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ORDINARY MEETING, MAY 7, 1877.

C. BROOKE, F.R.S., VICE-PRESIDENT, IN THE CHAIR.

The Minutes of the last Meeting were read and confirmed, and the following elections were announced :—

MEMBER :—R. W. Bradford, Esq., Sutton.

ASSOCIATES :—Rev. T. R. Robinson, D.D., F.R.S., F.R.A.S., M.R.I.A., Director of the Observatory, Armagh; Rev. Canon C. Lane, M.A., Sevenoaks; Rev. A. G. Pemberton, M.A., London; Rev. P. D. La Touche, M.A., Ireland; M. R. Butler, Esq., London; J. L. Palmer, Esq., R.N., F.R.C.S., F.S.A., &c., Birkenhead.

Also the presentation of the following Works for the Library :—

"Proceedings of the Royal United Service Institution," Parts 89 and 90. *From the Institution.*

"Proceedings of the Smithsonian Institution." *From the Institution.*

"Proceedings of the United States Geological and Geographical Survey," Bulletin 4; and on the Grotto Geyser. *From the Survey.*

Smaller works from M. R. Butler, Esq., and Rev. G. D. Copeland.

The following paper was then read by the Rev. J. L. CHALLIS, M.A., the author being unavoidably absent :—

ON THE INDESTRUCTIBILITY OF MATTER. By the Rev. Professor CHALLIS, M.A., F.R.S., F.R.A.S., Plumian Professor of Astronomy and Experimental Philosophy in the University of Cambridge.

IN the title prefixed to this essay I have adopted an expression, the current signification of which is, that no existing particle of matter ever will be or can be destroyed.

I think it right to state at the outset that I propose to adduce arguments, drawn both from physical science and from Scripture, which lead to the conclusion that this view of the quality of matter is untrue.

2. Taking, first in order, the arguments which have relation to physical science, I have no hesitation in beginning with the admission that chemical experiments have shown that whatever modifications substances may undergo by analysis or synthesis, and in whatever way different substances may be combined, the quantity of matter as measured, either by the number of the indivisible elements, or by weight, remains unchanged. Such experimental facts seem to have suggested the idea of the indestructibility of matter, and the inference would be perfectly valid if physical science consisted exclusively of what is known by experiment, and if we could learn nothing about matter beyond what experiment teaches. But I shall maintain that this is not a true definition of physical *science*, inasmuch as such science, when complete, rests not on experiment alone, but on experiment combined with *reasoning*. Experiment may establish *laws*, but science perfected consists in giving *reasons* for laws. The conclusion to which the argument I am about to adduce relative to the intrinsic quality of matter points, wholly depends on this twofold character of physical science, and on the mutual relation of the two parts; but before entering upon the general argument, it is necessary to go through a preliminary discussion of the nature of the *facts* with which we are concerned in physics. These facts are not all of the same kind, but range themselves under two essentially different categories.

3. The last assertion may be exemplified by the following familiar instance. From ordinary experience we know that *sounds*, whether unmusical or musical, are generated by agitations produced in the air: if, guided by experiment, we define the air to be a perfectly elastic fluid substance, pressing always in exact proportion to its density if its temperature be given, and susceptible of no change as to quantity by states of pressure or motion, we can, according to the principles of the science of Hydrodynamics, obtain differential equations, the complete solution of which would be adequate to tell us the consequences which result from certain disturbances of the fluid produced under given circumstances. In particular, we might thus ascertain, in the instances of disturbances which are found to generate *musical* sounds, what are the laws of the movements and variations of pressure of the air that produce this effect. It would, in fact, be thereby shown that the movements are *vibratory*, that they are subject to a law of propagation, and that being accompanied by variations of

pressure, they are capable of acting dynamically on the solid organs of the ear, to which they are carried by the propagation. The agitation thus communicated to the parts of the ear immediately acted upon by the aërial impulses, is eventually conveyed, through the auditory apparatus and nerves, to the brain, and there our investigation of the consequences of the initial disturbance comes to an end. It remains, however, to make the remark that this tracing of consequences does not lead up to the *sensation* which all the world calls sound, but is solely concerned with the *material* conditions, antecedent and concomitant, without which the sensation is not *felt*.

4. This distinction, which has a very important bearing on the argument I propose to adduce relative to the destructibility of matter, has been much overlooked both by physicists and metaphysicians, and for some reason, which I do not understand, appears to be with difficulty apprehended. I called attention to it in the Introduction to my work entitled *Creation in Plan and in Progress*, published in 1861, where I have maintained, as I still do, that the sensation of sound is a *fact* of a certain class, but essentially different from the class of the facts, such as the pressure and vibrations of the air, under which, as material conditions, the sound is perceived. Just so, on the reasonable hypothesis that phenomena of light result from agitations of a universal ethereal medium, the sensations of light and colours are entities altogether diverse from the concomitant vibrations of the ether. So, also, the sensations of taste and smell are of a character not to be confounded with the materiality of the conditions under which alone they are felt. In short, it must be admitted, that in physics there are brought before us facts of two kinds, in such manner distinguished from each other, that whereas one kind cannot be dissociated from properties of matter, the other is certainly *not material*. Further, it may be asserted that co-ordinately with this distinction as to essence, there exists such *correspondence* between the two classes of facts that for every variation as to quality or degree in the material conditions, there is an analogous variation in the immaterial sensations, or *vice versâ*.

5. The foregoing separation of physical facts into two classes is a necessary preliminary to the argument that will be subsequently unfolded respecting the destructibility of matter. The argument will have to commence with establishing the position, already referred to in sec. 2, that physical science consists of two parts; what is known by experiment merely, and what is derivable from the results of experiment by joining therewith results obtained by theoretical reasoning; and that

to constitute it in its entirety one of these parts is as indispensable as the other. In order to maintain this position completely, it would be requisite to go over the same ground as that occupied by the major part of the paper "On the Metaphysics of Scripture," which I submitted to the Institute on May 1 of last year. For my present purpose it may suffice to recapitulate some of the arguments adduced in that paper, and to cite others by reference to the numbers prefixed to the paragraphs in which they are contained.

6. It will be found that in that communication I have distinguished between the two departments of physics by saying, that one part wholly consists in the discovery of facts and laws by means of experiment and observation, and the other in accounting for the facts and laws by *mathematical reasoning* founded on certain antecedent *premisses*. Reference was made, for illustration, to the scientific labours of Galileo, Kepler, and Newton. It was argued that Newton's calculation of the movements produced by the action of *forces* on material particles, was not possible till Galileo had certified by experiment the parabolic motion of a projectile acted upon by terrestrial gravity. And again, after Newton had discovered how to calculate the effects of an attractive force emanating from a centre (a vast achievement), and had proved abstractedly, on the *hypothesis* that the force diminished with distance according to the law of the inverse square, that a particle of matter under its influence would describe a conic section, the result would have been barren and simply speculative, unless observations, such as those of Tycho Brahé and Kepler, had shown that the elliptic movement was a physical reality. This is an instructive instance of the mutual relation between the parts respectively performed by observation and by theoretical reasoning. It is obvious that we know more about the movements of the planets than could have been gathered from the results of Kepler's labours, because from these alone it was not possible to learn whether, or in what manner, the movements were determined by the action of *force*. Newton's reasoning not only accounted for the elliptic motion, but also indicated that it was *caused* by force acting in an ascertained definite manner: the Newtonian theory of gravitation appears to have exhibited the very first instance of a fact of nature being demonstratively ascribed to a *causative* antecedent.

6*. It is a distinguishing characteristic of the theoretical department of physical science, that the reasoning it requires is always and necessarily founded on *hypotheses*. The reason for this necessity is, that the very purpose of theoretical investigation is to ascertain the truth or untruth of hypotheses

by comparison of results derived from them by mathematics with certified matters of fact. In so far as the results account for the matters of fact, the truth of the hypotheses is established, and an advance is made in physical science. The hypotheses of the theory of universal gravitation are, first, that the force varies with distance according to the law of the inverse square; and, secondly, that it emanates from every particle of matter and acts according to that law on all other particles. The combination of the reasoning of physical astronomy with the data of observational astronomy is considered at the present day to have fully established the truth of those hypotheses. It is sometimes supposed that Newton demonstrated the law of the inverse square. This is true only so far as he gave a proof of it *à posteriori*, that is, by deducing, mathematically, from the hypothesis of that law, results which were found to be verified by facts of observation. It is not possible by any such reasoning as that employed for demonstrating the propositions of physical astronomy to give an *à priori* demonstration of the law of gravity. I do not say that an *à priori* demonstration is not possible; but if it be possible, it must be effected by theoretical reasoning of a more comprehensive order, including, together with the law of gravity, the laws of other physical forces.

