, or figs thistles.

At the same time this transmission of qualities from parent to offspring is not perfect: there is a limited range of variation, such that no two individuals are absolutely alike; contrary to the common belief, one pea is always distinguishable from another pea, and in more complex organisms the variations are still more marked.

The complexity of the problem which the scientific evolutionist endeavors to solve is so great that every attempted explanation of the theory leads one to the verge of absolute incredulity. Indeed, nothing can better illustrate the limitations of human thought in its endeavor to compass the nature of ultimate causes than the efforts of our leading philosophical naturalists to explain the law of heredity as displayed in the actual history of the vegetable and animal kingdoms; for not only are all these explanations manifestly incomplete in themselves and founded upon ultimate assumptions which defy explanation, but they are all so far unintelligible, or perhaps we should say inconceivable, that none of them can be made clear to anybody, not even to their own authors.

Not to attempt an exhaustive catalogue of these theories, it is sufficient to refer to a few which have attracted most attention by reason of the eminence of their advocates.

From Buffon and Bonnet of the eighteenth century we have inherited the theory that the original germs from which the whole succession of plants and animals have been evolved included within them miniatures of the whole succession. This has often been illustrated to the popular mind by the supposition that the bud of the oak contained in it a miniature tree, and that behind the bud was a still smaller miniature, and so on *ad infinitum;* so that the process of evolution was but an unfolding of real forms impressed upon the germ at the original creation.

Herbert Spencer's theory is that "germ-cells are essentially nothing more than vehicles, in which are contained small groups of the physiological units in a fit state for obeying their proclivity towards the structural arrangement of the species they belong to."[1] By "physiological units" he means "vitalized molecules" in "all of which there dwells the intrinsic aptitude to aggregate into the form of that species."[2] These vitalized molecules possess a mysterious polarity which he accepts as an ultimate fact.[3]

Mr. Darwin's theory was named by the author Pangenesis at first, and was thought by him to have some resemblance to the foregoing theory of Mr. Spencer; but from one of Darwin's letters[4] we learn that Mr. Spencer was unable to see any resemblance between the two theories, which, Darwin confesses, greatly relieved his mind, since he himself had utterly failed to be sure what Spencer meant by his polarized physiological units, and "so [to avoid charge of plagiarism] thought it safest to give my [Darwin's] view as almost the same as his [Spencer's]," while Spencer it seems returned the compliment by saying that he was not sure that he understood Darwin; yet, says

[1] Biology, Vol. i. p. 254. [2] *Ibid.*, p. 181. [3] *Ibid.*, p. 183.
[4] Vol. ii. p. 260.

Darwin, "I took such pains, I must think I expressed myself clearly." But that there was some difficulty with the theory Darwin was compelled to fear, since so few of his friends acknowledged their ability to understand it; for, he writes, "Bates says, he has read it twice, and is not sure that he understands it"; while "Old Sir H. Holland says he has read it twice, and thinks it very tough; but believes that sooner or later 'some view akin to it' will be accepted." Still Darwin declares that he feels "sure if Pangenesis is now stillborn it will, thank God, at some future time reappear, begotten by some other father, and christened by some other name."

The intellectual difficulties into which one is plunged by attempting "to connect by some intelligible bond" the facts of heredity may be best presented by giving a somewhat detailed account of Pangenesis and of the wonderful feats which it is supposed to accomplish in nature.

Briefly stated, the theory is, that organic bodies are composed of cells and colonies of cells which, though organized into unity by some mysterious power, are themselves units possessing a remarkable degree of independence, and "propagate themselves by self-division, or proliferation, retaining the same nature."[1] In a mysterious way some of these cells are made to contain the potentiality of the whole organism. In the lower forms of life every cell contains this power of reproduction, while in the higher forms the power is only partially limited. From any small section of the leaf of a begonia, for example, a perfect plant may be grown. Some freshwater worms when cut into forty pieces arise again to life in forty perfect animals. When the limbs of some of the lower animals are amputated, new and perfect limbs grow out to replace the old. Nor is this power wholly absent in the highest animal forms. Without this power of self-reproduction on the

[1] Animals and Plants, Vol. ii. p. 448.

part of the cells, there would be no such thing as the healing of a wound in the human body or the joining together of fractured bones.

