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II.—VARIATION, HEREDITY AND CONSCIOUSNESS.

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Introduction. A mechanist answer to the vitalist challenge.

FROM the days of Democritus to those of Darwin there were many attempts by materialistic philosophers to explain the seemingly purposive phenomena of life and mind in terms of the physical categories of science. The total of these efforts netted more of failure than of success. One after another of the problems of inorganic nature had been conquered by the patient application of mechanistic methods, but the outstanding characters of living matter had resisted elucidation by these methods and maintained a stubborn independence. Some of the organic processes and their material products had, to be sure, been reduced to terms of physics and chemistry, but the correlation of organs and functions in the individual, and the adaptation of the various species to one another and to the environment, remained quite unexplained. Up to the time of Darwin the materialists were forced to rely mainly upon an appeal to faith rather than proof. Their method had succeeded in the inorganic fields of astronomy, physics, and chemistry, and should be trusted to achieve a similar triumph in the fields of biology and psychology.

Since the coming of Darwin, however, the balance against materialism has become a balance in its favour. The fact of evolution itself affords a presumption of the ultimate homogeneity of organic and inorganic laws; and the great idea of natural selection as a method by which the adaptation of organs and the evolution of species can be at least partially explained without the aid of design, has put the opponents of materialism on the defensive. Biology and Psychology can no longer be regarded as islands of safety in which the teleological

philosophers may take refuge from the steadily rising tide of mechanistic science. And yet despite the threatening situation in which they find themselves the defenders of the doctrine of teleology have by no means abandoned hope. Bergson in France, MacDougall in England, and Driesch in Germany, have attacked mechanistic philosophy as not only inadequate to cope with the known facts of phylogeny, ontogeny, and consciousness, but as being definitely in conflict with those facts.

The present status of the controversy as I see it is this: In the first place, the anti-mechanists—whether out and out idealists or mere dualists—have succeeded in demonstrating that mechanistic categories, even when strengthened by the Darwinian principle of Natural-Selection, fail to explain the basic characters of vital activity. And they have shown that this failure is not due to the mere complexity of living systems but rather to the incorrigible purposiveness which life exhibits, whether it be studied externally as in biology, or internally as in psychology, and whether we consider its development in the individual or in the species.

In the second place, however, it seems to me that the success of vitalism in the way of destructive criticism is offset by its failure to afford a constructive principle of explanation. Whether we consider the relatively definite entelechy theories of Driesch, MacDougall, and Bergson, or the more general appeals to a category of organicity and to a "fitness of the environment," which characterize respectively the idealism of Dr. Haldane and the Neo-Paleyism of Professor Henderson, we find a failure to provide principles which are homogeneous with the established truths and fruitful methods of mechanistic science. In short, we are confronted at the present time with a situation in which the teleological and psychical characters of living beings remain as aliens in the country of science. The mechanists would have us forcibly deport these dangerous foreigners and then ignore, so far as possible, their very

existence. In other words, they would reduce teleology to an illusion and consciousness to an epiphenomenon. On the other hand, the vitalists would permit teleological processes and psychic agencies to run amuck throughout the whole domain of science, introducing destruction and paralysis, and generally disorganizing the peaceful industry of producing a material cause for every material effect. Each of these plans is dangerous, and in the end fruitless. The real remedy is to assimilate or naturalize the alien entities of teleology and consciousness and give them citizenship in the society of the mechanistic sciences. Until they are thus naturalized, they will continue a menace to the experimental study of nature.

The present paper is an attempt to point out one way in which the process of naturalization can be brought about. Variation, Heredity and Consciousness are the three aspects of life which give most trouble to the advocates of a mechanistic world view. And the fact that the comments which I wish to offer upon these three sets of problems have a certain unity of principle, is my only excuse for dealing in a single paper with such vast and diversified fields of knowledge. Aside from the pretentiousness of its title there is another and more serious defect of my essay for which I ask forgiveness. I have been obliged to use old-fashioned and more or less discredited categories in order to express my thought. In the writings of Hume, Mill and Comte, of Mach and Pearson, and now of Professor Whitehead and Mr. Russell, there has been a steady development of the methodological standpoint of positivism or descriptionism. A notable aspect of this development of descriptionism is the tendency to abandon the old conception of Force, as a mere unjustifiable hypostatization of our feelings of effort and muscular strain. In the face of this formidable consensus of experts, I have talked in my paper about forces and still more questionable entities such as "super-forces." I would plead in defence that the experiences of pressure and effort have as good a claim to objective validity as have visual

