THE MONIST.

MAN'S GLASSY ESSENCE.

In The Monist for January, 1891, I tried to show what conceptions ought to form the brick and mortar of a philosophical system. Chief among these was that of absolute chance for which I argued again in last April's number.* In July, I applied another fundamental idea, that of continuity, to the law of mind. Next in order, I have to elucidate, from the point of view chosen, the relation between the psychical and physical aspects of a substance.

The first step towards this ought, I think, to be the framing of a molecular theory of protoplasm. But before doing that, it seems indispensable to glance at the constitution of matter, in general. We shall, thus, unavoidably make a long detour; but, after all, our pains will not be wasted, for the problems of the papers that are to follow in the series will call for the consideration of the same question.

All physicists are rightly agreed the evidence is overwhelming which shows all sensible matter is composed of molecules in swift motion and exerting enormous mutual attractions, and perhaps repulsions, too. Even Sir William Thomson, Lord Kelvin, who wishes to explode action at a distance and return to the doctrine of a plenum, not only speaks of molecules, but undertakes to assign definite

* I am rejoiced to find, since my last paper was printed, that a philosopher as subtle and profound as Dr. Edmund Montgomery has long been arguing for the same element in the universe. Other world-renowned thinkers, as M. Renouvier and M. Delboeuf, appear to share this opinion.
magnitudes to them. The brilliant Judge Stallo, a man who did not always rightly estimate his own qualities in accepting tasks for himself, declared war upon the atomic theory in a book well worth careful perusal. To the old arguments in favor of atoms which he found in Fechner's monograph, he was able to make replies of considerable force, though they were not sufficient to destroy those arguments. But against modern proofs he made no headway at all. These set out from the mechanical theory of heat. Rumford's experiments showed that heat is not a substance. Joule demonstrated that it was a form of energy. The heating of gases under constant volume, and other facts instanced by Rankine, proved that it could not be an energy of strain. This drove physicists to the conclusion that it was a mode of motion. Then it was remembered that John Bernoulli had shown that the pressure of gases could be accounted for by assuming their molecules to be moving uniformly in rectilinear paths. The same hypothesis was now seen to account for Avogadro's law, that in equal volumes of different kinds of gases exposed to the same pressure and temperature are contained equal numbers of molecules. Shortly after, it was found to account for the laws of diffusion and viscosity of gases, and for the numerical relation between these properties. Finally, Crookes's radimeter furnished the last link in the strongest chain of evidence which supports any physical hypothesis.

Such being the constitution of gases, liquids must clearly be bodies in which the molecules wander in curvilinear paths, while in solids they move in orbits or quasi-orbits. (See my definition solid II, 1, in the "Century Dictionary.")

We see that the resistance to compression and to interpenetration between sensible bodies is, by one of the prime propositions of the molecular theory, due in large measure to the kinetical energy of the particles, which must be supposed to be quite remote from one another, on the average, even in solids. This resistance is no doubt influenced by finite attractions and repulsions between the molecules. All the impenetrability of bodies which we can observe is, therefore, a limited impenetrability due to kinetic and positional energy. This being the case, we have no logical right to suppose that absolute impenetrability, or the exclusive occupancy of space, belongs to molecules or to atoms. It is an unwarranted hypothesis, not a vera causa.* Unless we are to give up the theory of energy, finite positional attractions and repulsions between molecules must be admitted. Absolute impenetrability would amount to an infinite repulsion at a certain distance. No analogy of known phenomena exists to excuse such a wanton violation of the principle of continuity as such a hypothesis is. In short, we are logically bound to adopt the Bosovichian idea that an atom is simply a distribution of component potential energy throughout space, (this distribution being absolutely rigid,) combined with inertia. The potential energy belongs to two molecules, and is to be conceived as different between molecules A and B from what it is between molecules A and C. The distribution of energy is not necessarily spherical. Nay, a molecule may conceivably have more than one centre; it may even have a central curve, returning into itself. But I do not think there are any observed facts pointing to such multiple or linear centres. On the other hand, many facts relating to crystals, especially those observed by Voigt,† go to show that the distribution of energy is harmonical but not concentric. We can easily calculate the forces which such atoms must exert upon one another by considering that they are equivalent to aggregations of pairs of electrically positive and negative points infinitely near to one another. About such an atom there would be regions of positive and of negative potential, and the number and distribution of such regions would determine the valency of the atom, a number which it is easy to see would in many cases be somewhat indeterminate. I must not dwell further upon this hypothesis, at present. In another paper, its consequences will be further considered.