But it is in the reproduction of plants and animals in connection with sexual processes that the profoundest mysteries are forced upon our attention. In these organisms the species is perpetuated only through the agencies of special cells, and that ordinarily when those of different sexes are united. The mystery is only appreciated when we consider both the minuteness of these cells and the burden which is laid upon them. To begin with, they are microscopical objects ordinarily invisible to the naked eye; yet upon them is laid the burden of receiving from all parts of the body or of the plant the potentialities which shall reproduce the individual in its entirety and continue to transmit specific characters to future generations.

In his efforts to connect the facts by "some intelligible bond," Mr. Darwin supposes that every cell in the body of the plant or animal "throws off minute granules or atoms, which circulate freely throughout the system, and when supplied with proper nutriment multiply by self-division, subsequently becoming developed into cells like those from which they were derived."[1] To these atoms he gives the name of gemmules. The "gemmules are supposed to be thrown off by every cell or unit, not only during the adult stage, but during all the stages of development." Lastly, he assumes "that the gemmules in their dormant state have a mutual affinity for each other, leading to their aggregation either into buds or into the sexual elements."

The smallness of these gemmules did not escape the notice of Mr. Darwin, nor did it stagger his belief in them, for, he says, "As each unit, or group of similar units throughout the body, casts off its gemmules, and as all are contained within the smallest egg or seed, and within each

[1] Animals and Plants, Vol. ii. p. 448.

spermatozoon or pollen-grain, their number and minuteness must be something inconceivable. I shall hereafter recur to this objection, which at first appears so formidable; but it may here be remarked that a codfish has been found to produce 4,872,000 eggs, a single Ascaris about 64,000,000 eggs, and a single Orchidaceous plant probably as many million seeds. In these several cases, the spermatozoa and pollen-grains must exist in considerably larger numbers. Now, when we have to deal with numbers such as these, which the human intellect cannot grasp, there is no good reason for rejecting our present hypothesis on account of the assumed existence of cell-gemmules a few thousand times more numerous."[1]

The strength and precision of the elective affinity displayed by these prolific gemmules is illustrated by Darwin in the case of the Compositæ, the species of which number about ten thousand; yet "there can be no doubt that if the pollen of all these species could be, simultaneously or successively, placed on the stigma of any one species, this one would elect with unerring certainty its own pollen."[2] The precision is still more wonderfully shown among animals when different varieties are crossed. For example, if a short-horned cow is crossed with a long-horned variety, the progeny shows the effect in the horns, and not in the horny hoofs, which are of the same material; while the "offspring from two birds with differently colored tails have their tails, and not their whole plumage, affected."[3] Still further he concludes that each particular feather of a bird "generates a large number of gemmules" which are possibly aggregated into a compound gemmule; for, complex as is the structure of a feather, "each separate part is liable to inherited variations."[4]

Having shown that sexual and asexual generation are

[1] Animals and Plants, Vol. ii. pp. 453–454.
[2] *Ibid.*, p. 455. [3] *Ibid.*, p. 455. [4] *Ibid.*, p. 458.

fundamentally the same, Parthenogenesis seems no longer wonderful to Mr. Darwin; "in fact, the wonder is that it should not oftener occur."[1] But while "the reproductive organs do not actually create the sexual elements," but "merely determine or permit the aggregations of the gemmules in a special manner," these organs do still have "high functions to perform." "They give to both elements a specific affinity for each other. . . . They adapt one or both elements for independent temporary existence, and for mutual union." At the same time it is refreshing to learn that "what determines the aggregation of the gemmules within the sexual organs we do not in the least know."[2] Finally, after saying that "the power of propagation possessed by each separate cell determines the reproduction, the variability, the development, and renovation of each living organism," and that "no other attempt has been made to connect under one point of view these several grand classes of facts," Darwin frankly confesses that "we cannot fathom the marvelous complexity of an organic being; but, on the hypothesis here advanced, this complexity is much increased. Each living creature must be looked at as a microcosm—a little universe, formed of a host of self-propagating organisms, inconceivably minute and as numerous as the stars in heaven."[3]

