ON THE ORGANIZATION OF ATOMS AND MOLECULES.

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IN his dialogues on *The Plurality of Worlds*, Fontenelle represents the sages of antiquity as being spectators at the opera, watching the play of the Universe. The subject is supposed to be Phaeton carried away by the winds. The dancer who represents Phaeton is made to fly away through the upper part of the scenes, much to the admiration of the lookers-on. The wise ones now begin to speculate, and attempt to explain the extraordinary movement of Phaeton. An Aristotelian says, "Phaeton has an occult quality which carries him away." A Pythagorean says, "Phaeton is composed of certain numbers that make him move upwards." Another one says, "Phaeton has a longing for the top of the theatre, and is not easy until he gets there." He explains the universe by love and hate. Another one says, "Phaeton has not a natural tendency to fly, but he prefers flying to leaving the top of the theatre empty," — which is the doctrine of Nature's abhorrence of a vacuum. After all these come Descartes and some other modern philosophers; and they say, "Phaeton goes up because he is pulled up by a weight that goes down behind the scenes."

This is the mechanical philosophy that has been employed so successfully in the unravelling of phenomena once thought to be altogether occult. It is the philosophy that explains every phenomenon of *visible* motion as due to some antecedent motion, which may or may not itself be visible. Since the time of Sir Isaac Newton and the discovery of the laws of motion, there has been no room for mysterious forces operating to give movements to matter of visible magnitude. Guiding spirits like Kepler's are no more thought of as being necessary to account for them than are Arabian genii.

When, however, we come to the phenomena manifested by atoms and molecules, it is plain that the mechanical philosophy

has not only not been applied, it has not even been assumed : and all sorts of visionary entities and special forces have been summoned to explain their behavior. Phlogiston and Caloric for heat, fluids for electricity ; crystallizing force and vital force for the phenomena of organization in crystals and living things, — a continuation of the philosophies of the pre-Newtonian period, which proved to be inappropriate, inadequate, and unnecessary when applied to larger masses. The assumed explanation was more mysterious, and needed explanation more than the phenomenon to be explained by it ; for the latter are admitted to be mechanical, while the assumed explanations are of a super-mechanical sort, for which there is no evidence apart from its implied necessity for accounting for the special movements observed.

Another Fontenelle might fairly make game of modern philosophers who offer such inappropriate explanations of the movements of matter, whether they be large or small, and who refuse, in any case, to assume a mechanical cause for any mechanical operation. To be sure, Caloric and Phlogiston and electric fluids are no longer serviceable in physics, for it is conceded that *heat is a mode of motion* ; and as for electricity, it is also conceded that, whatever it may be, it is certainly not a fluid ; and many are not ashamed to admit being electrical agnostics, and say they don't know what it is.

It is certainly the business of physical science to explain physical phenomena ; and there are certain fundamental principles sufficiently well attested which may be assumed at the outset of every investigation ; namely, the laws of motion, and that these laws are always operative and quantitatively never change. Hence every change in the position or collocation of a mass of matter of any magnitude is referable to the laws of motion of matter, is purely mechanical, and is to be explained solely upon the assumption of antecedent motion.

Even the so-called properties of matter are amenable to this principle. Physical terminology is, perhaps, to blame for not a little of the incoherence, as is the case when the expansibility of a gas or its pressure upon the walls of a containing vessel are explained as due to molecular *repulsion*, seeming to endow the molecules with an unmechanical property. When a base-ball rebounds from the side of a house against which it has been

thrown, no one thinks of saying that the house and ball repel each other; instead, it is recognized as the result of the impact of elastic bodies. In like manner, the impact of elastic molecules upon the sides of the containing vessel produce a pressure upon it proportional to the momentum of the molecules; and when molecules collide, they have their direction of movement changed, and they separate.

Chemical affinity is another term that seems to imply that atoms are endowed with essential selective properties by which they are enabled to combine in definite ratios. In late years chemists have adopted the term *Chemism* in place of chemical affinity, and have given to it a greater range of proclivities, finding no difference but one of degree between it and cohesion. It makes but little difference to one who uses it who is concerned solely with chemical reactions; but it makes a good deal of difference to one who is to explain the relations of chemical changes to other physical changes, whether or not, as soon as he touches atomic phenomena, he has to import into his discussion a factor which has no physical antecedent that can move and arrange atoms and molecules thus and thus, and yet itself not be subject to the laws that obtain among larger masses. As chemists no longer contend for a chemical force that is not derived from antecedent physical conditions, it is alluded to here for the double purpose of calling attention to the positive mischief that often comes from inappropriate terminology, and to the fact that, so far as my knowledge goes, chemists have not attempted to give a physical explanation of the cohesion of atoms into molecules, but have stopped with chemism, as if it were an ultimate fact or property.