I cannot assume that the students of philosophy who read this magazine are thoroughly versed in modern molecular physics, and

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* By a vera causa, in the logic of science, is meant a state of things known to exist in some cases and supposed to exist in other cases, because it would account for observed phenomena.
† Wiedemann, Annalen, 1887-1889.
‡ See Maxwell on Spherical Harmonics, in his Electricity and Magnetism.
therefore it is proper to mention that the governing principle in this branch of science is Clausius's law of the virial. I will first state the law, and then explain the peculiar terms of the statement. This statement is that the total kinetic energy of the particles of a system in stationary motion is equal to the total virial. By a system is here meant a number of particles acting upon one another. Stationary motion is a quasi-orbital motion among a system of particles so that none of them are removed to indefinitely great distances nor acquire indefinitely great velocities. The kinetic energy of a particle is the work which would be required to bring it to rest, independently of any forces which may be acting upon it. The virial of a pair of particles is half the work which the force which actually operates between them would do if, being independent of the distance, it were to bring them together. The equation of the virial is

\[ \frac{1}{2} \sum m v^2 = \frac{1}{2} \Sigma \Sigma R r. \]

Here \( m \) is the mass of a particle, \( v \) its velocity, \( R \) is the attraction between two particles, and \( r \) is the distance between them. The sign \( \Sigma \) on the left hand side signifies that the values of \( m v^2 \) are to be summed for all the particles, and \( \Sigma \Sigma \) on the right hand side signifies that the values of \( R r \) are to be summed for all the pairs of particles. If there is an external pressure \( P \) (as from the atmosphere) upon the system, and the volume of vacant space within the boundary of that pressure is \( V \), then the virial must be understood as including \( \frac{1}{2} PV \), so that the equation is

\[ \frac{1}{2} \sum m v^2 = \frac{1}{2} PV + \frac{1}{2} \Sigma \Sigma R r. \]

There is strong (if not demonstrative) reason for thinking that the temperature of any body above the absolute zero (\(-273^\circ\)C.), is proportional to the average kinetic energy of its molecules, or say \( n \).

* The word system has three peculiar meanings in mathematics. (1.) It means an orderly exposition of the truths of astronomy, and hence a theory of the motions of the stars; as the Heliocentric system, the Copernican system. This is much like the sense in which we speak of the Calvinistic system of theology, the Kantian system of philosophy, etc. (2.) It means the aggregate of the planets considered as all moving in somewhat the same way as the solar system, and hence any aggregate of particles moving under mutual forces. (3.) It means a number of forces acting simultaneously upon a number of particles.

where \( u \) is a constant and \( \theta \) is the absolute temperature. Hence, we may write the equation

\[ a \theta = \frac{1}{2} \sum m v^2 = \frac{1}{2} PV + \frac{1}{2} \Sigma \Sigma R r, \]

where the heavy lines above the different expressions signify that the average values for single molecules are to be taken. In 1872, a student in the University of Leyden, Van der Waals, propounded in his thesis for the doctorate a specialisation of the equation of the virial which has since attracted great attention. Namely, he writes it

\[ a \theta = (P + \frac{c}{V^2})(V - b). \]

The quantity \( b \) is the volume of a molecule, which he supposes to be an impenetrable body, and all the virtue of the equation lies in this term which makes the equation a cubic in \( V \), which is required to account for the shape of certain isothermal curves. But if the idea of an impenetrable atom is illogical, that of an impenetrable molecule is almost absurd. For the kinetical theory of matter teaches us that a molecule is like a solar system or star-cluster in miniature. Unless we suppose that in all heating of gases and vapors internal work is performed upon the molecules, implying that their atoms are at considerable distances, the whole kinetical theory of gases falls to the ground. As for the term added to \( P \), there is no more than a partial and roughly approximative justification for it. Namely, let us imagine two spheres described round a particle, as their centre, the radius of the larger being so great as to include all the particles whose action upon the centre is sensible, while the radius of the smaller is so large that a good many molecules are included within it. The possibility of describing such a sphere as the outer one implies that the attraction of the particles varies at some distances inversely as some higher power of the distance than the cube, and, to speak more clearly, that the attraction multiplied by the cube of the distance diminishes as the distance increases; for the number of particles at a given distance from any
one particle is proportionate to the square of that distance and each of these gives a term of the virial which is the product of the attraction into the distance. Consequently unless the attraction multiplied by the cube of the distance diminished so rapidly with the distance as soon to become insensible, no such outer sphere as is supposed could be described. However, ordinary experience shows that such a sphere is possible; and consequently there must be distances at which the attraction does thus rapidly diminish as the distance increases. The two spheres, then, being so drawn, consider the virial of the central particle due to the particles between them. Let the density of the substance be increased, say, $N$ times. Then, for every term, $R_T$, of the virial before the condensation, there will be $N$ terms of the same magnitude after the condensation. Hence, the virial of each particle will be proportional to the density. and the equation of the virial becomes