The force of this concluding remark will be lost if we do not pause for a little to bring before our minds some of the facts concerning the principle of reversion which Darwin declares to be "the most wonderful of all the attributes of inheritance"; for, as he truly says, "what can be more wonderful than that characters which have disappeared during scores, or hundreds, or even thousands of generations, should suddenly reappear perfectly developed." So that "we are led to believe that every character which occa-

[1] Animals and Plants, Vol. ii. p. 459. [2] *Ibid.*, p. 459. [3] *Ibid.*, p. 483.

sionally reappears is present in each generation . . . ready to be evolved under proper conditions."[1]

With many of the facts underlying these statements we are all so familiar that we cease to be impressed by their marvelous character. We know, for example, that a child oftentimes resembles his grandparent more than he does his parent, and indeed we are not much surprised when, through the law of reversion, the child reproduces the peculiar attributes of some even more remote ancestor. So strong is this tendency to reversion that the preservation of an improved variety of plants or an improved breed of animals can be maintained only at the price of constant vigilance on the part of the horticulturist or the breeder. It is doubtless true, as Darwin says, that "by the aid of a little selection, carried on during a few generations, most of our cultivated plants could probably be brought back, without any great change in their conditions of life, to a wild or nearly wild condition."[2]

When one adds to these facts the marvels concerning the metamorphoses through which the individuals of many species constantly pass, as when the caterpillar changes to the butterfly, and when peculiar instincts and mental characteristics develop only after a series of alternate generations or at particular stages in the life of the individual, one does not wonder at the difficulty experienced by some of Darwin's most eminent friends in seeing just what he meant by his theory, and in failing to find that "positive comfort" in it which the author himself professed to experience. It is not strange that "Hooker . . . seems to think that the hypothesis is little more than saying that organisms have such and such potentialities,"[3] or that Huxley failed "to gain a distinct idea" "when it is said that the cells of a plant, or stump, include atoms derived from

[1] Animals and Plants, Vol. ii. p. 447. [2] *Ibid.*, p. 45.
[3] Letters of Darwin, Vol. ii. p. 262.

every other cell of the whole organism and capable of development"; but preferred to say that "a single cell of a plant, or the stump of an amputated limb, have the 'potentiality' of reproducing the whole—or 'diffuse an influence'"[1] towards the accomplishment of this result, even though these words could give Darwin no positive idea.

At the present time the theoretical point most under discussion relates to the inheritability of acquired characteristics. It was the theory of Lamarck, that variation in animals was mainly produced by the effort of individuals to attain objects which were a little beyond the reach of their present capacity; and this principle was not wholly ignored by Darwin, who believed that the use or disuse of organs had much to do in producing transmitted variations. Still it puzzled him to see, on his theory, how this could be. "Nothing," he says, "in the whole circuit of physiology is more wonderful. How can the use or disuse of a particular limb or of the brain affect a small aggregate of reproductive cells, seated in a distant part of the body, in such a manner that the being developed from these cells inherits the character of either one or both parents?"

Weismann answers this question by absolutely denying the influence of external conditions on heredity. On the other hand, he affirms that acquired characteristics are not and cannot be inherited. In his view, variations originate wholly apart from the external conditions. He believes that immortality is an attribute of the cell, or what he calls the germ-plasm, and that there is absolute continuity in the development of this hypothetical basis of life. Wallace is in substantial agreement with Weismann, and these two leaders are supported by a large following of eminent younger naturalists who are designated as neo-Darwinians. The late Professor Romanes devoted the last years of his life largely to the defense and develop-

[1] Letters of Darwin, Vol. ii. p. 264.

ment of Darwin's views upon these points, and to answering the arguments of Weismann and Wallace.

The many criticisms to which Weismann's theory has been subjected have drawn out from him at last not only a defense, but an explicit statement of what is involved in his views, which is both exceedingly instructive and significant of the close connection between scientific theories concerning the origin of things and metaphysics.