7. The department of theoretical science designated above as physical astronomy, is only a limited portion of the whole domain of science that may be comprehended under the terms "theoretical physics." It is, however, a part separated from the rest by the circumstance that the calculations it requires consist in the formation and solution of differential equations containing in the ultimate analysis *two* variables. For assisting the human intellect in extracting from given relations between what is known and what is unknown information respecting the latter, no other general method has been invented than that of forming equations in accordance with the data, and obtaining the desired information by solving the equations. Common algebraic equations, as is well known, are formed so as to express given relations to which a certain number of unknown quantities are subject, and it is proposed by treatment of these equations, according to rules of reasoning, to extract from them the values of the unknown quantities. In order that this may be done, the number of the equations must be equal to the number of the unknown quantities, and by known rules they have to be reduced to a single equation containing one of the unknown quantities. Then the value of this unknown quantity is ascertainable by solving the equation according to certain specific rules, and when this is known, all

the others are derivable from it. It is to be noticed that what is thus found out is an unknown *quantity*. In an analogous manner, the solution of a *differential equation* containing two variables, determines an unknown relation between the variables in the form of an *algebraic equation*, involving the variables together with arbitrary constant quantities introduced by the rules of the solution. This equation expresses the relation that subsists between the variables under every change of their actual values, and is, in fact, the answer which it was proposed to obtain by forming the differential equation. It was virtually by this process that Newton proved that the form of the orbit of a planet is given by the equation of a conic section. By having the arbitrary constants at disposal, the abstract solution may be made to apply to an actual instance. For example, a few observations such as those which Kepler employed to determine the form of the orbit of Mars, would suffice to fix very approximately the arbitrary constants in the analytical solution, and thereby obtain that equation of the planet's elliptic path which Kepler deduced with so much labour from a very large number of observations. In physical astronomy we have often to deal with equations involving more than two variables; but in such cases the number of the variables is always one more than the number of the equations, so that the several equations are reducible to a single one involving only *two* of the variables.

8. But in physical science problems come before us of such kind that the single differential equation to which the several differential equations formed to express the given conditions of a proposed question are reducible, contains not fewer than *three* variables. The problems I refer to relate to phenomena of *light, heat, electricity*, and *magnetism*. The analytical solutions of equations that contain three or more variables, and the applications of the solutions in answering questions of the above-mentioned classes, constitute an advance in physical theory of the same kind as that which was made when the solutions of equations containing two variables were applied in physical astronomy. But on account of the greater comprehensiveness of the equations, and complexity of the conditions which their solutions have to satisfy in order to account for experimental facts, the answers to these questions are attended with difficulties, which, hitherto, can only be said to have been partially overcome. It is certain, however, that if physical science be something more than the certifying of facts and laws by experiment, and if, in order to be complete, it must be capable of accounting for experimental facts and laws by reasoning based on definite and intelligible principles, there

is no other course by which it can advance towards perfection than by improved methods of solving and interpreting the solutions of partial differential equations. As in the case of physical astronomy, *hypotheses* have first to be made (see sec. 6*), differential equations have to be formed on the basis of the hypotheses, these equations have to be solved, and the solutions brought into comparison with the data of phenomena proposed for explanation. In proportion as special facts, or facts grouped under formulated laws, are by this process accounted for, the hypotheses are proved to be true, and our knowledge of the natural operations whereby phenomena are produced, is augmented.

9. I have already, in secs. 13–29 of my Paper on "The Metaphysics of Scripture," indicated the principles which, according to the Newtonian philosophy, regulate the hypotheses of theoretical physics. The most important governing principles are, first, that the essential or ultimate qualities of matter and force are such as can be fully understood from *personal sensation and experience*, and, in the second place, that qualities which are proper to be made the basis of theoretical calculation cannot themselves be quantitatively variable, or expressible in numerical terms, because it is the very purpose of theoretical inquiry to account for all facts and laws so expressible. Accordingly, the law of the inverse *square*, as involving a numerical term in its expression, ought to admit of being accounted for theoretically. This point will be adverted to farther on.

10. After these preliminary considerations, I am prepared to state in distinct terms the *hypotheses of theoretical physics* which will be adopted in the subsequent general argument. They are simply these:—

I. All matter that we are cognizant of by our senses is composed of discrete atoms.

II. An atom is a very small sphere, inert, movable, and of finite and invariable magnitude.

III. All *active* physical force is pressure upon the atoms of visible and tangible substances by a uniform and indefinitely extended ethereal medium, itself atomically constituted, and pressing always and everywhere in exact proportion to the number of its atoms, conceived to be all of the same size, in a given space, or, what for brevity will be called, "its atomic density."

These hypotheses have been adopted in conformity with *à priori* principles enunciated by Newton at the beginning of the third book of the *Principia* and in its concluding paragraph. It is not

pretended that Newton either did state, or, considering the deficiencies of mathematical and physical knowledge in his day, could have stated, the axioms of natural philosophy in exactly the foregoing terms; but the views propounded in the portions of the *Principia* referred to, and especially what he has asserted, in the Third Rule of Philosophizing, to be "the foundation of all philosophy," are in perfect accordance with the three kinds of hypotheses above defined, and, I may say, have to a great extent suggested them.

11. Before proceeding to inquire by what arguments the truth of these hypotheses may be established, it must first be settled that they conform to the two regulative conditions stated in sec. 9, according to which they must be perfectly intelligible from sensation and experience, and must not involve any assertion expressive of variation or degree. With respect to the first hypothesis, since we know by common experience that masses can be broken up into parts, and these parts into smaller parts, and so on, it is quite conceivable that all bodies may be composed of very minute parts, and it is not inconceivable that there may be a limit to the divisibility into parts. Thus to say that matter is composed of *atoms* properly so called, is an intelligible assertion, apart from and prior to any evidence that such is its composition. And the further assertion that matter is composed of *discrete* atoms, that is, atoms with intervening spaces, is alike intelligible.

12. Again, when it is said of an atom, that it is a very small inert sphere of invariable magnitude, there is nothing in this definition which is not perfectly intelligible from sensation and experience; for from sensation we can perceive what inertia is in masses, and thence infer what it is in their component parts (see sec. 15 of "Metaphysics of Scripture"), and by the senses of sight and touch we can understand what is signified when an atom is said to be a sphere of invariable magnitude. Thus the atom, as above defined, is conformable to *both* the regulative principles laid down in sec. 9.

13. With respect to the third hypothesis, the definitions of the ether and of the mode of its pressure on the atoms involve no postulates that are not perfectly intelligible from what we know by experience of the dynamical properties of air of given temperature. And as to the quality of *pressure*, it suffices in this philosophy to appeal to the fact that we *feel* what it is when we press with the hand against any solid substance. (More will be said on this point in a subsequent part of the essay.) It might, however, be urged that inasmuch as the third hypothesis assumes that the pressure of the ether is always and everywhere proportional to its atomic density, it

implies that the density and pressure admit of *variation*, and consequently violates the second of the regulative principles stated in sec. 9, according to which a primary hypothesis must contain nothing expressive of variability. An explicit answer may be given to this objection. The two hypotheses which precede the third affirm conjointly that all matter consists of an aggregation of inert spherical atoms, of invariable magnitude, susceptible of motion, and separated from each other by intervening spaces. Hence it is a direct *inference* from the antecedent hypotheses, and not a new hypothesis, to say that matter may be conceived of as composed of atoms in different degrees of aggregation, or that the number of atoms of a given substance in space of given dimensions may be different at different times and different positions. This inference may consequently be logically employed in the enunciation of the third hypothesis, which assumes not only that the ether *presses*, but that the pressure is always and everywhere in exact proportion to its atomic density. This last assertion is certainly a *primary* hypothesis, and as such is required to be conformable to the same regulative principles as the other primary hypotheses. Now the mathematical expression of this hypothesis affirms that there exists, under all circumstances of the motion and density, an invariable numerical quantity by which, if the variable numerical quantity expressing the atomic density be multiplied, the product is the numerical quantity expressing the pressure. Hence as the quality of pressure, and the variability of atomic density, may, from what is said above, be legitimately assumed in stating the third hypothesis, it follows that this hypothesis only postulates the existence of that *invariable* factor, and consequently, as being also expressed in intelligible terms, it may be pronounced to be conformable to rule. Mathematical investigation founded on the hypothesis has shown that the constant factor signifies that the fluid is endowed with *a constant intrinsic elasticity*, in virtue of which it has the property of pressing, and also of propagating the effect of any agitation produced in it at a constant rate through space.