$$a\bar{h} = \frac{P}{\bar{h}} + \frac{a}{\bar{h}}$$

This omits the virial within the inner sphere, the radius of which is so taken that within that distance the number of particles is not proportional to the number in a large sphere. For Van der Waals this radius is the diameter of his hard molecules, which assumption gives his equation. But it is plain that the attraction between the molecules must to a certain extent modify their distribution, unless some peculiar conditions are fulfilled. The equation of Van der Waals can be approximately true therefore only for a gas. In a solid or liquid condition, in which the removal of a small amount of pressure has little effect on the volume, and where consequently the virial must be much greater than $P\bar{h}$, the virial must increase with the volume. For suppose we had a substance in a critical condition in which an increase of the volume would diminish the virial more than it would increase $P\bar{h}$. If we were forcibly to diminish the volume of such a substance, when the temperature became equalised, the pressure which it could withstand would be less than before, and it would be still further condensed, and this would go on indefinitely until a condition were reached in which an increase of volume would increase $P\bar{h}$ more than it would decrease the virial.

In the case of solids, at least, $P$ may be zero; so that the state reached would be one in which the virial increases with the volume, or the attraction between the particles does not increase so fast with a diminution of their distance as it would if the attraction were inversely as the distance.

Almost contemporaneously with Van der Waals's paper, another remarkable thesis for the doctorate was presented at Paris by Amagat. It related to the elasticity and expansion of gases, and to this subject the superb experimenter, its author, has devoted his whole subsequent life. Especially interesting are his observations of the volumes of ethylene and of carbonic acid at temperatures from 20° to 100° and at pressures ranging from an ounce to 5000 pounds to the square inch. As soon as Amagat had obtained these results, he remarked that the "coefficient of expansion at constant volume," as it is absurdly called, that is, the rate of variation of the pressure with the temperature, was very nearly constant for each volume. This accords with the equation of the virial, which gives

$$\frac{dp}{dn} = \frac{d}{dn} - \frac{a}{n}$$

Now, the virial must be nearly independent of the temperature, and therefore the last term almost disappears. The virial would not be quite independent of the temperature, because if the temperature (i.e. the square of the velocity of the molecules) is lowered, and the pressure correspondingly lowered, so as to make the volume the same, the attractions of the molecules will have more time to produce their effects, and consequently the pairs of molecules the closest together will be held together longer and closer; so that the virial will generally be increased by a decrease of temperature. Now, Amagat's experiments do show an excessively minute effect of this sort, at least, when the volumes are not too small. However, the observations are well enough satisfied by assuming the "coefficient of expansion at constant volume" to consist wholly of the first term, $a/\bar{h}$. Thus, Amagat's experiments enable us to determine the values of $a$ and thence to calculate the virial; and this we find varies for carbonic acid gas nearly inversely to $\bar{h}^4.5$. There is, thus, a rough approximation to satisfying Van der Waals's equation. But the
most interesting result of Amagat’s experiments, for our purpose at
any rate, is that the quantity $a$, though nearly constant for any one
volume, differs considerably with the volume, nearly doubling when the
volume is reduced fivefold. This can only indicate that the mean kinetic energy of a given mass of the gas for a given tempe-

rature is greater the more the gas is compressed. But the laws of
mechanics appear to enjoin that the mean kinetic energy of a moving
particle shall be constant at any given temperature. The only
escape from contradiction, then, is to suppose that the mean mass
of a moving particle diminishes upon the condensation of the gas.
In other words, many of the molecules are dissociated, or broken up
into atoms or sub-molecules. The idea that dissociation should be
favored by diminishing the volume will be pronounced by physi-
cists, at first blush, as contrary to all our experience. But it must be
remembered that the circumstances we are speaking of, that of a
gas under fifty or more atmospheres pressure, are also unusual.
That the “coefficient of expansion under constant volume” when
multiplied by the volumes should increase with a decrement of the
volume is also quite contrary to ordinary experience; yet it un-
doubtedly takes place in all gases under great pressure. Again,
the doctrine of Arrhenius\(^*\) is now generally accepted, that the mo-

cular conductivity of an electrolyte is proportional to the disso-
ciation of ions. Now the molecular conductivity of a fused electrolyte is
usually superior to that of a solution. Here is a case, then, in which
diminution of volume is accompanied by increased dissociation.