The theory of Weismann with respect to the origin and development of species from germ-plasm was originally closely akin to the necessitarian theological systems which rested everything upon foreordination, and left nothing for free-will. This, however, was seen to overburden the material particles of germ-plasm upon any mechanical theory of their action. The great objection to his theory lay in the fact that variations in plants and animals are not haphazard; for, if they occurred at haphazard, definite varieties could not be maintained, even on the highest view of natural selection. To maintain a variety the selector must have something definite to select. Weismann meets the difficulty by throwing the principle of variation and of selection back into the unknown realm of germinal activity, supposing that in that realm, which is out of sight, if not beyond the realm of thought even, there is a struggle for existence going on analogous to that of which we hear so much in the visible realm of natural history. There is a survival of the fittest among the particles of Weismann's germ-plasm. Thus he says, "The struggle for existence takes place at all the stages of life between all orders of living units from the biophores recently disclosed, upwards to the elements that are accessible to direct observation, to the cells, and still higher up, to individuals and colonies." [1]

[1] Germinal Selection. An address delivered before the International Congress of Zoölogists at Leyden, September 16, 1895; translated from MS., by T. J. McCormack; published in The Monist, January, 1896, pp. 250–293; especially p. 291.

"If," he goes on to say, "there is any solution possible to the riddle of adaptiveness to ends,—a riddle held by former generations to be insoluble,—it can be obtained only through the assistance of this principle of the self-regulation of the originating organisms. . . . Selection of *persons* alone is *not sufficient* to explain the phenomena; *germinal* selection must be added. . . . It is true it leads us into a terrain which cannot be submitted directly to observation by means of our organs of touch and by our eyes, but it shares this disadvantage in common with all other ultimate inferences in natural science, even in the domain of inorganic nature: in the end all of them lead us into hypothetical regions."[1]

Earlier in this same address Weismann had confessed that "we cannot penetrate by this hypothesis to the last root of the phenomena"; and that "all our knowledge is, and remains throughout, provisional"; expressing surprise that "any living being could have the temerity to pretend even so much as to guess at the *actual* ultimate phenomena in evolution and heredity"; for, he avers, the whole question is a matter of symbols only, just as it is in the matter of 'forces,' 'atoms,' 'ether undulations,' etc., the only difference being that in biology we stumble much earlier upon the unknown than in physics."[2]

The appropriateness of these last-quoted phrases from Weismann is made even more clear when we consider the theory of life units and of living fluid as it is defended by Professor Minot,[3] who maintains that Darwin's theory of Pangenesis and of gemmules is untenable, and that Spencer's conception of "*physiological units*," although an advance on Pangenesis, is still insufficient; while the plastidules of Hæckel and the biophores and determinants of

[1] Monist, January, 1896, p. 292. [2] *Ibid.*, p. 286.

[3] Art. "Microscopical Study of Living Matter," North American Review, May, 1896, pp. 612–620; "On Heredity and Rejuvenation," American Naturalist, January and February, 1896, pp. 1–9, 89–101.

Weismann "have made a gay tournament of hypotheses," thus[1] leaving no theory so probable as his own; namely, that life is perpetuated not by hypothetical life units, but by means of a living fluid which he thus describes:—

"The physical basis of life is protoplasm; protoplasm consists of two fluids, intimately commingled, yet separate, and which may include various granules of solid organic substances, more or less complex, and also include globules of various liquids. This theory in its best form has been termed the foam theory, because foam offers the most familiar illustration of the kind of structure conceived by this theory as characteristic of living matter. As in foam, air and water are commingled, so in protoplasm are cell-sap and the proteid or albumenoid fluid commingled. The latter it is, which, when coagulated by our so-called preserving reagents, gives under the microscope the familiar appearance of a network of solid threads. This theory I consider by far the best theory of the nature of protoplasm yet advanced. . . . It seems to me [he says further] that we have now reached a point when we need no longer divide protoplasm into its living and not living constituents. It is all living, the water and salts as much as the proteids and other organic compounds. Its phenomena are displays of energy resulting, so far as we at present know, from chemical actions, the possibility of which is given by the commingling of substances in the foam-structure."