To give such a physical explanation of chemism or atomic cohesion, and to extend it to the building up of geometrical crystalline forms, is the object of this paper. It is not claimed to be demonstrated, but as a hypothesis having a good degree of probability in its favor. But even if it be inadequate, at least it gives one a mechanical idea of how such forms necessarily result from mechanical conditions.

Investigations into the relations of chemical reactions to heat have developed the fact that all chemical changes involve definite quantities of heat, either absorbed or evolved. That all such changes are absolutely dependent upon the exchanges in

motion that constitute what is called heat, and are therefore measurable in heat units. As a heat unit can do a definite amount of mechanical work, namely, raise 426 kilograms a metre high, this latter quantity is called the mechanical equivalent of heat. Chemical work is therefore expressible in mechanical units. For example, when a kilogram of hydrogen combines with oxygen to form water, there are given out in the operation 34,000 heat units, capable of doing $426 \times 34,000 = 14,484,000$ kilogrammetres of work. A kilogram of coal when burnt gives out 8080 such units, and the elements thus combined can only be separated again by the expenditure of as much energy upon them as they gave out when combining. This department of chemistry is known as Thermo-Chemistry. The relation between heat and work, as explained above, is known as the first law of Thermodynamics.

Again, from the second law of Thermodynamics it may be shown that the total heat energy of a body, or its ability to do work, is proportional to its absolute temperature. Hence at absolute zero no chemical work could be done; that is, chemism does not exist, and no work would be spent against cohesion to separate the elements in a molecule. From this it may be inferred that chemism is a derived property, and is the *result* of heat; and also that Chemistry itself is a department of Thermodynamics.

In order to understand more definitely how heat can bring about such phenomena as selective combinations and the organization of atoms into molecules and crystalline forms, it becomes necessary to know more precisely what the nature of heat motions is that enables it to produce such mechanical effects.

If one turns to the text-books for a definition of heat, he will quite likely be perplexed by the different statements to be found in them. One may say that heat is energy; another, that it consists of ether waves; a third, that it is a mode of motion; and still others treat it in all three senses. The trouble comes from the failure to distinguish between heat and some of the effects of heat. Really they all agree that heat is a kind of atomic and molecular vibration, as distinguished from oscillatory, rotary, or free-path motions, and that is the meaning of it as applied here. It is a necessary *change of form* of the atoms or molecules, and will be easily understood by considering the diagram, Fig. 1.

The heavy-lined circle represents the atom, which is certainly an elastic body, whatever may be its dimensions; and if it be subjected to pressure or impact, will yield like the prong of a tuning-fork or the mouth of a bell; and if spherical or circular, will assume an elliptical outline; and if free to move, will execute a series of elliptical phases at right angles to each other, as represented by the dotted lines in the figure. This change of form

FIG. 1.

is a mechanical necessity when bodies are elastic, and that quite independent of what the form of the body may be. The evidence for the statement that this is the real character of the motion that constitutes what is called heat comes from Spectroscopy, especially that of heated gases, where molecules have time to execute vibrations between impacts, in which case they give out radiations of definite wave lengths, and in harmonic series, which of course must be derived from the harmonic vibrations of the particles of matter that are heated. It has been demonstrated that the ultimate particles of matter, atoms, cannot be spherical in shape; and to-day the only theory of the constitution of matter we have is the *Vortex Ring Theory* of Sir William Thomson. One must either adopt that or be without any; but evidence for its being a true theory is fast accumulating, and there has as yet no serious objection been offered to it from either physics, chemistry, or mathematics.