14. In addition to being conformable to the rules above indicated, the hypotheses are required to satisfy the condition of giving the means of instituting *theoretical calculation*, by the results of which, compared with observation and experiment, their truth may be tested. Their applicability and sufficiency for this purpose in all the different departments of physics will accordingly have to come under consideration in the sequel of our argument.

15. Before proceeding farther in the general argument, it

will be proper to remark that hypotheses proposed for physical inquiry are adapted to meet every demand that may be legitimately made upon them, if they are expressed in terms rendered intelligible by sensation and antecedent experience; and if they consist only of definitions and postulates which involve no variable elements, and on that account are suitable for being made foundations of theoretical calculation. Presuming, as I think I may for the reasons already given, that the adopted three hypotheses do in fact fulfil those conditions, I am entitled to disregard any mere expression of disapproval of them, whether wholly or in part, inasmuch as their claim to acceptance is to be tested, and can only be established, by comparison of results obtained from them by *mathematical reasoning* with certified facts. Any arguments, however, bearing upon the validity of such reasoning, I am bound to take notice of, and, to the best of my ability, shall endeavour to answer.

16. It will be also worth while to advert here to a mode of philosophy advocated in the present day, which is directly opposed to the *rules* of philosophizing laid down in Newton's Principia. It appears that some of my contemporary physicists absolutely refuse to accept the method of conducting physical inquiry by means of *à priori* hypotheses, although (as has been argued in secs. 6–8), Newton adopted this process in his theory of universal gravitation; and also gave rules for applying an analogous method to account theoretically for the laws which govern the various kinds of relation between matter and force. This opposition to the Newtonian *à priori* principles of philosophy comes mainly from the advocates of views such as those which are developed in the work entitled *The Unseen Universe*. I propose, therefore, as contributing to the purpose of this essay, to state briefly what I conceive to be the origin and character of those views, and why they are incompatible with the Newtonian philosophy.

17. The principles of physical philosophy as respects the ultimate qualities of matter and force, which were so well propounded at the epoch of Locke and Newton, were in a short time set aside by the admission of hypotheses not conformable with the Newtonian rules of philosophizing. In particular, it was assumed that two portions of matter in presence of each other mutually attract, in virtue of *intrinsic* force resident in an unintelligible manner in each, and acting in an unintelligible manner through the space between them. Newton distinctly repudiated this hypothesis. It was so framed that while it allowed of ascertaining the *law* of the mutual action as depending on the distance between the bodies, it precluded all inquiry

as to any extraneous *cause* of such action, or as to the reasons for its being attractive rather than repulsive. Taking advantage of the defect of knowledge respecting the *modus operandi* of gravity necessarily incident to an early stage of physical science, Hume made the gratuitous assertion that in philosophy we have nothing to do with *causes*, but only with *laws* of sequence of phenomena, and that such laws are fixed and immutable. This doctrine was maintained, or involved, in most of the writings of succeeding metaphysicians, and some of those of Germany even sought to prove, by metaphysical argument, that "the action at a distance" is a necessary truth. It is not to be wondered at that the prevalence of such views should have had the effect of promoting attention to the *empirical* part of philosophy, which is concerned only with facts and laws, as certified, either directly or by mathematical inference, by experiment, to the exclusion of *theoretical* philosophy truly so called, which accounts for facts and laws by mathematical reasoning founded on intelligible hypotheses. This tendency of modern empirical philosophy to put aside true and ultimate theory is conspicuous in the work above mentioned (sec. 15), and seems to have determined in great measure the character of its contents. That I have ground for saying this will appear from the following quotation taken from the sixth page of *Lectures on some Recent Advances in Physical Science*, by Professor P. G. Tait, one of the authors of *The Unseen Universe*. He there asserts that "physical science, in order that advances may be made in it, is to be based entirely on experiment, or mathematical deductions from experiment. There is nothing physical to be learnt *à priori*. We have no right whatever to ascertain a single physical truth without seeking for it physically" (meaning, I suppose, experimentally). Accordingly in this empirical system, there is entire silence respecting the hypotheses which Newton considered to be the foundation of all philosophy, and mathematical calculation for determining on the principles of hydrodynamics the motions and *pressure* of the ethereal medium, is persistently avoided. Yet there is actually no contrariety between these two aspects of physical philosophy—the one just as much as the other being dependent for its establishment on observation and experiment. They are, in fact, related to each other in the same manner as are observational astronomy and physical astronomy, the latter of which derives its foundation and reality from the other. The author of the above passage is clearly not aware that empirical philosophy is only a step towards true and ultimate philosophy, and that physical *science* is really *advanced*, only so far as the physical laws discovered and formulated by means

of experiment are shown by mathematical reasoning to be consequences of ulterior intelligible principles. The perfection of physical science consists in giving reasons for physical laws.

18. In order, farther, to exhibit the antagonism of the philosophy of *The Unseen Universe* to that of Newton, I quote as follows from Art. 139, page 107 (1st ed.):—"After inertia, which is not accounted for by any of the hypotheses as to the ultimate nature of matter which we have just given, the most general property of matter which we recognize is that of universal gravitation." This assertion can, I think, be only understood as meaning that gravity is a property of matter in the same category as inertia; whereas Newton says, at the end of his Third Rule of Philosophy, that he by no means affirms gravity to be essential to bodies, that he takes *vis inertiæ* to be the only intrinsic ("insita") force, and that this force is invariable ("immutabilis"), whilst, on the contrary, gravity diminishes with increase of distance from the earth. (These views accord with the rule I have adopted in sec. 11, of not admitting qualities susceptible of variation to be primary, which rule, of course, excludes gravitation from the class of primary qualities.) It is right, however, to take into consideration that although these authors speak of gravitation as a "property" of matter, they fully assent to Newton's dictum respecting the unreasonableness of the assumption of action at a distance without intermediate agency (*U. U.*, Art. 140, p. 109). But the acceptance of Newton's authority in this particular, which is hardly consistent with their treatment of his philosophy in other respects, is followed by a statement of various suppositions made to account for gravitation, which appear to be of an extremely speculative and arbitrary character. Preference seems to be given to the agency of "ultra-mundane corpuscles, in infinite numbers, flying about in all directions with velocities enormously great." These corpuscles are supposed to rain freely on the interior particles of masses, and by their impacts to produce the effect of gravitation. It is a peculiarity of the phase of philosophy I am referring to, to substitute for pressure, as ordinarily understood, the effect of the impacts of an immense number of exceedingly minute particles. Thus Professor Tait, in page 324 of the before-cited Lectures, says, "One of the results arrived at as to the motion of swarms of impinging particles is, that in a mass of hydrogen at ordinary temperature and pressure, every particle has, on an average, 17,700 millions of collisions per second with other particles—that is to say, that number of times in every second it has its course changed. And yet the particles are moving at a rate

of something like 70 miles per minute." But it is admitted that this flying about of particles does not do work properly unless it be supplemented by "*guidance*" applied to some of the particles by the finite intelligence of certain "demons" (*U.U.*, Arts. 111–112, pp. 87–89). Added to all this, Professor Sir William Thomson says that we are to conceive of these particles as being simple, or involved "vortex-rings," which are strictly *atoms*, because having the property of "wriggling" they cannot be *cut* (*U. U.*, Art. 133, p. 103). This conception of the form and qualities of the atom is derived solely from the solution of a hydrodynamical problem by Helmholtz, from which, in the opinion of Professor Thomson, there results vortex-motion of so absolutely unalterable a character that if the atom be taken to be a vortex-ring, an argument might thence be deduced "in favour of the eternity of ordinary matter." (See *U. U.*, Art. 152, p. 118.) Having for many years bestowed particular attention on hydrodynamical questions, I might, if the occasion permitted, dispute the validity of this interpretation of Helmholtz's solution, and, at all events, call in question the applicability of his reasoning to determine the ultimate form and destination of matter. But it will suffice for my present purpose only to remark that a system of philosophy which arrives at the qualities of the atom by means of an abstruse piece of mixed mathematics is utterly at variance with the Newtonian rule of defining an atom in terms intelligible from *the common sense* and experience of mankind, the reality of the hypothetical atom being left for decision by an adequate number of comparisons of results obtained by mathematical reasoning based on this and related definitions with matters of fact.

19. The foregoing exposition of the character and results of this novel scheme of physical philosophy will, I hope, enable members of the Institute interested in these questions to form a judgment of the weight to be given to views which the upholders of such philosophy may express in opposition to the argument with which I am about to follow up the preceding introductory considerations. For my part, I have no hesitation in saying, that, according to my judgment, the arbitrary speculations detailed above, and the inferences drawn from them, go quite beyond the limits of sober philosophy. Now it may be asserted that the course taken by these physicists is avowedly a departure from the Newtonian abstract principles of "Natural Philosophy," the adoption of which forms an essential part of my argument. Hence, since it appears that mathematical physicists of undoubted ability, who have rejected those principles, have been conducted by a course of empirical reasoning

to results such as it is impossible to accept, I feel all the more assured of the correctness of the process of *à priori* reasoning I have entered upon, and accordingly I shall carry on the argument to the end, without having further regard to the adverse views of empirical theorists.