qualities of extension and shape; and one of the advantages of the latter for purposes of description is not incompatible with according an objective status to qualities like force and effort which are methodologically less useful. For example, the assumption of the *methodological* behaviourist that mind can best be described in terms of its manifestation in bodily movement, does not imply the conclusion of the *metaphysical* behaviourist that mind itself is therefore unreal. And it seems to me that in quite the same way we could hold that the methodological advantage of describing *force* in terms of its overt and measurable manifestation in change of motion need not imply the metaphysical conclusion that force itself is therefore unreal. And, in addition to the above excuse, I would urge, that as it has proved possible in many branches of physics to translate, without serious change of meaning, the older dynamic terminology of explanation into the modern language of kinematic description, so it might also be possible for a friendly scientific critic to translate into the language of to-day the old-fashioned concepts which my ignorance compels me to use

Finally as to the actual errors which I may have committed quite irrespective of terminology, I can only hope that they are not too grave or too numerous to render the paper altogether worthless, and that among the experts here present there may be some who, after demonstrating the errors, will be willing to undertake the more difficult business of explaining to what extent if at all my hypotheses can be amended to fit the facts as they know them.

And now, without further preamble I proceed to the consideration, in turn, of the three distinct yet related aspects of vital activity which appear to offer most resistance to mechanistic explanation. It will be my aim to show that as regards each of the three sets of problems it is possible to point out a solution which is statable in mechanistic terms, but which at the same time provides full satisfaction to the demand of the

vitalist or anti-mechanist that the purposive and psychic characters of life be not reduced to an epiphenomenal status of dependence upon blind processes but be recognized as genuinely operative factors in the economy of nature.

I. VARIATION.

The analogy of the germinal telogenesis of congenital variation to the psycho-cerebral telogenesis of creative imagination, and the mechanistic explanation of each as the resultant of a system of biological vectors.

Phylogenetic evolution consists in the progressive realization in the species of organs which are fitted to cope with the environment. Each of these organs of adaptation is a *telos* or purposive structure, and once granted the origin of variations in sufficient number and of a sufficient degree of utility, the teleological process by which they are actualized in the species can be mechanistically explained by Darwin's principle of Natural Selection. But before a *telos* can be actualized in the organism it must have originated in the germ. Teleology must be preceded by *Telogenesis*.

Since the abandonment of Lamarck's conception of the transmission of acquired characters, the most vulnerable point in the mechanistic theory of evolution, and the point against which the vitalists have aimed some of their strongest attacks, is the notion that the useful variations on which Natural Selection must work are accidental or non-purposeful in origin. In matters of purely quantitative variation such as size and weight, we might well admit that good or plus variations and bad or minus variations in the germinal determinants of any organ are equally probable; and a perfectly "blind" or mechanistic conception of their origin would suffice. But the development through a succession of minute variations of such organs as eyes and lungs is a very different matter. The number of meaningful combinations of letters is infinitely

smaller than the number of meaningless juxta-positions; and similarly the number of useful combinations of cells and cell-elements such as would be required to constitute an organ like an eye, is infinitely smaller and their occurrence is therefore infinitely less probable than the number of useless or harmful arrangements. That the molecules and atoms of a fertilized germ-cell should group themselves by mere chance, *i.e.*, by merely physical or blind forces, in such a way as to initiate or advance the formation of a useful bodily organ, would seem to be enormously improbable. Such general considerations, combined with the more special objection that the earlier stages in the development of useful organs have no survival value on which Natural Selection can work, have led the vitalists to believe in what is called "orthogenesis," *i.e.*, an intrinsic tendency of the germ-plasm to vary in one of the comparatively few directions that make for progress rather than in any of the virtually infinite number of ways that would be useless.