It will be adopted for the purposes of this paper, and hence the diagram, Fig. 1, may be considered as a vortex ring capable of changing its form and vibrating with an amplitude determined by its size, thickness of ring, etc. Such an atom has a definite fundamental rate of vibration, and a series of harmonic rates which are 2, 3, 4 . . . n times the fundamental rate, which is the one represented. It is to be noted that where such vibrations are taking place there are certain places upon the vibrating body where the motion is at a maximum, called the *loops*, and also intermediate places where the motion is least, called *nodes*. In the diagram there are four of each. If the body has a series of harmonic vibrations, there will then be 2, 3, 4, and so on, number of times the nodes of the fundamental. The number of times such vibrations can occur among the atoms of matter is determined by dividing the velocity of light by the wave

length of any particular ray that is produced by the vibration. Thus, if the red hydrogen rays have a wave length of 0.000656 of a millimetre, the frequency of vibration of the hydrogen atom that produces it is 457,000,000,000,000 times per second. This particular vibration is the 20th harmonic of hydrogen. What is of most moment here is to bear in mind that waves of so-called light, having definite and constant wave lengths, are the result of the heat vibrations of the atoms and of molecules, which must therefore be vibrating at a constant rate, not irregularly; and to vibrate thus is one of the fundamental mechanical properties of atoms as elastic bodies.

In order now to see what must follow from such motions, it will be best to consider some of the phenomena of vibrations as manifested in bodies of visible magnitude, say a tuning-fork. If a light body like a pith ball be brought near the prong of a vibrating tuning-fork, it will move towards the prong as if the latter attracted it, and this is explained as being due to the fact that a vibrating body reduces the air pressure adjacent to it. How a vibrating body can reduce the pressure of the medium about it may be understood by remembering that the pressure is proportional to the density. If the vibration lessens the density, it lessens the pressure. Let the inner circle of the dia-

FIG. 2.

gram, Fig. 2, represent an elastic sphere capable of extension to the dimension of the outer circle. When it is thus expanded, of course it excludes the air from the space it occupies. When it contracts again, the air must follow. Suppose the contraction should take place at a rate greater than the air could move; then

there would be a vacuum between the surface and the advancing air, and that would be the condition all about the sphere; but at whatever rate the contraction took place there would still be a partial vacuum next the surface of the sphere, else there would be no movement of the air towards it; that is to say, the pressure is less next to the sphere than at a distance from it. Suppose the sphere to contract and dilate between the limits of the lines in the figure, say one hundred times per second; then the density would be less between those limits than it would be beyond the outer one, with the consequence that the lessened density would lessen the pressure upon the sphere in every

direction about it, and this condition would be maintained as long as the vibration was maintained. Another body near the vibrating sphere would be subject to a pressure on its further side greater than on the side adjacent to it, and as a consequence would be pushed towards the sphere. It would appear as if the latter attracted it. The space about the vibrating body within which such lessening of pressure occurs, may be called its *mechanical field*, because the effects noted are mechanical effects. This expression is in accordance with usage in electrical and magnetic phenomena. The magnetic field is that space about a magnet within which magnetic effects take place. In the case of the sphere the shape of the field would be spherical; but if the vibrating body was a rod or fork or disk or ring, the shape of the field would be different, and evidently would depend upon the shape of the body as well as upon its characteristic vibrations. A tuning-fork does not have such a uniform field as the imagined sphere, but presents two nodes, radiating from the outer edge of each prong. These nodes, or spaces of no vibration, may easily be detected by holding the fork near the ear and rotating it with the fingers while it is vibrating. As the lessening of density depends upon the amplitude of vibration, it is plain that the greatest disturbance and least pressure will be in the plane of vibration of the fork and near the ends of the prongs, and here is where it makes itself obvious by its apparent attraction of other bodies. If a paper wind-mill three or four inches in diameter be held by a thread near to a vibrating Chladni plate, it will be made to rapidly rotate by the difference in pressure above and below the arms of the mill. A smaller one that may be moved to different parts of the plate will be found to be but little affected at the nodal points and lines. This mechanical field of the Chladni plate extends an inch or more from its surface both above and below, and its form, of course, varies with the number of vibrations the plate is making and the energy of the components of the sound.