20. Having now shown that the three hypotheses in sec. 10 are proper for being employed as a basis of theoretical investigations conducted by mathematical reasoning, and having also argued that empirical theory derived immediately from experiment, being contributory to the establishment of ultimate theory resting on true *à priori* hypotheses, cannot be contradictory to the latter, I proceed, in the third place, to inquire whether it can be *proved* that the three hypotheses constitute *a true and adequate foundation of a general physical theory*. Very important consequences, relative to the material universe, follow from an affirmative answer to this inquiry. Now it may be taken for granted that the only possible way in which the answer can be reached, is to accept the hypotheses as foundations for applying mathematical reasoning in the several departments of physics in conformity with their respective definitions, and then to test numerical values obtained relatively to given phenomena by means of the theoretical calculation, by comparisons with numerical values relative to the same phenomena obtained directly by experiment. Moreover, the answer cannot be completely given till the test has been fully applied in *every* department of experimental physics. To contribute towards making progress in this large field of inquiry has been the professed object of my mathematico-physical researches during many years. Before adverting to the results arrived at, it will be proper to direct attention to a special dynamical quality pertaining to the atom, and essentially involved in those researches, which hitherto I have not expressly taken into consideration.

21. According to definitions in secs. 10–12, the hypothetical spherical atom is not susceptible of change, either as to form or magnitude; in other words, it is capable of unlimited *resistance* to pressure applied to its surface. This quality of the atom is particularly objected to by those physicists whose views of the relations of matter and force are professedly derived entirely from experiment, since, as it seems, they are unable, on that account, to admit that solid matter can be devoid of *elasticity*, yielding in greater or less degree to compression. But, according to our philosophy, this property cannot be included in the definition of the ultimate atom, because it involves *variability* as to form or condition, and is consequently the result of force acting according to laws,

which have to be accounted for by reasoning from ulterior principles. It is, however, true that to attribute to the atom the quality of unlimited resistance to change of form is, in fact, to postulate the existence of a *real* physical force, distinct from that which is supposed, in hypothesis III, to be resident in the ether. The latter is an *active* force; the other is simply *reaction*, called into operation only so far as the surface of the atom is pressed by the ether. The theories of the different kinds of physical force, and of their laws, which I have proposed in various scientific publications, depend in an essential manner on the *co-existence* of this force of reaction at the surfaces of atoms with the active force of the ether. Similarly the force of gravity causes a planet to move in an elliptic orbit, only in consequence of the co-existing passive resistance to change of the direction and amount of the motion, which is due to the planet's *vis inertiæ;* the resistance to change of the motion being an actual intrinsic quality of the atom, analogous to its hypothetical intrinsic quality of resisting change as to form.

22. It remains to consider by what reasoning it may be ascertained whether the three hypotheses are true or false. I have already said that the only possible process is to compare results mathematically deduced from them with quantities derived from experiment, for the purpose of determining whether the calculated quantities are in such accordance with the experimental values as the verification of the hypotheses demands. By a known rule of philosophy, a large number of accordances will only establish a presumption of the truth of an hypothesis, whereas a single instance of positive contradiction is conclusive proof of its being untrue. It would extend this essay to an unreasonable length to cite all available instances of such comparisons, for the purpose of estimating the amount of evidence they give of the truth of the three hypotheses; I can do no more than refer for the evidence in full which has been brought to bear on this inquiry, to the various discussions of physical problems contained in my published philosophical writings. There is, however, one characteristic of these hypotheses which may be considered to be important evidence of their truth, and may suitably be treated of here; namely, the facility with which, although few in number, they admit of being applied in the whole range of experimental physics. This point, as giving *primâ facie* proof of the *adequateness* of the hypotheses to constitute the foundation of physics, is dwelt upon at considerable length in my paper on "The Metaphysics of Scripture," especially in secs. 24–28, and, consequently, I do not think it necessary to go

over this ground on the present occasion; but a few items of evidence, which more especially appear to strengthen the main argument, I propose to introduce here.

(1.) In sec. 5, reference has already been made to the hypotheses of the Theory of Universal Gravitation, which I shall now enunciate again for the purpose of expressing the second one in more definite terms: (a.) The force of gravity varies according to the law of the inverse square of the distance; (b.) it is universal as to the extent of its operation, and emanates from *every elementary portion* of visible and tangible substances. It is *not* assumed, in the theoretical calculations, that the force emanates from every *atom*, inasmuch as a vast number of atoms, in a state of aggregation, may be supposed to be contained in the space-element usually adopted in calculating the effects produced by the force which emanates from a given substance of given finite dimensions. Now as these two hypotheses are quantitatively expressed, it is a necessary consequence, according to the principles of our philosophy, that they should be deducible from its *à priori* hypotheses. I have, in fact, shown, on the supposition that every atom is a centre of ethereal vibrations by reason of the reaction at its surface, that the undulations, resulting from the composition of the minor undulations propagated from all the atoms of a given small element, are capable of acting as an accelerative force on a distant atom, attracting it towards the element, and that this attractive force varies inversely as the square of the distance from the centre of the element. The universality of the force follows from the hypothesis of the unlimited extent of ether. In my early researches, I could not decide whether or not the fact of the equal acceleration of all bodies by the force of gravity was due to the elements being composed of atoms all of the same size; but at length I succeeded in demonstrating on hydrodynamical principles that the gravity-undulations had the effect of accelerating equally atoms of different sizes. (The investigations here referred to are given in an article on the Hydrodynamical Theory of Attractive and Repulsive forces, contained in the Number of the *Philosophical Magazine* for September, 1876.)

(2.) By a well-known experiment Gauss proved that the action of a large *magnet*, having its axis fixed, upon a small one restricted to oscillate about its middle point fixed, in a plane passing through the axis of the other, is, for the same distance between the middle points of the magnets, *twice* as great when the axis of the large magnet is directed towards the middle point of the small one, as when the axis of the latter is directed towards the middle point of the large one, and that

in both cases the magnetic action varies very nearly inversely as the *cube* of the distance between the centres of the magnets. I have accounted for both these laws by means of a hydrodynamical theory of magnetism founded on the same *à priori* hypotheses. (See the *Philosophical Magazine* for July, 1869, p. 42.)

(3.) The Astronomer Royal has given in vol. clxii. of the *Philosophical Transactions* the results of an experiment for determining the intensity and direction of the action of a galvanic coil on a small magnet placed in various positions round the coil, and restricted to oscillate, with its middle point fixed, in a plane passing through the axis of the coil. On the principles of hydrodynamical theories of *galvanism* and *magnetism* resting on the same basis, I have been able to account for the laws of this action, and to make a successful numerical comparison of theoretical values, giving the direction and intensity of the galvanic force, with values obtained directly from the experiment. (This problem is discussed at length in the Numbers of the *Philosophical Magazine* for September, November, and December, 1874.)

(4.) Much interest has recently been excited by the phenomena of Mr. Crookes' Radiometer, which have been supposed to give indication of the existence of a *new* physical force. It might, therefore, reasonably be asked whether the proposed general hydrodynamical theory of the physical forces was competent to explain these phenomena. On making application of it, I was led to conclude, without adding to, or deviating from, in any particular principles previously admitted, that the action of light on the surfaces of the vanes induces, in combination with the law of heat-exchanges always in operation between neighbouring bodies, an abnormal disposition of the superficial atoms not unlike that produced in electrical experiments by friction, and that in consequence of the inequality of this action on the opposite black and bright surfaces of the vanes, steady ethereal currents are generated (just as in the hydrodynamical theory of frictional electricity), the pressure of which on the individual atoms causes the movement of the vanes. An experiment by Mr. Crookes which showed that a pith ball, suspended near the revolving vanes in a cup inclosing the Radiometer and very nearly exhausted of air, was made to oscillate if the rotation was not very rapid, seems to justify the supposition of an electric action. (I have treated of the theory of the Radiometer in the numbers of the *Philosophical Magazine* for May and November, 1876, and April, 1877.)

It may here be mentioned, as peculiarly confirmatory of the

actuality of the hypothetical atom, that the foregoing explanations, numbered (1), (2), and (3), depend wholly on the assumption of its *spherical* form.

23. Although I cannot expect that the foregoing arguments will produce in others the degree of conviction which, after long attention to theoretical philosophy, I have myself arrived at as to the truth of the three hypotheses, still, as it may possibly be conceded that a presumption of their truth has been established, the course of the general argument now requires a statement to be made of the inferences deducible from these hypotheses on the supposition of their being true; which accordingly I proceed to do.