The truth is that several different kinds of dissociation have to
be distinguished. In the first place, there is the dissociation of a
chemical molecule to form chemical molecules under the regular
action of chemical laws. This may be a double decomposition, as
when iodhydric acid is dissociated, according to the formula

$$HI + HI = HH + II;$$

\(or, it may be a simple decomposition, as when pentachloride of phosphorus is dissociated according to the formula

$$PCl_5 = PCl_4 + Cl;$$

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it is likely that most of these enter into the composition of protoplasm. Now, since the numbers of chemical varieties increase at an enormous rate with the number of atoms per molecule, so that there are certainly hundreds of thousands of substances whose molecules contain twenty atoms or fewer, we may well suppose that the number of protoplasmic substances runs into the billions or trillions. Professor Cayley has given a mathematical theory of "trees," with a view of throwing a light upon such questions; and in that light the estimate of trillions (in the English sense) seems immoderately moderate. It is true that an opinion has been omitted, and defended among biologists, that there is but one kind of protoplasm; but the observations of biologists, themselves, have almost exploded that hypothesis, which from a chemical standpoint appears utterly incredible. The anticipation of the chemist would decidedly be that enough different chemical substances having protoplasmic characters might be formed to account, not only for the differences between nerve-slime and muscle-slime, between whale-slime and lion-slime, but also for those minuter pervasive variations which characterise different breeds and single individuals.

Protoplasm, when quiescent, is, broadly speaking, solid; but when it is disturbed in an appropriate way, or sometimes even spontaneously without external disturbance, it becomes, broadly speaking, liquid. A moner in this state is seen under the microscope to have streams within it; a slime-mound flows by force of gravity. The liquefaction starts from the point of disturbance and spreads through the mass. This spreading, however, is not uniform in all directions; on the contrary, it takes at one time one course, at another another, through the homogeneous mass, in a manner that seems a little mysterious. The cause of disturbance being removed, these motions gradually (with higher kinds of protoplasm, quickly) cease, and the slime returns to its solid condition.

The liquefaction of protoplasm is accompanied by a mechanical phenomenon. Namely, some kinds exhibit a tendency to draw themselves up into a globular form. This happens particularly with the contents of muscle-cells. The prevalent opinion, founded on some of the most exquisite experimental investigations that the history of science can show, is undoubtedly that the contraction of muscle-cells is due to osmotic pressure; and it must be allowed that that is a factor in producing the effect. But it does not seem to me that it satisfactorily accounts even for the phenomena of muscular contraction; and besides, even naked slimes often draw up in the same way. In this case, we seem to recognise an increase of the surface-tension. In some cases, too, the reverse action takes place, extraordinary pseudopodia being put forth, as if the surface-tension were diminished in spots. Indeed, such a slime always has a sort of skin, due no doubt to surface-tension, and this seems to give way at the point where a pseudopodium is put forth.

Long-continued or frequently repeated liquefaction of the protoplasm results in an obstinate retention of the solid state, which we call fatigue. On the other hand repose in this state, if not too much prolonged, restores the liquefability. These are both important functions.

The life-slimes have, further, the peculiar property of growing. Crystals also grow; their growth, however; consists merely in attracting matter like their own from the circumambient fluid. To suppose the growth of protoplasm of the same nature, would be to suppose this substance to be spontaneously generated in copious supplies wherever food is in solution. Certainly, it must be granted that protoplasm is but a chemical substance, and that there is no reason why it should not be formed synthetically like any other chemical substance. Indeed, Clifford has clearly shown that we have overwhelming evidence that it is so formed. But to say that such formation is as regular and frequent as the assimilation of food is quite another matter. It is more consonant with the facts of observation to suppose that assimilated protoplasm is formed at the instant of assimilation, under the influence of the protoplasm already present. For each slime in its growth preserves its distinctive characters with wonderful truth, nerve-slime growing nerve-slime and muscle-slime muscle-slime, lion-slime growing lion-slime, and all the varieties of breeds and even individual characters being preserved in the growth. Now it is too much to suppose there are billi
of different kinds of protoplasm floating about wherever there is
food.

The frequent liquefaction of protoplasm increases its power of
assimilating food; so much so, indeed, that it is questionable whether
in the solid form it possesses this power.