The remedies proposed by the vitalists are, however, worse than the disease which they are designed to cure. We must grant the existence of something like orthogenesis; but to explain it by abandoning mechanistic categories and invoking an *anima et machina* as first aid to the physiologist when in trouble is bad hypothetical methodology and hurtful to scientific progress. The activities of a Drieschian *entelechy* or a Bergsonian *elan vital* are at best hopelessly incommensurable with the known modes of bodily activity.

The first and most natural way out of the difficulty would consist in a revival of the Lamarckian belief in the ability of the soma-plasm to impart to the germ-plasm which it contains the specific adaptive improvements in eyes or lungs which had been acquired by the animal through functional adjustment to the light and air of its environment. But lack of empirical evidence for the inheritance of such acquirements, combined with the absence of any known mechanism by which specific somatic improvements could be transmitted to the reproductive

cells, suffice to convince the great majority of biologists that this way out is fruitless. Moreover, even if Lamarckianism were acceptable, it would scarcely apply to some of the most striking of the congenitally useful characters, such as those of the worker bees, in which there has been little chance for the parents to have acquired the advantageous capacities which appear in their offspring.

A second way out of the difficulty might seem to be furnished by the mutation theory of De Vries; but this innovation upon Darwinism meets the difficulty to which the parent theory was subject in the matter of explaining how Natural Selection could act on those organs which in their incipient stages possessed no survival value, only at the price of increasing to a preposterous degree the overdrafts on the theory of probability. For, if it is difficult to see how merely physical or chemical disturbances in the germ-plasm could suffice to produce even the minutely favourable variations which Darwin himself believed in, it is proportionately more difficult to believe that "mutations" or large variations could be the product of blind or mechanical causes. It is hard enough to believe that handfuls of letters thrown into the air would fall into place as intelligible words; it is infinitely harder to believe that they would so fall as to make whole sentences. In short, any advantages of the De Vriesian mutations (as substitutes for the minute variations of the Darwinians) are fully offset by the greater improbability of such mutations arising mechanistically.

In difficulties of this character it is often possible to derive help from analogies; suppose then that we turn aside for a moment from the problem of the origin of useful variations in the germ to that other problem (too much neglected by psychologists) as to the origin of useful variations in conscious life. It is so natural for us to consider the teleological phase of mental activity in which purposes are deliberately realized in conduct or in art, that we are apt to forget that earlier and

more spontaneous telogenetic phase in which the ideal or purpose originates. Yet this earlier telogenesis is at least as important as the later teleology; and it is most certainly its necessary condition. Before an ideal can be actualized it must have originated.

Telogenesis is the heart of what Bergson calls "creative evolution"; and that great philosopher has clearly demonstrated that creative evolution depends upon the cumulative preservation of the past. Because of this preservation of the past every product of a telogenetic process must have two basic characteristics: first, the characteristic of *pertinence* and, second, the characteristic of *novelty*. Since a telos arises from the past, it must be pertinent or relevant to it; it must carry on or carry out the tendencies which generate it, and make explicit what was implicit. But that which is a function of the whole past cannot be a mere repetition of a part of the past; hence the telos that arises will not merely be *pertinent*, it will also be *novel*. Real duration of the old is the condition and cause of a real creation of the new.

The theory that evolution is the working out of a divine plan—a repetition in time of what pre-existed in eternity—is criticized by Bergson on the ground that such an explanation does not solve the problem of design in the cosmos, but merely shifts it from the relatively accessible domain of the evolution of species in nature to the relatively inaccessible domain of the genetic psychology of the Deity. The question of how purposes can originate in the world is not answered by saying that they originated at a previous time in a divine or absolute mind.

Let us now consider some of the ways in which the two characteristics of *pertinence* and *novelty* are expressed in the telogenetic processes of consciousness.

(1) In cognitive experience, the formation of a hypothesis which harmonizes and explains a mass of data is a typical case of telogenesis. The hypothesis flashes up in the creative

imagination of the scientist. It is *novel* in that it differs from each of the remembered facts which contributed to generate it; and at the same time it is *pertinent* in that it explains them all. It reconciles their hitherto conflicting or unrelated tendencies, and carries them out and through to a victorious peace.