(1.) First and chiefly, they prove the existence of *two* classes of natural facts quite distinct from each other, one primary, the other derivative. The first class are primary in the sense of not being logically ascribable to any antecedent natural cause, whereas the other, whether consisting of individual facts, or of facts related in a manner expressed by analytical formulæ, may be logically reached by reasoning from the first as premisses. Such reasoning reveals the laws which govern the second class of facts. *Laws* so determined are absolutely unchangeable, because the process and the results of right reasoning from given premisses admit of *no variation*, being the products of a human faculty which in essence is identical with the supreme reason of the Governor of the Universe. But it by no means follows that the premisses themselves are also unchangeable. For want of being able to distinguish between the two kinds of facts, Hume fell into the great error of assuming that *all* facts are subject to immutable laws. This error has held its ground up to the present day, its influence being conspicuous in the writings of Stuart Mill, Strauss, and modern metaphysicians generally, who have all rightly judged that metaphysical inquiry should be conducted with reference to physics, but failed to discern the exact relation between the two departments of human knowledge. The late Professor Grote of Cambridge discerned the unsatisfactoriness of the prevailing views of metaphysicians on this point, but did not profess to clear up the difficulty.

(2.) As the existence of the primary facts is not referable to any antecedent natural conditions or causes, it may be asked, What was their origin? How did they begin to be? The only possible answer to this question is, that they were *made*, and made to be such as they are, by the sole will and power of the Creator of the Universe. We ourselves can *make*, and we give to the things we make special forms and qualities to answer special purposes. We may draw, therefore, from our

own consciousness the conclusion that the Creator *formed* the atoms and the ether from the beginning, assigning to them the qualities, and disposing them in the order, which by His wisdom He foreknew to be adapted to give rise through the exertion of His power to laws of operation whereby His purposes in the creation would be fulfilled. It seems to me not too much to assert that in making the primary entities such as to be intelligible to *us* through sensation and experience, and the laws of operation such as to be deducible from the primary facts by human reasoning, the Creator purposed that, together with other ends, His creation should have the effect of revealing to *man* His wisdom, power, and Godhead.

(3.) It is surely reasonable to admit that the Creator of the primary entities and Disposer of their mutual relations, retains for exercise, when for special purposes it seems good to Him, the prerogative of changing existing conditions in respect to the number, magnitudes, and arrangements of the atoms (without alteration of essential qualities), and that too whether the substance be inorganic or organic. It must be fully admitted that to do this is to work a *miracle*. At the same time it may be maintained that in so doing there is no violation of *laws*, but only change of conditions under which established laws operate. It will thus be seen that the recognition in our philosophy of two kinds of facts frees it from that antagonism to the admission of miracles which forms so prominent a feature in much of the philosophy accepted at the present time.

(4.) I come now to the conclusion of the general argument. If the foregoing course of reasoning has sufficed to certify that matter must have come into existence by the will and operation of a personal and intelligent Creator, by the same reasoning it is proved that matter is *destructible*, inasmuch as a power that created it can destroy it, and if it be indestructible, it could not have been created. This is an axiom so self-evident that there is no way of sustaining it by argument. I leave to those who maintain the indestructibility of matter, the task which their position imposes upon them of proving that it was not created.

24. The preceding inferences from the three hypotheses have immediate relation to the quality of *matter*. Others are deducible from them with which the quality of *force* is intimately concerned. Before mentioning these, it is necessary to recall to notice the reasoning in secs. 2–4. It is there argued that in physical science we have to do with *immaterial* as well as material facts, and that the former are perceived only in coordination with the other kind. This view was exemplified by

reference to the sensations of sound and light, the intrinsic characters of which our mathematical researches make no approach to, although we can thereby obtain very distinct conceptions of the material conditions under which they are felt. They *coexist* with, and *correspond* to, these conditions, solely by the will and power of the Creator. Now, according to the third hypothesis, all active force is resident in the ether, and by the argument in sec. 13 it is shown that, besides atomic constitution, all that is predicated of the ether is, that it is endowed with a *constant elastic force* as a *primary* quality. It would, therefore, be a contradiction in terms to say that this quality results from antecedent material conditions: we can only say of it that it is an *immaterial* concomitant of the existence of a material ether, just as the immaterial sensation of sound accompanies certain movements of the material organs of hearing, and that of light certain movements of the material organs of seeing. Thus, in short, the constant force of the ether is the result of immaterial, or *spiritual*, agency. For this reason we might with propriety call that force the *energy* of the universal ether, this term having already an established usage relative to mental or spiritual operation.

25. The truth of the foregoing inference may, I think, be confirmed by the following considerations. Assuming that all active force is exerted by means of the ether, it must be by the same medium that force is exerted when of our own will, under conditions and limitations of organization, we move our limbs, or set in motion any extraneous body. But in this case our own consciousness tells us that the exertion of the force is a mental or spiritual act. (See sec. 13.) We may hence draw the general conclusion that the quality of the constant force pertaining to the ether is, as was said above, spiritual. This force—this constant and universal energy—is power of God, "who is a Spirit," a share of which power He communicates under conditions either of organization, or of external natural phenomena, to voluntary agents, to men or to angels; but still it is His power. "In Him we *move*," as is said in Scripture.

26. In sec. 21 a distinction has been drawn between the active force resident in the ether, and the passive forces pertaining to the atom, namely, its *vis inertiæ* and its unlimited *resistance* to change of form. What, it may be asked, is the essential character of these forces? It can only be answered that they exist as primary, and therefore underivable, qualities, immediately imposed and maintained by the power of the Creator of the atom; and, being inseparable from it, may be called innate or *inherent* qualities. According to the philosophy of Mr. Herbert Spencer, the non-annihilation of matter means

that "the force a given quantity of matter exercises, remains always the same." But this assertion does not take account of any distinction between one kind of force and another. As far as regards the passive forces above mentioned, inasmuch as these are *inherent* in atoms, it may well be admitted that the non-annihilation, or the annihilation, of the force and the matter must go together. But since, as I conceive, it has been shown that matter is destructible, it follows that *this* kind of force, apart from the active force not in like manner attached to the atoms which constitute visible and tangible substances, may come to an end. I cannot forbear adverting here to an analogy of much interest between the modes of operation by which the Governor of the Universe effects His purposes in His natural kingdom and in His spiritual kingdom. As was said in sec. 21, natural effects are produced by the antagonistic tendencies of active and passive forces, and by the prevailing of the former over the other. So also, it would seem, in the existing economy of God's spiritual kingdom, the powers of good and evil are antagonistic, until by the eventual subduing of the latter, the final purpose of the spiritual creation is accomplished. Possibly the conception of such an analogy may have given rise to the idea, so long and so widely entertained, of a connection between matter and evil.

27. I beg to take this occasion to say that the philosophy which I have now and before advocated, is utterly opposed to the *Agnosticism*, which, in recent publications, has been so much insisted upon. I think that some defenders of Scriptural truth have given great advantage to sceptical writers by the admissions they have made respecting the unknowable. For myself I do not hesitate to express the view (already maintained in part in this essay), that the Author and Ruler of the world purposely ordered His works and His ways, both in the natural kingdom and the spiritual kingdom, so that they may be understood by intelligence such as ours, and may consequently communicate to us a knowledge of *Himself*. This belief accords with the philosophy taught by the Apostle Paul, where he says, "that which is known (τὸ γνωστόν) of God is manifest *in* them (ἐν αὐτοῖς); for God hath showed it to them. For the invisible things of Him from the creation of the world, are clearly seen, being understood by the things that are made, even His eternal power and Godhead" (Rom. i. 19, 20). In agreement with the apostle's words, "manifest in them," I have made reference, in the course of argument, to information derivable from *personal consciousness*.

28. I propose to conclude this essay with taking account of an argument, drawn from the assumed indestructibility

of matter, which has been employed to give a reason for the perpetuation of *personal identity*. It has been thought that the identity of an individual may, supposing matter to be indestructible, be continued after death and the dissolution of the body of the present life, by the entrance of a single particle of that body into the composition of the risen body of the life to come. The physical philosophy I have been endeavouring to explain, which makes an absolute distinction between the immaterial and material parts of man (see sec. 24), and admits the destructibility of matter, points to the dependence of whatever is perpetuated on the immaterial—the spiritual. The same result is arrived at by considering what takes place in *perfect sleep*: consciousness departs, the body is there, the *Ego* is not there; I am as if I were not. If, then, the body, in its integrity, is incapable of maintaining continuity of consciousness, how should there be, in a very small portion of it, the virtue to maintain continuity of person? The teaching of Scripture appears to be, that the Creator of spirits has in His keeping the spirit of every man departed, to the end that, when united after resurrection to "spiritual body" (not the *same* body), it may give account of the deeds done in the body of flesh, whether good or bad. It is by this relation of deeds now to judgment then, that the power of God ensures personal identity. For these reasons, I do not admit that it is allowable to assume matter to be indestructible, in order to account for the maintenance of personal identity. "If our earthly tabernacle-house were dissolved, we have a building of God, a house not made with hands, eternal in the heavens" (2 Cor. v. 1).