The life-slime wastes as well as grows; and this too takes place
chiefly if not exclusively in its liquid phases.

Closely connected with growth is reproduction; and though in
higher forms this is a specialised function, it is universally true that
wherever there is protoplasm, there is, will be, or has been a power
of reproducing that same kind of protoplasm in a separated organ-
ism. Reproduction seems to involve the union of two sexes; though
it is not demonstrable that this is always requisite.

Another physical property of protoplasm is that of taking habits.
The course which the spread of liquefaction has taken in the past is
rendered thereby more likely to be taken in the future; although
there is no absolute certainty that the same path will be followed
again.

Very extraordinary, certainly, are all these properties of proto-
plasm as extraordinary as indubitable. But the one which has
hext to be mentioned, while equally undeniable, is infinitely more
wonderful. 'It is that protoplasm feels. We have no direct evidence
that this is true of protoplasm universally, and certainly some kinds
feel far more than others. But there is a fair analogical inference
that all protoplasm feels. It not only feels but exercises all the func-
tions of mind.

Such are the properties of protoplasm. The problem is to find
a hypothesis of the molecular constitution of this compound which
will account for these properties, one and all.

Some of them are obvious results of the excessively complicated
constitution of the protoplasm molecule. All very complicated sub-
stances are unstable; and plainly a molecule of several thousand
atoms may be separated in many ways into two parts in each of
which the polar chemical forces are very nearly saturated. In the
solid protoplasm, as in other solids, the molecules must be supposed
to be moving as it were in orbits, or, at least, so as not to wander
indefinitely. But this solid cannot be melted, for the same reason
that starch cannot be melted; because an amount of heat insufficient
to make the entire molecules wander is sufficient to break them
up completely and cause them to form new and simpler molecules.
But when one of the molecules is disturbed, even if it be not quite
thrown out of its orbit at first, sub-molecules of perhaps several
hundred atoms each are thrown off from it. These will soon acquire
the same mean kinetic energy as the others, and therefore velocities
several times as great. They will naturally begin to wander, and
in wandering will perturb a great many other molecules and cause
them in their turn to behave like the one originally deranged. So
many molecules will thus be broken up, that even those that are in-
tact will no longer be restrained within orbits, but will wander about
freely. This is the usual condition of a liquid, as modern chemists
understand it; for in all electrolytic liquids there is considerable
dissociation.

But this process necessarily chills the substance, not merely on
account of the heat of chemical combination, but still more because
the number of separate particles being greatly increased, the mean
kinetic energy must be less. The substance being a bad conductor,
this heat is not at once restored. Now the particles moving more
slowly, the attractions between them have time to take effect, and
they approach the condition of equilibrium. But their dynamic
equilibrium is found in the restoration of the solid condition, which
therefore takes place, if the disturbance is not kept up.

When a body is in the solid condition, most of its molecules
must be moving at the same rate, or, at least, at certain regular sets
of rates; otherwise the orbital motion would not be preserved. The
distances of neighboring molecules must always be kept between a
certain maximum and a certain minimum value. But if, without
absorption of heat, the body be thrown into a liquid condition, the
distances of neighboring molecules will be far more unequally dis-
tributed, and an effect upon the virial will result. The chilling of
protoplasm upon its liquefaction must also be taken into account.
The ordinary effect will no doubt be to increase the cohesion and
with that the surface-tension, so that the mass will tend to draw it.
self up. But in special cases, the virial will be increased so much
that the surface-tension will be diminished at points where the tem-
perature is first restored. In that case, the outer film will give way
and the tension at other places will aid in causing the general fluid
to be poured out at those points, forming pseudopodia.

When the protoplasm is in a liquid state, and then only, a solu-
tion of food is able to penetrate its mass by diffusion. The pro-
toplasm is then considerably dissociated: and so is the food, like all
dissolved matter. If then the separated and unattenuated sub-mole-
cules of the food happen to be of the same chemical species as sub-
molecules of the protoplasm, they may unite with other sub-mole-
cules of the protoplasm to form new molecules, in such a fashion
that when the solid state is resumed, there may be more molecules
of protoplasm than there were at the beginning. It is like the jack-
knife whose blade and handle, after having been severally lost and
replaced, were found and put together to make a new knife.