It is here assumed that vibrating atoms must have a *field* in the same sense as larger bodies, and that mechanical effects must be produced in them not dissimilar to what takes place in larger masses. The atoms, however, vibrate in the ether; but we know from various other phenomena presented by atoms,

molecules, and ether, that the latter is affected by motions of the former because they spend their energy upon it in some cases, and in others receive energy from it. This is true for light, for magnetism and electricity, and these are explained as setting up undulations or special stresses in the ether. If one considers the space affected by a heat vibration of an atom as its field, it appears to be as large as the universe, for the undulation travels on in straight lines to an indefinite distance, as do sound vibrations in the air; but the maximum displacement or change in the density or stress in the medium must necessarily be greatest where the amplitude of motion is greatest; namely, immediately adjacent to the vibrating body itself. Assume that the vibrating atom lessens the density of the ether adjacent to it, and at once it is seen that other atoms near by will be crowded towards the one thus vibrating—there is an apparent attraction within its field. But the heat vibrations of an atom, as represented in Fig. 1, will have a field somewhat like

FIG. 3.

that of a tuning-fork; for, as shown, there are four nodes where there would be no lessening of the pressure, and four parts where such lessening would be at its maximum. Consider, then, two atoms adjacent to each other, but not in contact, and one of them vibrating in its fundamental rate, Fig. 3.

The nodes are at 1, 2, 3, and 4; and if the spaces marked 5, 6, 7, and 8 represent the variable pressure spaces or the field of the atom, it is shown that the other atom will be in a space of less pressure at 6 than at 9, and consequently will be crowded towards 6, where the amplitude is greatest; but because it is greatest, it will be in unstable position, and will move to one or the other nodes, 1 or 2, where it will be held while the vibration is kept up. If the second atom vibrates also, that will only double the strength of the field at 6 and make the pressure towards each other stronger than before, and the two will join nodes at 1 or 2. But there are four nodes, and consequently as many places

where other atoms can join, in which case, if all were vibrating similarly, there might be a conjunction, as shown in Fig. 4,—an atom at each one of the nodes; but such an arrangement in one plane would not be a stable arrangement. The point of attachment of any one might be considered as a kind of hinge, allowing a swing to and fro. Imagine two opposite ones, as 2 and 4, to swing upwards so as to touch each other. If these be vibrating, their points of contact will be nodes. They will, therefore,

FIG. 4.

cohere by another bond, and such an atomic arrangement will be a stable one. If the rings have equal dimensions, an edge view would show them as an equilateral triangle with nodes at the apices, Fig. 5. We might call such a combination a molecule, and say it was held together by chemism. Each molecule thus constituted must have a mechanical *field*, which will be the resultant of all the atomic fields that compose it; and indeed this will be true for such molecules of every degree of complexity. Molecules having similar fields fit together for obvious mechanical reasons, and cohere because they are pressed together by the medium they vibrate in. If similar triangular forms to the one above unite, they may form hexagonal prisms, as Fig. 6 shows, in cross-section, and such as is the crystalline forms assumed by water, silica, and some other minerals having three atoms in the molecule.

FIG. 5

FIG. 6.

Now let 2, 3, 4, and 5 of Fig. 4 swing upwards; they too will touch each other at their sides and at nodes, so as to form a stable figure held by eight bonds,—an atomic box without a lid,—yet having four nodes on the open end to which another

similar atom could be attached by its four bonds, forming a cubical box having a high degree of mechanical stability. It will have a symmetrical, but not a uniform, field; the corners being the places having maximum displacements, and the middle of each edge the minimum, as the nodes are all in such positions. Hence other similar cubes would be moved to assume symmetrical positions when in contact, and thus a cubical structure, or prismatic form, would be built by aggregation of similar molecules. This is on the supposition that all the atoms combining thus together are equal in size as well as uniform in their vibrations; and this cubical form is one in which not a few of the elements crystallize; for example, gold, iron, copper.

If one would see more clearly how these nodes and loops fit together in such structures, let him make paper models, drawing a set of circles with their peripheries touching at one point, as shown in Fig. 4. Make points upon each circle to indicate the nodes, and then bend them up as described. If another one similar to 3 be made hinged at 6, it will form the cover to the cube, and all the nodes will be adjacent.