The CHAIRMAN.—Our thanks are due to Professor Challis for the valuable paper with which he has favoured us.

Mr. T. HARRIOT.—I think that Professor Challis has somewhat mixed up the spiritual and the material in one section of his paper. Let us not forget that whilst St. Paul says that God may be known to man by His works in the natural world, He also tells us that the natural man cannot know the things of the Spirit of God, because they are spiritually discerned.

The CHAIRMAN (C. BROOKE, Esq., F.R.S.).—I very much regret that Professor Challis was not here to-night, to read his own paper; because, though I am entirely in accord with him in regard to the drift of it, which, in fact, is contained in the paragraph on sec. 23, 4th part, to the effect that,

"If the foregoing course of reasoning has sufficed to certify that matter must have come into existence by the will and operation of a personal and intelligent Creator, by the same reasoning it is proved that matter is *destructible*, inasmuch as a power that created it can destroy it, and if it be indestructible, it could not have been created. This is an axiom so self-evi-

dent, that there is no way of sustaining it by argument. I leave to those who maintain the indestructibility of matter, the task which their position imposes upon them of proving that it was not created."

This, in point of fact, appears to me to be the gist of the paper, and in this, I am sure I am entirely in accord with the author. But there are several points in the argument about which I should like to have asked him for some information. In the same page (sec. 24) he says—

"According to the third hypothesis, all active force is resident in the ether."

It must be apparent to any mind, that this ether has an altogether hypothetical existence. We know nothing about it. We never can see, feel, test, or weigh it. In fact, we have no evidence of its existence beyond the necessity for the existence of some exceedingly elastic matter, to convey from the sun, the vibrations which constitute light and heat, to this earth. We know that some highly-elastic matter must exist and fill the whole of space between us and the sun, in order to convey the light and heat so essential to the development of life on the earth. But beyond this we know nothing about it. In the next page the author says—

"It must be by the same medium that force is exerted, when of our own will, under conditions and limitations of organization, we move our limbs, or set in motion any extraneous body. But in this case our own consciousness tells us that the exertion of the force is a mental or spiritual act."

Now, it is quite clear to my mind that the mental act, that is, the act of volition, is an antecedent cause to the exertion of the force. The exertion of the force is the contraction of the muscular fibres, the muscular fibres that move the arm, for instance; the contraction of these fibres is the immediate agent in the exertion of the force. This certainly is a material, and not a spiritual, act. The antecedent volition is the spiritual act; but it appears to me the exertion of the force is not a spiritual act.

Mr. CHALLIS.—The Professor goes beyond the muscles, and speaks of that which puts them in action.

The CHAIRMAN.—He does not say it in so many words, but I conclude from section 4, that he considers—and in this I entirely agree with him—that sound, as well as light and heat, have no objective existence; that sound, light, and heat are entirely subjective sensations, and that all that exists objectively is the vibratory motions. In sec. 10, with regard to the laws he propounds, the first is, "All matter that we are cognizant of by our senses, is composed of discrete atoms." The second is, "An atom is a very small sphere, inert, movable, and of finite and invariable magnitude." Now, it appears to me that the assumption that the form of an atom is a sphere, rather involves more difficulties than it obviates, because by the laws of crystallization, the form of crystals necessitates that there should be unequal attractive forces between the molecules and the substance of the crystal, one or two, sometimes three unequal—sometimes in

two, sometimes in three different directions; and it appears to me more easy to conceive that these unequal forces should exist in a molecule which is of unequal dimensions in its different directions; and it would be very easy to conceive that the form of the molecule is not a sphere. But, at the same time it is not a matter of great consequence, for, according to the Newtonian hypothesis, when the space between particles of matter is indefinitely large, compared with the magnitude of the particles themselves, it does not matter what we suppose the form to be. It appears to me rather more comprehensible that the forms are different in those atoms in which there are necessarily different attractive forces in different directions. I daresay the Professor would have given us some reason for superseding the view I have just enunciated. At the bottom of sec. 18 he speaks of the Newtonian expression, *vis inertiæ*. It appears to me that the consideration of *inertia* as a force, tends only to mystify and confuse our ideas in regard to what force means. Force, as commonly defined, is that which tends to alter the condition of a body with respect to its state of rest or motion. Now, if this be the correct definition of the term force, clearly *inertia* does neither one nor the other.

Mr. CHALLIS.—He speaks of it as a quality.

The CHAIRMAN.—As a force.

Mr. CHALLIS.—As reaction (in sec. 21).

The CHAIRMAN.—He quotes Newton, and says :—

"He by no means affirms gravity to be essential to bodies; that he takes *vis inertiæ* to be the only intrinsic ('insita') force, and that this force is invariable ('immutabilis'), whilst, on the contrary, gravity diminishes with increase of distance from the earth. (These views accord with the rule I have adopted in sec. 11, of not admitting qualities susceptible of variation to be primary, which rule, of course, excludes gravitation from the class of primary qualities.)"

Mr. CHALLIS.—I think that is discussed further on, where he speaks of it simply as a quality of resistance.

The CHAIRMAN.—It does appear to me that it is an unfortunate expression of Newton's; to call *inertia* a force, confounds our ideas of force altogether.

Mr. CHALLIS.—I think the Professor in using that term does not adopt it in speaking of action, but only in speaking of re-action.

The CHAIRMAN.—Then with regard to gravitation, he speaks of gravitation as a variable force. I think this again is a little looseness of language, because how do we estimate our measure of force? We estimate it by its action on a unit of matter at a unit of distance. Now that is constant. The amount of gravitation will depend upon the distance. The force of gravitation I maintain to be constant and uniform, because we can only measure it by its action on a unit of matter at a unit of distance.

Mr. CHALLIS.—He speaks of it as not being a primary quality or fact, because it may be measured.

The CHAIRMAN.—Because it is variable.

Mr. CHALLIS.—Because it is quantitative.

The CHAIRMAN.—The action is quantitative. The question is, is the force quantitative?

Mr. CHALLIS.—I do not think there is any ground of objection there. The action of gravity, as due to the ether, is a step beyond the action measured experimentally.

The CHAIRMAN.—Then, with regard to the idea that is expressed in this paper,—with regard to the force being entirely due to the ether,—it seems to me the idea conveyed is that, in gravitation, the tendency of bodies to fall together in consequence of the force of gravitation, depends, not on the bodies themselves, but on their being pushed against each other by the force of this hypothetical ether. This appears to me the gist of the hypothesis.

Mr. CHALLIS.—It results from the application of mathematics to that ether, as it is defined.

The CHAIRMAN.—The difficulty appears to me that, granting that ether, and granting these molecules impinging in countless multitudes and with immense velocity upon the particles of matter, I do not see why they should impinge on one side more than another; and if they impinge on all sides alike, it seems to me that would have no effect at all. I do not see why the supposed impact of molecules should tend to bring the particles together.

Rev. J. FISHER, D.D.—Professor Challis has made some good points against the authors of the *Unseen Universe*. I think the three hypotheses which he lays down as the foundation of a general physical theory are all sound and good. With regard to the atom, although we have never seen one and never shall, his argument is of the highest degree of probability. Then as to his different classes of facts, physical science consisting not only in experiment but reasoning, the one giving laws, the other reasoning from laws, I think that is a point he brings out very clearly. As to the two classes of fact, primary and derivative, I think that is very clear and plain; as also are a great many other points. There are some things at the end of the paper with which I do not fully agree; for instance, where he says he leaves those who do not like his argument to prove the negative. Now we cannot call upon any one to prove a negative. The name of the essay is "On the Indestructibility of Matter." But he has only one sentence about that, while he goes on to prove the creation of matter. Having done that satisfactorily, he says the other is of small importance. He has proved the creation, and it is very good proof too, but I think he would have done well to have brought out the other a little more clearly.

A VISITOR.—I think there is one point of considerable importance which has not been touched upon. Professor Challis says in his paper,

"If the foregoing course of reasoning has sufficed to certify that matter must have come into existence by the will and operation of a personal and intelligent Creator, by the same reasoning it is proved that matter is destructible, inasmuch as a power that created it can destroy it."