(2) In the conative sphere, telogenesis is virtually identical with external adjustment or *adaptation*. When in action, our problems are solved not by carrying out in detail a pre-meditated plan, but rather by novel and pertinent adaptation to the exigencies of the environment. This power to make unpurposed yet purposeful adjustments is sagacity.

(3) In the domain of affective experience, telogenesis is exemplified in almost any case of artistic creation or expression. Humour, in particular, because of the suddenness and spontaneity which is of its essence, is a perfect case of telogenetic activity. The flash of wit or pat remark, when at its best, is the acme of both pertinence and novelty. It is fresh, sudden, original, yet it expresses the quintessence of a prior situation with more accuracy than could be attained by the most laborious copying. I think we may say that, in general, it is only second-rate art that is either romantic or realistic. For it is only when art is second-rate that it will have to secure novelty at the expense of accuracy, or accuracy at the expense of novelty. In first-rate art the best of the one will be the best of the other. The most pertinent illumination of nature will be also the most novel and original.

(4) One of the best examples of telogenesis, and one in which the cognitive, conative and affective interests are equally involved, is afforded by the activity of speech or talk. In talking, a man does not and cannot plan out his words in advance. His sentences are not duplicates of what pre-existed; they do not repeat his thoughts, they express them. It is only in giving a speech that has been committed to memory

that one's talk is teleological rather than telogenetic. In unpremeditated talk, the meanings demanded by the topic under discussion are held by the mind in solution, and the words spoken are the crystals precipitated from the solution. Now there are some psychologists who are so biassed in favour of teleology that they would explain these cases of telogenesis by assuming that the novel and pertinent creations of consciousness are always pre-existent in a sub-consciousness. Even if this were true, the problem of accounting for these useful variations would only be shifted to another and less manageable domain. We should immediately have to inquire as to how the words and sentences pre-existent in the sub-conscious had themselves originated. In short, the telogenetic process in which variations arise that are at once pertinent and novel, purposeful yet unpurposed, is an ultimate fact, and can in no way be reduced to mere teleology.

It will be recalled that we digressed from our primary problem as to the origin of useful variations in the germ-plasm in order to see if the better-known but analogous cases of telogenesis in conscious activity would afford any suggestion for a mechanistic solution. In what follows, I shall try to show that the foundation for such a mechanistic solution is afforded by the principle of *biological vectors*, and that that principle is applicable to the two types of telogenesis exhibited by vital systems to creative imagination no less than to congenital variation.

A vector is a quantity having both magnitude and direction. It may be symbolized by a straight line of definite length and definite direction. The sum of two vectors is given by the diagonal of a parallelogram whose two adjacent sides are the vectors to be added. Vectors or directed lines can represent not only velocities and accelerations or forces, but also the higher spatio-temporal derivatives such as accelerations of accelerations or "super-forces" which will be explained in the second part of the paper. The result of combining or

fusing two or more of such forces or "super-forces" will always be expressed by a resultant vector which is got by the process of geometrical addition just mentioned. A very simple case of the combination of vectors will serve as an illustration of the general law. A body acted upon by a westward force and a northward force, simultaneously, will move or tend to move in a north-westerly direction. If the magnitude and direction of the westward force is represented by a three-inch line pointing west, and the magnitude and direction of the northward force is represented by a four-inch line pointing north, and making a second side of a rectangle, then the magnitude and direction of the resulting motion or tendency to move will be represented by the diagonal of the rectangle, that is, by a line five inches long and having a direction slightly west of north-west. In this case, as in others, the resultant of a combination of vectors will be a vector having the qualities of *pertinence* and *novelty*. For the north-westerly force is pertinent in that it carries out the westerly and northerly characters of its components, while its novelty is manifest in its differing from each of those characters. It is like orange light which differs from the red and yellow from which it arises, while at the same time, in its own new and richer hue, it carries out and expresses the simpler and more primitive characters of its constituents.

Now, without committing ourselves to a strict psycho-physical parallelism we can accept the theory that mental states are somehow correlated with physical states. And these physical correlates of mental states can only be conceived as of the nature of velocities, accelerations or forces in the cerebrum, in other words as vectors and groups of vectors. The unity and continuity of the cerebral system will provide for a constant interaction and combination of these cerebral vectors, with the consequence that new vectors will be produced as resultants or summations. Each of these resultants will have the characters of *pertinence* and *novelty* in relation to

the constituents by which it was generated. It will, in short, have precisely the qualities which we found to be exemplified in the telogenetic products of psychic adaptation and creative imagination.