So far such vortex atoms have been considered as being all of one magnitude, or as all having a similar rate of vibration; but the different elements have different masses, and therefore vibrate with different rates; the greater the mass, the slower the rate, according to the laws of motion. When two elementary atoms come into contact with each other while vibrating at their individual rates, whether they can cohere or not will depend upon whether the vibratory rates are commensurate or not. If they are not, there will be what is called interference in their respective fields, and each will tend to destroy the other's field. When the vibrations of two tuning-forks not in unison or in a harmonic series are heard together, their interferences are audible, and are called *beats*. They are in opposite phases a portion of the time. Vibrating atoms must be subject to the same conditions. One ought, therefore, to expect that elements with different masses would show different degrees of coherence, as indeed they do. There are all degrees of these incompatible movements from that exhibited by oxygen and fluorine, which have never been made to combine at all, through the slight cohesions shown by gold, platinum, etc., for other elements, up to that exhibited by carbon for itself in the diamond,

and oxygen and aluminium in the ruby. Furthermore, an element having but a small mass like hydrogen could produce a field of slight strength compared to that of an element moving with the same velocity, yet having decidedly a greater mass, so that when it combined with any other element, it would be because of the greater energy of the other's field; that is to say, oxygen holds on to hydrogen rather than hydrogen to oxygen, and one would expect that hydrogen could be replaced by some other element in a compound more readily than any other element. Hence, whatever might be the relative rates of vibration when compared with other elements, one might infer it could be associated with them. One might explain its weak affinities by its small mass and consequent small vibrating energy. With larger masses, however, the case would be different. If one made five vibrations while the other made but one, they would be in the same phase but one-fifth of the time, and in more or less interference the other four-fifths; and unless there was a considerable disparity in their masses, there would apparently be but slight cohesion. If one made four while the other made one, they would be in similar phases three-fourths of the time, and could thus form a more stable alliance.

As has already been said, atoms vibrate in harmonic series, and this must frequently modify the position of the nodes when adhesions can occur. Now the harmonic series is 2, 3, 4, and so on, times the fundamental rate. If one will imagine such a vibrating ring to be cut at one of the nodes, and the two ends straightened out, it will be seen that there are really two vibrations, or stationary waves, as they sometimes are called, in the ring, and the harmonics are the fractional parts of one wave. Suppose each of these waves to be divided into three parts,—that is, to be accompanied by the second harmonic; then the circumference of the ring would have twelve nodes,—an arrangement that would permit three other rings to be hinged at angles of 120° apart; and if these were swung upwards until they touched each other, they would form a stable combination, but the angle made between the base and the side of this pyramidal structure would depend upon the relative diameters of the ring composing the base and sides. The smaller the latter, the greater the inclination. With similar structure there could grow up another hexagonal system, having a differently distributed field

from the other, but still symmetrical, and therefore capable of growing a symmetrical shape.

This has probably been carried far enough to show what was intended; namely, that because the atoms of matter are vibrating, and for all matter within our experience a long way above absolute zero, and because the motions of matter are known to affect the ether in a manner that depends upon the character of the motion, it follows that each atom has a field the shape of which, and the strength of which, must depend upon the kind of motion it has and the energy involved; that vibrating motions affect the density of the ether in different directions about the atom, and result in a pressure towards it, and on account of the harmonic motions, there are stationary nodes where atoms may cohere together, forming symmetrical figures of molecules and larger masses of crystals, each of which in its turn has a field which is the resultant of the combined fields of its constituents. It is the reaction of this field upon other molecules that organizes them into the larger geometrical shapes, and tends to replace upon imperfect crystals the parts that have been removed or which are not symmetrical with the rest — a phenomenon that has been observed.

The reaction of a field upon a body within it is recognized in the familiar phenomena of heat; for the ether waves that have been produced by a hot body compel other molecules, which these waves meet, to vibrate like those that produced the waves. The earth is heated by the sun for this reason.

Whenever the ether is put into a condition of motion or of an abnormal stress through the motions of atoms and molecules, other atoms and molecules must adapt themselves to the abnormal condition by adopting the motions, or changing their position, or both, the tendency always being to assume the condition of the original disturbing body. This explains why it is that a certain molecular combination possesses the ability to aid in the formation of other similar molecules, a property exhibited by the simplest as well as the most complex molecules, in non-living as well as living organisms.