"The conception of protoplasm above advocated seems at first to involve a complete materialism [he continues], but against this conclusion I must protest, for I hold that an opposite interpretation of life best accords with our knowledge—namely, that since there appear to be vital phenomena, which do not occur without life, it is legitimate to assume that there is a special vital power, which is not necessarily identical with any form of physical energy, though it may be conceived to cause the transformation of energy. Indeed, it is perfectly thinkable that the universe would come to rest, were not the balance of the forms of energy disturbed by the life-power."[2]

In an article on "Heredity and Rejuvenation," Professor Minot is more precise, holding "that the hereditary impulse is distributed in very different cells, and is probably distributed equally through all cells" (p. 95). Rejecting germ-plasm in Weismann's sense, which he affirms does not exist, Minot holds that "the development of an organism does not depend upon a substance stored in special cells, but on a special condition (stage) of organization" (p. 93).

[1] North American Review, p. 618. [2] *Ibid.*, pp. 619–620.

Rejecting Weismann's theory of the "continuity of germ-cells," and Darwin's conception of Pangenesis, he adopts the conception of Nussbaum of "the continuity of the germinal substance." The problem, according to Minot, therefore, now is, what "is the explanation of the germinating power, and the propagation of this power" (p. 91). This is indeed the problem, and has been from the beginning. But it is difficult to see the fundamental distinction between these various theories, or how any of them avoid materialism and the paradoxes into which all forms of materialism eventually run. How can a cell carry in it a pattern of all that is to come, unless there is some physical substratum for it, and on any theory the process of subdivision as we recede from germ to parent germ leads us to the contemplation of elements smaller than the very atoms out of which the physicist makes the world.[1]

[1] The mysteries involved in the cell theory appear in the following representation of it by Professor G. C. Browne of Oxford, in an article on "The Present Position of Cell-Theory," in Science Progress for June, 1896, pp. 321–323:—

"It was Professor W. K. Clifford, I think, who first drew a graphic picture of the molecular forces which are at work in any chemical compound, by describing the atoms as linked to one another and dancing a sort of merry-go-round within circumscribed limits. We may carry on the illustration, which, fanciful though it may seem, is supported by physical and mathematical considerations. A biont is a great organized war dance, performed by a whole army corps. The individuals composing each company are the atoms, they are linked to one another by companies and each company dances its own figure. Every company is a molecule, and every company dance is but a part of a larger dance, in which the companies act in relation to one another, as the individuals act in the company dance. The larger dances are regimental dances and every regiment is a micella. The regimental dances are but parts of still larger brigade dances, and the brigade dances are but part of the great dance of the whole army corps, which, taken as a whole, is a biont. The illustration is not quite exact, for each company must not be considered as consisting of like individuals, but of many individuals of all arms, some like and some unlike, linked in such various ways that no two companies are the same, partly because of the proportions of different kinds of individuals composing them, partly because of the way in which those

The truth is that every effort so far made to discover what Darwin calls "an intelligible bond" harmoniously

individuals are linked together. Nor must we imagine that individuals are permanently attached to companies, nor yet companies to regiments, but that in the course of the dance individuals are passed from company to company, and companies from regiments to regiments, each conforming temporarily to the particular figure of that part of the dance to which he or it for the time belongs. Further than this the individuals engaged in the whole dance are never long the same; there are bystanders who for a time do not participate in the dance but are caught up one by one, whirled through the figures, passed from company to company, from regiment to regiment, and brigade to brigade, and are eventually passed out of the dance again, after having participated in some or all of the figures as the case may be. Every individual in the dance is at some time passed out of the dance, becomes a bystander, and may again be caught up and whirled along in the dance once more.

"The illustration is fanciful, if you please, but it is of the same kind as illustrations used to depict the play of molecular forces in the inorganic world. It serves a purpose in that it gives the imagination something to work upon, and it enables one to conceive of the immense complexity which is possible in a chemico-physical process. The army dance which I describe is capable of any number of combinations, a number amply sufficient to satisfy the needs of those who insist so strongly on the marvellous complexity of life. Let anybody imagine an army to be composed of four brigades, each brigade of four regiments, each regiment of ten companies, and each company to contain 100 individuals of the eight kinds, carbon, oxygen, hydrogen, nitrogen, sulphur, phosphorus, potassium, and iron, in varying proportions, and let him work out the possible combinations. I think he will be satisfied with the complexity.