In this connexion it is important for us to realize that while mechanists are not agreed on any metaphysical theory of the nature of the relation of a mental state to its physical concomitant, they are agreed that the concomitance itself is a fact. Hence any fusion or combination of the cerebral correlates of mental states must be accompanied by a corresponding fusion or combination of the mental states themselves. And since the combination of cerebral factors is of necessity a vector addition whose sum must express in a new tendency the harmonious fulfilment and unification of the pre-existing tendencies, so on the mental side there would with equal necessity result those same unpurposed yet purposeful syntheses which were given as illustrations of telogenesis in the field of conscious activity.

How will our principle of biological vectors apply to the problem of the origin of useful variations in the germ-plasm?

The fertilized germ of an animal is like the human brain, in that it is the bearer of a mass of tendencies representing the past. In the brain these traces of the past constitute the memories from the synthesis of which arise the felicitous telogenetic novelties of *creative imagination*. In the case of the germ, the traces of the past constitute not memories but the hereditary determinants from whose orthogenetic synthesis arise the useful variations or telogenetic novelties of *creative evolution*.

If the millions of ancestral qualities which must be embodied as determinants in the chromatin of the germ-plasm are conceived as we conceived the physical correlates of the brain's memories, namely as of the nature of velocities, accelerations, or forces, they will together constitute a vector system, constantly giving rise to other vectors, which will be not only

novel but pertinent. Like the flashes of inspiration these resultant vectors will express in new ways the combined tendencies from which they arose, and without having abandoned the categories of mechanism we shall have justified orthogenesis.

In short, creative evolution and creative imagination are diverse in media, but identical in activity. Nature is not stone blind like the atoms of the older materialism, nor, on the other hand, is she as depicted in the older theism, a moral agent endowed with prevision and engaged in the realization of pre-existent plans. She is an artist who works as she goes, giving spontaneous inspiration rather than deliberate edification and beauty rather than goodness.

II. HEREDITY.

The preservation of the past in the present, and the teleology of assimilation, reproduction and ontogeny mechanistically explained by the conception of life as a system of super-forces.

There are two facts about heredity on which the vitalists base their protest against mechanism. In the first place there is the capacity of life to preserve in the germ the infinitely rich manifold of hereditary determinants embodying the past ancestry of the plant or animal, and in the second place there is the teleological capacity of life to actualize this heredity-manifold progressively in the stages of embryonic growth.

I shall try to show that if we conceive of the germ as a hierarchical system of what I will call "*super-forces*," it will be possible to explain both of these aspects of heredity in terms of mechanistic categories.

The basic concepts of physical science are Mass, Space and Time. The other conceptions are derived by combining these notions.

Thus, the velocity of a moving body is expressed by dividing the space through which the body moves by the time

during which it moves; and the velocity of the body at any instant can be expressed by the limit approached by the fraction as s and t approach zero. Acceleration is the rate at which a velocity is changing. Force is the product of the mass and the acceleration. Momentum can be expressed as the product of the mass and the velocity. Energy can be expressed as one-half the product of the mass and the square of the velocity. According to Professor Karl Pearson, while these conceptions are sufficient for the ordinary purposes of mechanics, we could form concepts of higher orders of acceleration which would conform to the same laws of geometrical representation and combination as apply to simple accelerations and to velocities. Thus the rate at which an acceleration was changing or tending to change would be the first of the higher orders of acceleration, and the rate at which this rate itself was changing or tending to change would be the second of the higher orders of acceleration. Each of these successive orders of acceleration is derived from the preceding order by dividing by the time factor and taking the limiting value which the resulting fraction approaches as the numerator and denominator approach zero. This process is known as differentiation; and the series of higher orders of acceleration which result from the process constitute what are called the higher derivatives of space with regard to time. Inasmuch as force is defined as the product of the mass and the simple acceleration to which the mass is subject, we can use the term "super-force" to denote the product of a mass-factor, and any higher order of acceleration which it may embody, or to which it may be subject.