The foregoing explanation of the organization of atoms into molecules, and molecules into crystalline forms, is made to depend upon the freedom of such bodies to assume their geometrical positions, such as gases and liquids permit; but it must

not be inferred that molecules could not cohere except at such nodal points. So long as the atoms vibrate, they produce fields; and this compels the molecules to assume a degree of compactness that depends upon the strength of the fields, and this may take place in the most irregular manner and without any special order. A piece of wrought iron may be made crystalline by repeated jarring, as it gives to the molecules a transient degree of freedom to assume any new position they have any tendency to take. In like manner, a bar of iron held in the proper position in a magnetic field will, if jarred by the stroke of a hammer, assume polarity; for the jar assists the molecules to rotate to the magnetic position induced by the field. But the strength of cohesion in crystals is generally less than in amorphous bodies, probably from the fact that when the molecules have moved to the vibratory nodes, forming geometrical figures, they have moved somewhat away from the place of greatest pressure, which is where the amount of motion is greatest, the atomic impacts at such places tending to move them towards less disturbed points. When molecules are very compact, such change of position is mechanically difficult, and vigorous jarring aids somewhat to the rearrangement. Hence the crystallization that often takes place in solids like iron.

Perhaps most who have read this so far have already foreseen the bearing it has upon organization as manifested in living things, rendering it unnecessary to do more than briefly to apply it.

Chemically, protoplasm is made up of complex molecules, not of so great a variety of elements, yet a thousand or more atoms in one molecule. As molecules increase in complexity, they become less stable, the interior atoms being in a much more uniform field than the outer ones, and therefore more easily displaced; but every such protoplasmic molecule, whether with or without a cell structure, must have a *mechanical field*, and therefore must compel other matter in proximity to it to assume the same arrangement as its own. If all the elements necessary are available, it will be done; that is to say, the protoplasmic mass *grows*. But this process is called life, or the results of life.

As the mechanical relation to the *field* is different for an atom deeply imbedded in a molecule from that of one on the surface,

as was pointed out a little way back, it follows that a greater degree of stability would be looked for in the materials upon the outside than upon the inside; and hence the cellular structure itself is a result of the mechanical relations between the molecules and their field.

The field of a given cell must depend upon the elements of its composition, their number and arrangement; and for any one of visible magnitude must be so complex that, at any rate, now it would be quite a hopeless task to attempt to describe it, yet there does not appear to be a good reason for not having a well-grounded conviction that in fact there must be such a field, and some sort of a mental picture of what it must be like.

As its source is purely mechanical, its properties must also be purely mechanical, the form assumed and the order exhibited being but an extension to complex molecules of the form and order displayed among relatively simpler bodies called crystals.

Now, vital force as an entity has been quite given up by all, except a few of the old school of biologists who have not yet, and probably never will learn that such a view is incompatible with almost everything we do know, as science, about the matter. The foregoing presentation shows that such an assumption is an unnecessary one, as fundamental mechanics will explain the phenomena without its aid. Its bearings upon some of the problems of biology must be apparent, as a prime factor in evolution, in explaining heredity, and in giving a very distinct answer to the question as to the cause of variation; for an extra molecule, even accidentally imbedded in a mass of other molecules, must change the configuration of the field, and hence the direction of growth. One does not need to go further than the formation of a cell that can organize a similar one, animal or vegetable, for the purposes of this article; but the next question to be asked by every one interested in the problems of life is, What is to be said of mind, consciousness? Has that, too, a mechanical antecedent, a mechanical equivalent, and does it depend solely upon mechanical conditions? Not long ago it was the custom to speak of *higher* and *lower* forces. These were mechanical forces on the lowest plane, then chemical, then vital and mental forces highest of all. Now two of these, the chemical and vital, have absolutely been absorbed into the mechanical one. In fact, it now seems absurd to speak of higher and lower

in physical phenomena in any philosophical sense. There is matter and its motions, rectilinear, rotary, vibratory, and vortical, each kind changeable into the other under proper mechanical conditions; and there is no sense in speaking of one of them as being higher than another. Each one of them has mechanical possibilities that do not belong to the others, and no one of them can be treated as first in order.

When it is ascertained that heat is a vibration, that light is an undulation, that electricity is a rotation, that is, that they are only conditions, it is seen that the questions *what is heat, what is light, what is electricity*, are philosophically improper questions, and the whole scheme of the universe mechanically considered is on one plane, and there is nothing common or unclear in it. This is to meet the objections of those who think that matter and its phenomena are of a low grade. As a matter of fact, mind is in some way associated with matter, and depends for its development upon matter and its properties. As it is associated with a certain cell structure, there is at the outset a presumption that the mechanical relations are not so different as they seem to be, and the explanation is to be found sooner or later in entire accordance with all other physical phenomena. If one is to attempt an explanation, it must be in accordance with what we do know, and not in accordance with what we don't know.