We have seen that protoplasm is chilled by liquefaction, and
that this brings it back to the solid state, when the heat is recov-
ered. This series of operations must be very rapid in the case of
nerve-slime and even of muscle-slime, and may account for the un-
steady or vibratory character of their action. Of course, if assimil-
lation takes place, the heat of combination, which is probably tri-
fling, is gained. On the other hand, if work is done, whether by
nerve or by muscle, loss of energy must take place. In the case of
the muscle, the mode by which the instantaneous part of the fatigue
is brought about is easily traced out. If the muscle contracts
it be under stress, it will contract less than it otherwise would do,
and there will be a loss of heat. It is like an engine which should
work by dissolving salt in water and using the contraction during
the solution to lift a weight, the salt being recovered afterwards by
distillation. But the major part of fatigue has nothing to do with
the correlation of forces. A man must labor hard to do in a quarter
of an hour the work which draws from him enough heat to cool his
body by a single degree. Meantime, he will be getting heated, he
will be pouring out extra products of combustion, perspiration, etc.,
and he will be driving the blood at an accelerated rate through mi-
nute tubes at great expense. Yet all this will have little to do with
his fatigue. He may sit quietly at his table writing, doing prac-
tically no physical work at all, and yet in a few hours be terribly
fagged. This seems to be owing to the deranged sub-molecules of
the nerve-slime not having had time to settle back into their proper
combinations. When such sub-molecules are thrown out, as they
must be from time to time, there is so much waste of material.

In order that a sub-molecule of food may be thoroughly and
firmly assimilated into a broken molecule of protoplasm, it is ne-
necessary not only that it should have precisely the right chemical
composition, but also that it should be at precisely the right spot at
the right time and should be moving in precisely the right direction
with precisely the right velocity. If all these conditions are not ful-
filled, it will be more loosely retained than the other parts of the
molecule; and every time it comes round into the situation in which
it was drawn in, relatively to the other parts of that molecule and
to such others as were near enough to be factors in the action, it will
be in special danger of being thrown out again. Thus, when a partial
liquefaction of the protoplasm takes place many times to about the
same extent, it will, each time, be pretty nearly the same molecules
that were last drawn in that are now-thrown out. They will be
thrown out, too, in about the same way, as to position, direction of
motion, and velocity, in which they were drawn in; and this will be
in about the same course that the ones last before them were thrown
out. Not exactly, however; for the very cause of their being thrown
off so easily is their not having fulfilled precisely the conditions of
stable retention. Thus, the law of habit is accounted for, and with
it its peculiar characteristic of not acting with exactitude.

It seems to me that this explanation of habit, aside from the
question of its truth or falsity, has a certain value as an addition to
our little store of mechanical examples of actions analogous to habit.
All the others, so far as I know, are either statical or else involve
forces which, taking only the sensible motions into account, violate
the law of energy. It is so with the stream that wears its own bed.
Here, the sand is carried to its most stable situation and left there.
The law of energy forbids this; for when anything reaches a position
of stable equilibrium, its momentum will be at a maximum, so that it can according to this law only be left at rest in an unstable situation. In all the statical illustrations, too, things are brought into certain states and left there. A garment receives folds and keeps them; that is, its limit of elasticity is exceeded. This failure to spring back is again an apparent violation of the law of energy; for the substance will not only not spring back of itself (which might be due to an unstable equilibrium being reached) but will not even do so when an impulse that way is applied to it. Accordingly, Professor James says "the phenomena of habit... are due to the plasticity of the... materials." Now, plasticity of materials means the having of a low limit of elasticity. (See the "Century Dictionary," under solid.) But the hypothetical constitution of protoplasm here proposed involves no forces but attractions" and repulsions strictly following the law of energy. The action here, that is, the throwing of an atom out of its orbit in a molecule, and the entering of a new atom into nearly, but not quite the same orbit, is somewhat similar to the molecular actions which may be supposed to take place in a solid strained beyond its limit of elasticity. Namely, in that case certain molecules must be thrown out of their orbits, to settle down again shortly after into new orbits. In short, the plastic solid resembles protoplasm in being partially and temporarily liquefied by a slight mechanical force. But the taking of a set by a solid body has but a moderate resemblance to the taking of a habit, inasmuch as the characteristic feature of the latter, its inexactitude and want of complete determinacy, is not so marked in the former, if it can be said to be present there, at all.