So much for the meaning of super-forces: I wish now to call attention to some of their characteristics which have a bearing upon the problem of the nature of the germ-plasm. In the first place, they can exist as physical realities without being visible or externally observable. Even velocity itself, the first of the derivatives of space with regard to time, is

only visible through a series of instants and not at a single instant. And when the velocity is zero, and the body appears to be quietly resting, it may possess any degree of acceleration, or of super-acceleration without exhibiting any sign of such potentialities. A single particle may be the bearer, at one and the same instant, of any number of successively higher super-forces. That is to say, it may have an acceleration, and a tendency to change that acceleration positively or negatively, and a tendency to change that rate of change, positively or negatively ; and so on without limit. And, as we have said, these excessive degrees of super-force are accurately expressible in terms of the successive derivatives of space with regard to time. From this there follows the important consequence that a very meagre system of molecules could be the bearer of an indefinitely rich manifold of super-forces, not existing side by side or extensibly and visibly, but superposed on one another intensively and invisibly. Now, despite our ignorance of the intimate molecular and inter-molecular structure of the germ-plasm, there are two things about it in this connexion which we know: (1) that the number of hereditary tendencies stored up in it from past generations is indefinitely rich ; and (2) that if by some impossibly perfect microscope we observed all that there was to observe in such a germ, we should see nothing but the chemical atoms with their constituent electrons grouped together in molecular and inter-molecular systems. The masses, sizes and shapes of these atoms, their relative positions and velocities, would be observable, and they would certainly seem to constitute a system rich enough to be an adequate causal ground for the somatic structures that are to issue from them. And yet, despite this seeming richness of the theoretically observable manifold of atoms in the germ-plasm, a moment's reflection will reveal the pitiful inadequacy of the merely spatial and kinematic aspect of the germ to afford a sufficient causal ground for the somatic effects that are to follow. For many,

if not all, of the resulting soma-cells will as individuals be as complex in structure as the original germ-cell; hence all the causal determinations of the germ will be needed to explain them. Yet this is only the beginning; for there is the whole incredibly complex and adaptive arrangement of these cells in the tissues and organs of the soma at any one stage of its development to be accounted for by the nature of the germ. Nor is even this all; for any one of these last-named somatic complexes is but one of the long series of diverse forms which evolve in a temporal series through all the stages of embryonic and post-embryonic growth. And this series shows in its temporal structure the same degree of purposeful complexity as is found spatially in any one of its stages. Nor can the environment help us here. For while it is of course an absolutely necessary condition for the development of the germ and is in perpetual relations with it, yet its role is relatively passive so far as concerns the specific hereditary characters which were all determined by what the germ contained, and which are preserved intact through all the interactions of the germ and its environing food. Indeed, as a final consideration showing the impossibility of accounting for the spatial and temporal richness of the soma in terms merely of the theoretically observable distribution of the atoms in the germ-plasm, we may note that if that distribution were all there was to the germ, its specificity such as it was, would be completely washed out and lost in the interaction with the environment; for the arrangement of the atoms of the system after the first contact with the environment would be as much characteristic of the latter as of the germ itself; so that as the interaction continued, the living being would lose more and more of the highly specific nature of its germinal origin and would take on more and more of the relatively unspecific character of its environment. And at the end of such a give-and-take process, the germ-cells of the next generation would have almost none of the characters of the species. Instead of this fading out of

the complex of germinal characters, through successive admixtures with the environment, we find, as we have just said, precisely the opposite state of affairs. The individual somehow preserves all its hereditary specificity quite intact throughout the long and complicated processes of its growth to maturity. If, then, it is impossible for these reasons to identify the hereditary characters no matter how numerous or complex, with the positions and velocities of the atoms of the germ-plasm, with what physical aspects of the latter can they be identified? With none, say the vitalists, who thereupon proceed to bring in their non-physical entelechies, psychoids, etc.