I think we should agree with this. I think it is the main argument of the paper, that matter does possess what the Professor calls primary qualities, which are being impressed upon it in a way we cannot account

for, and which are one great evidence of their being created at all. But he goes on to say, "If matter be indestructible, it could not have been created." I should like to see this point cleared up. "This," he says, "is an axiom so self-evident that there is no way of sustaining it by argument." I think we are in a very unfortunate position when we do not see the truth of an argument that is said to be self-evident, and when the men who bring it forward decline to argue with us. Now I think some strong reasons have been put forward that matter is not destructible; and what I want to know is, whether it does follow, if matter is proved indestructible, that it never could have been created? I think we can go to the analogy of the spiritual in man. We hold that our spirits are immortal—having been made in the image of God we are immortal; and whether we are saved or lost, we shall continue to exist. Does it follow, because this is the case, that we never were created? I do not think we should be willing to admit that. And it seems to me a very conceivable thing that God, who, according to the showing of this paper, has apparently endowed certain material atoms with what are called primary qualities, such as qualities of elastic resistance at their surfaces, may have endowed them with other qualities, with the power of indestructibility. It does not, to my mind, seem to be a logical sequence to say, even if it can be proved, that as matter is indestructible therefore it never could have been created. I know the difficulty of some, in regard to the existence of the Creator, lies here. They accept that which is stated to be true, that matter is indestructible, and then they say, what Professor Challis says, if it is indestructible, it never could have been created, and therefore we have no reason to believe in a Creator. I would say in answer to this difficulty, what I have just suggested, that it is possible for the Almighty with His infinite powers to endow matter, as He could endow spirit, with the quality of indestructibility. I think we have only these three alternatives. We must admit matter to be destructible, on the proof of the Professor saying that God, having created it, can destroy it; or we must say, what seems to me the truth, if this is not the case, it may have been endowed with the quality of indestructibility and yet have been created; otherwise, it seems to me we are left to that very dismal belief, that matter, being endowed with indestructibility, was never created at all, and therefore we have no grounds for believing in a Creator.

Rev. J. L. CHALLIS.—As Professor Challis will have an opportunity of replying, I will only observe, in reference to what has just been said, that the Professor refers to the will of the Creator as the ultimate cause of all things, by saying that He who originated everything can alter or take away. That is to my mind a complete answer to objections implying limitation of Divine Power. And I think the Professor is quite right in leaving those who maintain the indestructibility of matter to prove that it was not created. Again, the same reference to the will of the Creator is an answer to the remark about our own immortality. It is not that our spirits are immortal because the Creator has made them indestructible, so that He

Himself cannot destroy them, but they are immortal by the will of the Creator, and indestructible by the will of the Creator; and we have no right to say that He could not change them. It is declared to us in the Scriptures that our spirits are immortal, and that is sufficient. It is so by the will of the Creator, and nothing that is said in this paper affects this conclusion. The argument rather shows that they and all other things are ultimately the outcome of the will of the great Creator of all things.

The Meeting was then adjourned.

REPLY BY PROFESSOR CHALLIS.

HAVING received a printed copy of the report of the foregoing discussion, and perceiving from the remarks and questions of the speakers that on several points it was desirable I should give further explanation, I shall avail myself of the permission given me to supplement the discussion by some remarks in reply, to introduce such additional considerations on those points as may appear to be required.

Not knowing what section of the paper Mr. Harriot refers to in saying that I have "somewhat mixed up the spiritual and the material," I can only answer generally that with respect to distinguishing between what is spiritual and what is material, or between invisible things and things that are objects of sense, I think that I have only said what is in accordance with the doctrine taught by St. Paul in Rom. i. 19, 20, which passage is quoted in sec. 27. In 1 Cor. ii. 14, where the Apostle speaks of things which the natural man cannot know, because they are spiritually discerned, it seems, from what he says in verse 12, that spiritual discernment in its moral rather than in its intellectual sense is signified.

I am much gratified by the Chairman's assertion of his entire accordance with me with respect to the views contained in the passage which he quotes from sec. 23 (4) of the paper, and I quite agree with him in considering the main drift of my argument to be conveyed by the inferences drawn in that passage. If, notwithstanding this expression of assent to my views, I have thought it right to advert to some particulars in Mr. Brooke's subsequent remarks, it is because he has himself asked for further information on certain points, and because I think that a discussion of the points he has referred to will tend very much to elucidate the question of the destructibility of matter.

Mr. Brooke cites from sec. 24, "According to the third hypothesis, all active force is resident in the ether," and then proceeds to remark that "This ether is an altogether hypothetical existence. We know nothing about it. We never can see, feel, test, or weigh it. In fact, we have no evidence of its existence beyond the necessity for the existence of some exceedingly elastic matter to convey from the sun the vibrations which constitute light and heat

to the earth. We know that some highly elastic matter must exist and fill the whole space between us and the sun, in order to convey the light and heat so essential to the development of life on the earth. But beyond this we know nothing of it." To these remarks I reply as follows: It is the very principle of my argument to begin with regarding the ether and its qualities as "altogether hypothetical." But remembering Newton's rule of not making gratuitous suppositions "contrary to the tenour of experience" and "the analogy of nature," I take account from the first, in making the hypotheses, of the same ground of necessity as that adduced by Mr. Brooke for assuming the existence of some highly elastic matter by means of which light and heat are conveyed to us from the sun. So far, therefore, I can perceive no difference between Mr. Brooke's views and mine, excepting that I give a specific name to the elastic substance, and call it *ether*. I admit, however, that from this point I proceed to make particular hypotheses respecting the ether, as, that it presses, and that its pressure is always proportional to its density. Now these hypotheses are justifiable, *as hypotheses*, on the ground that they give the means of testing the reality of the ether and its assumed properties, by being appropriate foundations of mathematical reasoning for deducing results that may be compared with experimental facts. There are departments of physical science in which advance can be made only by proceeding according to this method of *hypotheses*. And although by such a method the hypotheses are not absolutely *proved* to be realities, a moral certainty that they are such is established in proportion to the number and the variety of the explanations they give of phenomena. Since, in my opinion, the mathematico-physical science of the present day has established a moral certainty of the reality of the ether, and of its being such as for the purpose of theoretical research it is assumed to be, I am unable to admit that, because we cannot apply experimental tests to it as we do to other material substances by seeing and handling them, we know nothing about it. It is true that we can never "see" it, because, being the means by which grosser bodies are seen, it is itself invisible. I think Mr. Brooke is hardly consistent in saying that we never "feel" it, because he admits (second page of Discussion) that sound and light are subjective sensations; and since we may be said to feel the air in our sensation of sound, we may with as good reason be said to feel the ether in the sensation of light. We have not the power, neither have we any need, to "test" its presence by seeing or handling it, inasmuch as the lightning flash, and the distant star, attest its presence near us, as well as in the remotest regions of space. We cannot "weigh" it, because, being the cause of all weight, it is itself imponderable.

With reference to the assertion in sec. 25, that "it must be by means of the ether that force is exerted when of our own will, under conditions and limitations of organization, we move our limbs, or set in motion any extraneous body," Mr. Brooke remarks that "the act of volition has an antecedent cause to the exertion of force." I agree so far with this view as to admit that volition, by whatever cause determined, is antecedent to the

exertion of force; but an "act" of volition I should consider to be, giving effect to will by action on matter, in conformity with that inscrutable relation between spirit and matter, whereby we have the power to move material substance, and can thus give overt evidence of our volition. Supposing this power to be exerted by the intervention of the ether under certain conditions of nerve and muscle, just as, in a well-known experiment, the limb of a dead frog is moved by a galvanic current of ether, it must still be regarded as a faculty immediately bestowed by our Creator, enabling us, when we please, to originate and bring into action the same physical conditions as those under which the motion in that experiment is produced. I can assent to Mr. Brooke's statement, that when a limb is moved, "the contraction of the muscular fibres is the immediate agent in the exertion of the force"; but at the same time, as was correctly affirmed by my son, Mr. Challis, in the course of the discussion, the views I advocate "go beyond the muscles." In sec. 21 of my paper on "The Metaphysics of Scripture" I have enunciated the following principle: "It is inconceivable that there can be any production or event which is not determined by antecedent will, and by the power, in operation, of a conscious agent." The adoption of this principle precludes the admission that the exertion of muscular force can be correctly called a "material act," or that in any case there can be exertion of force which is not a *spiritual act* followed by its material manifestation. Volition is the necessary antecedent of every manifestation of force, and consequently, as volition is an attribute of spirit, every exertion of power is a spiritual act.