The truth is that though the molecular explanation of habit is pretty vague on the mathematical side, there can be no doubt that systems of atoms having polar forces would act substantially in that manner, and the explanation is even too satisfactory to suit the convenience of an advocate of tychism. For it may fairly be urged that since the phenomena of habit may thus result from a purely mechanical arrangement, it is unnecessary to suppose that habit-taking is a primordial principle of the universe. But one fact remains unexplained mechanically, which concerns not only the facts of habit, but all cases of actions apparently violating the law of energy: it is that all these phenomena depend upon aggregations of trillions of molecules in one and the same condition and neighborhood; and it is by no means clear how they could have all been brought and left in the same place and state by any conservative forces. But let the mechanical explanation be as perfect as it may, the state of things which it supposes presents evidence of a primordial habit-taking tendency. For it shows us like things acting in like ways because they are alike. Now, those who insist on the doctrine of necessity will for the most part insist that the physical world is entirely individual. Yet law involves an element of generality. Now to say that generality is primordial, but generalisation not, is like saying that diversity is primordial but diversification not. It turns logic upside down. At any rate, it is clear that nothing but a principle of habit, itself due to the growth by habit of an infinitesimal chance tendency toward habit-taking, is the only bridge that can span the chasm between the chance-melody of chaos and the cosmos of order and law.

I shall not attempt a molecular explanation of the phenomena of reproduction, because that would require a subsidiary hypothesis, and carry me away from my main object. Such phenomena, universally diffused though they be, appear to depend upon special conditions; and we do not find that all protoplasm has reproductive powers.

But what is to be said of the property of feeling? If consciousness belongs to all protoplasm, by what mechanical constitution is this to be accounted for? The slime is nothing but a chemical compound. There is no inherent impossibility in its being formed synthetically in the laboratory, out of its chemical elements; and if it were so made, it would present all the characters of natural protoplasm. No doubt, then, it would feel. To hesitate to admit this would be puerile and ultra-puerile. By what element of the molecular arrangement then, would that feeling be caused? This question cannot be evaded or pooh-poohed. Protoplasm certainly does feel; and unless we are to accept a weak dualism, the property must be shown to arise from some peculiarity of the mechanical sys-
tem. Yet the attempt to deduce it from the three laws of mechanics, applied to never so ingenious a mechanical contrivance, would obviously be futile. It can never be explained, unless we admit that physical events are but degraded or undeveloped forms of psychical events. But once grant that the phenomena of matter are but the result of the sensibly complete sway of habits upon mind, and it only remains to explain why in the protoplasm these habits are to some slight extent broken up, so that according to the law of mind, in that special clause of it sometimes called the principle of accommodation,* feeling becomes intensified. Now the manner in which habits generally get broken up is this. Reactions usually terminate in the removal of a stimulus; for the excitation continues as long as the stimulus is present. Accordingly, habits are general ways of behavior which are associated with the removal of stimuli. But when the expected removal of the stimulus fails to occur, the excitation continues and increases, and non-habitual reactions take place; and these tend to weaken the habit. If, then, we suppose that matter never does obey its ideal laws with absolute precision, but that there are almost insensible fortuitous departures from regularity, these will produce, in general, equally minute effects. But protoplasm is in an excessively unstable condition; and it is the characteristic of unstable equilibrium, that near that point excessively minute causes may produce startlingly large effects. Here then, the usual departures from regularity will be followed by others that are very great; and the large fortuitous departures from law so produced, will tend still further to break up the laws, supposing that these are of the nature of habits. Now, this breaking up of habit and renewed fortuitous spontaneity will, according to the law of mind, be accompanied by an intensification of feeling. The nerve-protoplastm is, without doubt, in the most unstable condition of any kind of matter; and consequently, there the resulting feeling is the most manifest.

Thus we see that the idealist has no need to dread a mechan-

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ical theory of life. On the contrary, such a theory, fully developed, is bound to call in a tychistic idealism as its indispensable adjunct. Wherever chance-spontaneity is found, there, in the same proportion, feeling exists. In fact, chance is but the outward aspect of that which within itself is feeling. I long ago showed that real existence, or thing-ness, consists in regularities. So, that primeval chaos in which there was no regularity was mere nothing, from a physical aspect. Yet it was not a blank zero; for there was an intensity of consciousness there in comparison with which all that we ever feel is but as the struggling of a molecule or two to throw off a little of the force of law to an endless and innumerable diversity of chance utterly unlimited.

But after some atoms of the protoplasm have thus become partially emancipated from law, what happens next to them? To understand this, we have to remember that no mental tendency is so easily strengthened by the action of habit as is the tendency to take habits. Now, in the higher kinds of protoplasm, especially, the atoms in question have not only long belonged to one molecule or another of the particular mass of slime of which they are parts; but before that, they were constituents of food of a protoplasmic constitution. During all this time, they have been liable to lose habits and to recover them again; so that now, when the stimulus is removed, and the foregone habits tend to reassert themselves, they do so in the case of such atoms with great promptness. Indeed, the return is so prompt that there is nothing but the feeling to show conclusively that the bonds of law have ever been relaxed.