According to the hypothesis here defended self-perpetuating *complexes of hereditary characters can be and must be identified with the super-forces of the germ-plasm*. For while these super-forces are strictly physical in nature and capable of mathematical formulation as the higher derivatives of velocities, it is they and they alone which can constitute an indefinitely rich intensive manifold of separate specific tendencies, such as we know the germ to contain; and it is also they and they alone which are able to preserve their own systemic structure intact through all the vicissitudes of interaction with environing systems. That this last claim is justified can be seen by considering that even acceleration, not to mention super-acceleration, is not affected directly by a change of position. Thus when a falling body is stopped in its fall and brought to rest, its gravitative acceleration continues as before. The value of a derivative is not altered by an alteration in the value of the derivatives of lower order than itself, and consequently the super-accelerations or super-forces in the germ-plasm, which are represented by these higher derivatives can preserve their pattern unchanged throughout the morphological changes of embryonic growth.

And now that we have seen the striking correspondences that obtain between the rich intensive manifold of self-perpetuating hereditary characteristics in the germ-plasm and

the equally rich intensive manifold of self-perpetuating super-forces which we are suggesting as a mechanistic explanation of this germinal specificity let us consider the second of the basic characters of the germ-plasm, namely, the sequential teleology of the embryonic process in which are progressively unfolded the series of hereditary forms.

The process by which the fertilized cell divides into two cells, each possessing the life-pattern of the parent, involves the transposition of the complex of hereditary characteristics from the system of atoms which originally possesses it to the system of atoms which up to that time has not possessed it, but which as relatively simple food material has been stored in the cell. The initial mystery of growth is this mystery of assimilative anabolism by means of which one system of atoms within a cell conveys its life-pattern to another system. The actual division of the cells is only the climactic stage of the process of transference of a life-pattern of hereditary characteristics from the primary constituents of a cell to its secondary or food-constituents. Now it has long been noted that such phenomena as the splitting up of the chromosomes and the formation of duplicate centrosomes bear a *prima facie* resemblance to processes of magnetic and electrostatic induction in which a force-pattern is transferred from one body to another, but so far as I am informed, the resemblance of electrical induction to what happens in the cell is so vitiated by the multitude of differences between the complex protoplasmic substance and the relatively simple media of electrical and magnetic induction, that the analogy has not led to any fruitful results. Now if our hypothesis of the identity of the life-pattern of a cell with the hierarchical system of super-forces of which its atoms may be the bearer is correct, the analogy between biological and physical induction might be rescued.

And just as the electric or magnetic field constituting a pattern of relatively simple stresses can induce in suitable material nearby, a corresponding pattern of stresses, so we

should expect a cellular complex of super-forces to induce a corresponding pattern of super-forces in the suitable material nearby. And just as iron particles in the neighbourhood of a given magnet conform to the lines of force of that particular magnet, so would food particles within the field of a given cell conform themselves to the biological pattern of that particular cell, becoming nerve tissue, muscle tissue, or bone tissue, as the case might be.

Anabolism is thus the transmission of the chemical form of the substance that eats to the substance eaten. In this way living matter renews and increases its own substance at the expense of other matter.

When a cell has in this way increased its own substance to a certain point, then either with or without the stimulus of another cell, *i.e.*, either sexually or asexually, it reproduces itself in new cells. The daughter cells exhibit more or less of the pattern and chemical structure of the parent cell, and so in unicellular reproduction no less than in assimilation, the essence of the process is the transmission of a form or pattern from one body of matter to another.

Now the ontogeneses or embryonic development of a multicellular organism might appear to be of a quite different nature to the processes of assimilation and unicellular reproduction which we have just considered. For here we have a group of cells, which in their growth and reproduction result not only in new types of cell-pattern, but also in a whole series of cell-groupings. New tissues and new organs are progressively differentiated from the seemingly simple and homogeneous germ-cell. But here too we can regard the process as only another example of the capacity of living matter to impose and transmit its own form. For the cells of each new generation will have their natures determined not merely by the individual parent cells, but by the group of parent cells acting collectively. The pattern of the new cell will thus be a compound, one set of characteristics a direct inheritance or reproduction of its own