Mr. Brooke's next argument, which is directed against the assumption of the spherical form of the atom, is very nearly the same as that which I have met in the last paragraph but one of the Supplementary Reply attached to my paper on the "Metaphysics of Scripture" (Journal, Vol. XI. p. 245), where I make a distinction, apparently overlooked in that argument, between a molecule and an atom. The polarity of the crystallographical forces being referable, according to my view, solely to the *arrangement* of the atoms which constitute a molecule, I have no occasion to make hypotheses respecting the *form* of the atoms in order to account for it. Mr. Brooke now adds to the former argument the assertion, that if "the Newtonian hypophesis," according to which the spaces between the particles (? atoms) are very large compared to the spaces occupied by the particles themselves, be adopted, "it does not matter what we suppose the form to be." Although this might be granted so far as regards the phenomena of polarity above mentioned, it might still be maintained that there are other phenomena which essentially depend on the form of the atom. The spherical form is one of the primary hypotheses of the mode of philosophy I advocate; and, as stated at the end of sec. 22, I have, in fact, accounted for various physical phenomena by mathematical reasoning founded on the supposition of this form, and have thus established a reasonable presumption of the reality of spherical atoms.

With respect to Mr. Brooke's objection to the Newtonian expression, *vis*

inertiæ, I have only to remark that if the thing itself be understood from sensation and experience, it matters not whether it be called *inertia* or *vis inertiæ*. In secs. 15 and 21 of the paper before cited (Journal, Vol. XI. pp. 202 and 204), I have endeavoured by a familiar instance to make intelligible the fact and the quality of *inertia*, and have given reasons for concluding that "the reality of inertia as a quality pertaining to bodies is recognizable by a sense of personal effort." Probably the feeling that *inertia*, although not an active force, is something to be overcome by force, and the natural inference that what force overcomes is itself force, may have given rise to the expression *vis inertiæ*. I am aware that some eminent experimentalists have been indisposed to accept "inertia" as a philosophic term; but the theoretical calculator knows that he cannot proceed a step towards forming his equations of force without taking into account the intrinsic quality of matter which this term expresses.

Thinking that it may be expected of me to advert to the discussion which took place between the Chairman and Mr. Challis relative to the quality of the force of gravitation, I beg to make the following remarks on that question. Let it be granted that the unit-measure of the gravitating force of any mass is "the action [? moving force of the mass] on a unit of matter at a unit of distance," and that this measure is "constant and uniform," there still remains to be considered the noteworthy fact that the quantity of the gravitation of the *same* mass has to this standard measure a ratio which is different for every different distance from the mass. The circumstance of this variability in space is expressly adduced by Newton as the reason that gravity is not, as inertia is, an intrinsic quality of matter. This quantitative variation of gravity is precisely analogous to the difference of effect produced on the ear by the sound of a bell at different distances from the spot where it is sounded. In this instance we know that the variation arises from the sound being transmitted by the propagation of divergent waves of the air. Just so in the proposed theory of gravity, waves of the ether, superior in order of magnitude to those which produce heat or light, are supposed to emanate from all the parts of masses, and to produce an attraction varying in its effect on external bodies according to the law of the inverse square of the intervening distances. To make this argument good, it is necessary to prove that the vibrations of an elastic medium constituted like air of given temperature, are capable of drawing bodies towards the parts from which the propagated vibrations emanate. This I consider I have succeeded in doing in the communication which is referred to at the end of sec. 22 (1) of the present paper, as being contained in the *Philosophical Magazine* for September, 1876. The reasoning which conducts to this result depends essentially on the definition of the ether given in the third of the hypotheses enunciated in sec. 10. It is true, as Mr. Brooke has remarked, that, according to this view, bodies are "pushed" towards each other by the force of the hypothetical ether; but it is not correct to say that this force "does not depend on the bodies themselves," inasmuch as the gravity-waves which produce the effect have their origin in the bodies. Mr. Challis justly urged

in reply to the Chairman's objections, that the consideration of "the force of gravity, as due to the ether, is a step beyond measuring its action experimentally," and that the pushing of the ultimate parts of bodies by the action of the ethereal waves is a "result deduced from the application of mathematics to the ether [and atoms] as defined."

It only remains for me to take notice of the Chairman's concluding remarks, which seem to have been made under the misapprehension that the proposed theory of the cause of gravity involves the supposition of "molecules impinging in countless multitudes and with immense velocity upon the particles of matter." I have never in any of my writings given the least countenance to this hypothesis, which, on the contrary, I look upon as having no foundation in reason, and as having been gratuitously made for the purpose of evading the consideration in physics of such *pressure* as is commonly understood from sensation and experience. I am quite in accord with Mr. Brooke in his opposition to this way of accounting for gravity, and, adopting his words, can say that "I do not see why the molecules should impinge on one side of the particles more than another, and, if they impinge on all sides alike, how they should have any effect; nor do I see how the supposed impact of molecules should tend to bring particles together." In short, I cannot but regard this arbitrary hypothesis as a *retrograde* step in physical philosophy, fit only to be classed with Descartes' vortices, and far less excusable, inasmuch as Descartes had not, as we now have, mathematical and physical knowledge adequate to the treatment of such a question as the *modus operandi* of gravity. I have, in fact, for a long time maintained that the character and laws of *all* the physical forces, as ascertained experimentally, admit of being accounted for by the application of modern analytics to the Newtonian principles of natural philosophy, and, in particular, by means of mathematical reasoning so applied, I have been led to a conclusion which, in page 468 of my work on the "Principles of Mathematics and Physics" (published in 1869), is expressed in these terms :—"There are no circumstances under which the forces of nature can act *differentially* on two neighbouring atoms to such a degree as to overcome their mutual repulsion; and, consequently, the collision of atoms is an impossibility." It is to be understood that this repulsion is caused by pressure on the surface of each atom due to ethereal waves propagated from the other, and, as varying in some inverse ratio of the distance between their centres, is enormously increased by approach of the atoms towards each other. I think that I need not say more to show how utterly opposed my view of the cause of gravitation is to this hypothesis of "swarms" of impinging molecules.

In response to the Rev. Dr. Fisher's desire for a fuller statement of my reasons for regarding the proof of the creation of matter as involving the proof of its destructibility, I am prepared to give the following explanations, which, I admit, were not uncalled for. In the Epistle of St. Paul to the Galatians (ii. 18) there occurs the following remarkable passage : "If I build again the things which I destroyed I make myself a transgressor." These words, in which the first person is employed impersonally, signify that any

one who has the power to unmake and make the same things, to do and undo, or, as would be said in modern phraseology, is a *free-agent*, is the author of his own transgression. Although the Apostle has not used the word "free-agent" (it would have been surprising if he had done so), he expresses in concrete terms what may be considered to be a definition of free-agency, namely, that it consists in the power to perform actions which are the exact contraries one of another. Now, since free-agency must certainly be predicated of the omnipotent Creator of all things, it follows from this argument that the power to create implies the power to destroy, that what is created is destructible by the power that created it. Thus the proposed proof of the creation of matter, if valid, is a proof of its destructibility, or a *disproof* of its indestructibility. It is on this ground that I say, "If matter be indestructible, it could not have been created." See what is farther said on this point in the next paragraph.

The remarks of "A Visitor" are in part answered by what has just been said in reply to Dr. Fisher; but certain of his arguments require to be specially taken notice of. He says, "I think some strong reasons have been put forward that matter is not destructible," and then asks "whether it follows, if matter is proved indestructible, that it never could have been created?" Certainly it follows, if my argument be good, that if matter should be *proved* to be indestructible, its non-creation is also proved; but for the following reason I deny the possibility of such proof. The "strong reasons" alleged, as above said, for regarding matter as not destructible, rest, I presume, on experimental evidence, respecting which I have admitted (sec. 2) that it is capable of establishing the indestructibility of matter as a *law*. But it must be considered that while it is within the power of human intelligence to discover natural laws, it is the prerogative of the Creator to originate the laws, and that (by the argument in the preceding paragraph) the power that gave them existence can *abrogate* them. For this reason the proof of absolute indestructibility of matter *is not possible*, although it may be possible, by arguments which prove that it was created, to prove that it is destructible. Consequently, of the "three alternatives" "A Visitor" proposes, I adopt the first. With respect to the argument he derives from the immortality of spirit, I agree with Mr. Challis in the view that created spirits are immortal, or indestructible, not by any originally bestowed virtue or principle, but by the ever operative will and power of their Creator, who, as He made them and fashions them, can, if He will, destroy them. With respect, however, to this question, it is to be considered that, according to Scripture, our Creator has *promised* that in the "new heavens and new earth" that are to be created, righteousness, which is the basis of spiritual life, shall "dwell," and consequently assurance is given that the life of spirit will indeed be "indissoluble" (Heb. vii. 16), inasmuch as "it is impossible for God to lie" (Heb. vi. 18), or cease to fulfil His promise.