In short, diversification is the vestige of chance-spontaneity; and wherever diversity is increasing, there chance must be operative. On the other hand, wherever uniformity is increasing, habit must be operative. But wherever actions take place under an established uniformity, there so much feeling as there may be takes the mode of a sense of reaction. That is the manner in which I am led to define the relation between the fundamental elements of consciousness and their physical equivalents.

It remains to consider the physical relations of general ideas. It may be well here to reflect that if matter has no existence except
as a specialisation of mind, it follows that whatever affects matter according to regular laws is itself matter. But all mind is directly or indirectly connected with all matter, and acts in a more or less regular way; so that all mind more or less partakes of the nature of matter. Hence, it would be a mistake to conceive of the psychical and the physical aspects of matter as two aspects absolutely distinct. Viewing a thing from the outside, considering its relations of action and reaction with other things, it appears as matter. Viewing it from the inside, looking at its immediate character as feeling, it appears as consciousness. These two views are combined when we remember that mechanical laws are nothing but acquired habits, like all the regularities of mind, including the tendency to take habits, itself; and that this action of habit is nothing but generalisation, and generalisation is nothing but the spreading of feelings. But the question is, how do general ideas appear in the molecular theory of protoplasm?

The consciousness of a habit involves a general idea. In each action of that habit certain atoms get thrown out of their orbit, and replaced by others. Upon all the different occasions it is different atoms that are thrown off, but they are analogous from a physical point of view, and there is an inward sense of their being analogous. Every time one of the associated feelings recurs, there is a more or less vague sense that there are others, that it has a general character, and of about what this general character is. We ought not, I think, to hold that in protoplasm habit never acts in any other than the particular way suggested above. On the contrary, if habit be a primary property of mind, it must be equally so of matter, as a kind of mind. We can hardly refuse to admit that wherever chance motions have general characters, there is a tendency for this generality to spread and to perfect itself. In that case, a general idea is a certain modification of consciousness which accompanies any regularity or general relation between chance actions.

The consciousness of a general idea has a certain "unity of the ego," in it, which is identical when it passes from one mind to another. It is, therefore, quite analogous to a person; and, indeed, a person is only a particular kind of general idea. Long ago, in the
Journal of Speculative Philosophy (Vol. III, p. 156), I pointed out that a person is nothing but a symbol involving a general idea; but my views were, then, too nominalistic to enable me to see that every general idea has the unified living feeling of a person.

All that is necessary, upon this theory, to the existence of a person is that the feelings out of which he is constructed should be in close enough connection to influence one another. Here we can draw a consequence which it may be possible to submit to experimental test. Namely, if this be the case, there should be something like personal consciousness in bodies of men who are in intimate and intensely sympathetic communion. It is true that when the generalisation of feeling has been carried so far as to include all within a person, a stopping-place, in a certain sense, has been attained; and further generalisation will have a less lively character. But we must not think it will cease. Esprit de corps, national sentiment, sym-pathy, are no mere metaphors. None of us can fully realise what the minds of corporations are, any more than one of my brain-cells can know what the whole brain is thinking. But the law of mind clearly points to the existence of such personalities, and there are many ordinary observations which, if they were critically examined and supplemented by special experiments, might, as first appearances promise, give evidence of the influence of such greater persons upon individuals. It is often remarked that on one day half a dozen people, strangers to one another, will take it into their heads to do one and the same strange deed, whether it be a physical experiment, a crime, or an act of virtue. When the thirty thousand young people of the society for Christian Endeavor were in New York, there seemed to me to be some mysterious diffusion of sweetness and light. If such a fact is capable of being made out anywhere, it should be in the church. The Christians have always been ready to risk their lives for the sake of having prayers in common, of getting together and praying simultaneously with great energy, and especially for their common body, for "the whole state of Christ's church militant here in earth," as one of the missals has it. This practice they have been keeping up everywhere, weekly, for many centuries. Surely, a personality ought to have developed
in that church, in that "bride of Christ," as they call it, or else there is a strange break in the action of mind, and I shall have to acknowledge my views are much mistaken. Would not the societies for psychical research be more likely to break through the clouds, in seeking evidences of such corporate personality, than in seeking evidences of telepathy, which, upon the same theory, should be a far weaker phenomenon?

C. S. Peirce.