"What then of heredity and of the capacity which I have mentioned for acquiring historic qualities?

"Believing as I do that the vital processes must in the end be attributed to a particular mode of molecular motion, I believe that it is the form of movement which is transmitted. Returning to my illustration, I would say that it is the figure of the whole dance which makes up the species, and that it is the figure—the mode of motion—which is inherited, clearly not the individuals engaged in the dance, except in a very small degree, for they are constantly coming into the dance anew and as constantly being passed out of it. Under certain circumstances there may be an excess of one or more kinds of new individuals pressing into one part of the dance which will affect the figure of the company dance which they crowd into, and this will affect regimental figures and ultimately, in decreasing degrees, the whole army figure. In this way we may picture to ourselves the action of external influences in bringing about variation."

connecting together the incalculable diversity of facts exhibited in the life of plants and animals becomes not only a mystery, but a paradox, and brings all investigators to a precipice facing a boundless metaphysical fogbank. The theories of the nineteenth century are not preëminently clearer than were those of the eighteenth. It is easy to show that Bonnet's theory of "incasement" rested on expressions which contained utter vacuity of meaning. He indeed supposed an evolution which was real—the pattern of the progeny having a real existence in the parental germ, supposing that the pattern of the whole development was really "incased" in the original created germ. "But," he says, "it is not necessary to suppose that the germ has all the features which characterize the mother as an individual. The germ bears the original imprint of the species, and not that of the individuality. It is on a small scale a man, a horse, a bull, etc., but it is not a certain man, a certain horse, a certain bull, etc."[1] As another has well expressed it, "in organs conceived as infinitesimal, shape, size, proportions, signified nothing.' "The ears, for example, in the germs of the horse were supposed to preexist as actual ears, but in what shape and proportions Bonnet never undertook to say. . . . They must have shape, but not the particular shape presented in the adult state."[2]

Careful study of more recent theories shows that in their ultimate analysis they are each as paradoxical as was their great predecessor. It is easy for Weismann to show that Spencer's theory of "physiological units" involves an incomprehensible complexity of molecular motion in every organic variation for which no cause is assigned, thus leaving his theory to rest on nothing. It is equally easy for Minot to show that Darwin's "gemmules" and Weismann's "biophores" are too clumsy to go through with all the ev-

[1] Quoted by C. O. Whitman, Monist, April, 1895, p. 423.
[2] *Ibid.*, pp. 422–423.

olutions demanded of them, but it is difficult to see how his own theory of "foamy germ-plasm" has any physical basis at all to stand upon.

The moral of this discussion may be stated in a few words. Religious philosophy does not by any means possess a monopoly of all the mysteries of existence. The truths of religion are not the only truths which apparently rest on paradoxical statements. All verbal statements of ultimate truth are paradoxical; but this arises partly from the essential infirmities of language. It is no less true in science than it is in theology that the whole truth is too complex to be compressed into single statements. The human imagination does not give us the full measure of the truth which we are compelled to believe.

These conclusions at once clear the field of a great mass of current objections to Christianity, since they show us that our knowledge of nature even at the close of the nineteenth century is entirely too superficial to give any weight to *a priori* objections to the central facts of the Bible. Nothing which we have learned of the constitution of matter or of the universe renders the conception of a miracle impossible, or materially increases its improbability. The worst foes of Christianity are not physicists, but metaphysicians. Hume is more dangerous than Darwin; the agnosticism of Hamilton and Mansel is harder to meet than that of Tyndall or Huxley; the fatalism of the philosophers is more to be dreaded than the materialism of any school of science. The sophistries of the Socratic philosophy touching the freedom of the will are more subtle than are those of the Spencerian school. Christianity, being a religion of fact and history, is a free-born son in the family of the inductive sciences, and is not specially hampered by the paradoxes which are connected with all attempts to give expression to ultimate conceptions of truth. The field is free for the reception of such moral evidence as it has pleased the Creator to afford us.