Suppose, then, there be in the universe a mental field, no matter how that was produced. Wherever there should chance to be a collocation of matter, with a field upon which the first could react, the second would be mechanically endowed with the property that maintained the field; that is to say, mental phenomena would manifest themselves for precisely the same reason that other properties manifest themselves. The character of the mental manifestations would in such a case depend upon the character and complexity of the material structure that was acted upon, giving scope for all the degrees of intelligence exhibited by the animal creation including man.

Perhaps most persons would say I have now invoked the *deity*, to which I do not object; but as my purpose is to show how things can be so and so in accordance with mechanics, I have spoken of the *mental field* without regard to other than its mechanical relations to such matter as makes up the nervous

matter of animals. When the needle of a compass turns from its normal position, we know that a new magnetic field is acting upon it, and we do not need to know whether that was produced by a permanent magnet or a current of electricity in a neighboring conductor. Its behavior is explained without regard to the antecedents of the field.

REMARKS.

As the foregoing article cannot be said to come strictly within the scope of this JOURNAL, a note of explanation is here appended. The nature of formative energy was briefly adverted to in a previous number, and the views there presented elicited some critical comments by letter from Professor Dolbear. The outcome of the correspondence was that Professor Dolbear prepared, at my solicitation, a paper for the JOURNAL, in which the question is treated from the physicist's standpoint. An article of such exceptional interest, bearing directly on a problem underlying all animal and vegetable morphology, can hardly be regarded as out of place in these pages, and I am confident that its perusal will not leave the reader over-solicitous on such a point.

It is not my purpose here to discuss the bearings of the mechanical hypothesis presented by Professor Dolbear, but a brief comment or two may not be amiss.

According to this hypothesis, the formative agency is ether-pressure, acting under conditions induced and maintained, not by unit-action of the organism, but by vibratory motions of its constituent elements mechanically associated. Attraction is banished from the universe. Chemism and cohesion, and presumably gravitation too, are but different degrees of ether-pressure. Crystallization, development, growth, are all mere expressions of the interaction of atomic vibration and ether-pressure.

Now consider the elements out of which the organic world is to be evolved: *Atoms*, absolutely inert, and utterly destitute of all *qualitative* distinctions; impressed, vibratory *motions*, measured and timed by the magnitude of the atoms; and *ether-pressure*, compelling purely mechanical associations. Then we have the *mechanical field*, and with this captivating conception, we rise to that of an automaton in the *form* of man. But alas! the all-important psychical qualities are missing. We have just what we started with — unconscious, inert atoms, played upon by ether-impressions. Of course we had no right to expect more;

for if qualities are left out at the beginning, they will not turn up at the end. *Ex nihilo nihil fit*. Now I may be mistaken, but I think there are few biologists to-day who will object to an hypothesis because it is mechanical ; but there are at least some who find it difficult to accept any hypothesis that ignores qualities. The evolution of function proceeds *pari passu* with that of structure, and the basis for both must be postulated at the outset. There is no place anywhere for the sudden apparition of qualities for which no basis previously existed. And here the question forces itself upon us : If it be inadmissible for a physicist to import into his discussion of atomic phenomena anything which has no physical antecedent, how much has he lessened the difficulty by postponing the forbidden act till after his automaton has been constructed? And yet we are told that the psychical factor, once introduced, transforms the machine into a microcosm, and henceforth exhibits itself in vibrations that do not upset the previous mechanical harmony. If the mechanical field be the avenue of admission for the psychical factor, then why may not our mechanical hypotheses endure its presence at one stage with as much composure as at another? If the doctrine of the conservation of energy allows a "mental field," impressing itself upon a mechanical field, then it surely will not break down under the burden of a few qualitative distinctions imported into our atoms and molecules. Then, too, I am tempted to ask, is not the "mental field" a needless invention? It claims to add nothing to the organism except motion, and if qualitative distinctions need no other basis, why seek an unknown source for what is furnished in the elements with which we have to deal?

But there is no end to questions, and my interest in Professor Dolbear's admirable exposition has already carried me beyond the first intention of my comments, and perhaps beyond the forbearance of the reader.

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