parent cell, and the rest of its characteristics determined by the structure of the group and its position in that structure. We should thus expect a unified system of developing cells to exhibit a progressive differentiation of form. To symbolize the process let us denote the original fertilized cell from which a complex organism is to develop by A, and the two daughter cells into which it divides by A_1 and A_2 . Now, when one of these daughter cells, say A_1 proceeds in its turn to divide, the resulting cells should be determined in their pattern not merely by A_1 , but by A_1 modified by A_2 . The compound pattern thus resulting in the second generation we could symbolize by B. The B cells will in their turn give rise to new cells whose pattern will be a compound of the B characteristics modified by the pattern imposed by the cell group. This third type of cell we could symbolize by C, and so on. These familiar facts are generalized in the statement that the character of any part of an organism is determined partly by its immediate cell parents and partly by its relation to the entire organism. Now certain experiments, described by Driesch, which have been performed upon the embryos of frogs, throw an interesting light on the connexion of the two features. If a part of the embryo of a frog be properly separated from the rest, it will develop; but sometimes it develops into an entire tadpole of reduced size and sometimes into a specific part of a tadpole. These divergent results would seem to indicate that the two sets of characteristics which constitute the cell-pattern of each cell in a multi-cellular organism are relatively distinct, and that sometimes one set and sometimes another dominates in its descendants. In the case in which a separated part of the embryo develops into an entire animal the original characters of the parent cells have proved more potent than the characters superimposed by the general group. The germ plasm, as we might say, triumphs over the soma-plasm and the cells act like germinal or reproductive cells. But in the case in which the fragments of the embryo develop only into specific parts of the

animal, such as special tissues and organs, why here it is the soma-plasm characters that triumph over the germ-plasm characters. That is to say, the differential characters in each cell which have been superimposed upon it, not by its parents but by the whole group of cells, in virtue of its position in that group, determine a continuance of its development into the special tissues and organs demanded by the group as a whole.

Now, in the light of such facts, it is possible to understand in general, although the details are hidden from us, how certain of the cells of a complex organism might, and probably would, always retain as their dominant characteristics the pattern inherited from the parent cells, rather than the differentiating pattern which would be due to their relation to the group. Such cells would be the germinal or reproductive cells whose function it is to reproduce the new organism as a whole rather than some special organ or tissue. So, though each cell in a complex organism might be regarded as theoretically capable of reproducing, under proper conditions, the organism as a whole, yet only those cells which were not forced by the demands of the group as a whole to develop some special instrument of service would actually serve as the seeds of a new generation.

Now all this is of course merely descriptive and not explanatory. But in view of the general theory I am arguing for, I have thought it worth while to indicate how the distinctively vital processes of growth and reproduction can all be regarded as the different manifestations of a single principle—the principle in accordance with which living substance imposes its characteristic form or nature upon new matter. And it is here that the concept of each cell as a complex of super-forces appears to me to be helpful. We know that it is a characteristic of a system of forces or potential energies not only to pass into motion and to result from motion, but also to superimpose its form upon its environment. Every stress implies a counter-stress of the same character as itself. A magnet not only tends to produce motion in the iron filings that come into its

field but it imposes upon them its own stress pattern. An electric charge not only attracts or repels into motion another charge, but it induces a counter-charge on neighbouring bodies. If any part of a living cell is the bearer of a complex system of stresses or potential energies we should expect to have those stresses imposed upon and duplicated in any matter that was suited to take them. The process by which food substance is assimilated to the tissue of the cell would be, as we have said before, analogous to the process by which iron filings arrange themselves in accordance with the field of force of a magnet. In protoplasm, however, the stress patterns that are transmitted are primarily of a chemical rather than a physical order, and manifest themselves in the grouping of atoms into new molecules. It is apparently only in carbon compounds of the kind that compose protoplasm that there is sufficient flexibility of molecular structure to allow of any very noticeable or continued propagation and variation of stress patterns from one molecule to another. Crystallization, which has always been recognized as more or less remotely analogous to life, may be identically the same in principle but with the single all-important difference that in crystallization it is only a stress pattern between molecules that is reproduced, whereas in protoplasm, thanks to the peculiar structure of carbon, instead of the meagre variations of intermolecular or physical stress patterns, it is possible to transmit by a process analogous to electrostatic inductions those intramolecular systems which we have termed "super-forces."

The hierarchical systems of super-forces of which protoplasm is the bearer, are, however, not only incomparably more varied than the simple stress-symptoms of crystals, but in their chemical manifestations they seem to furnish an exclusive instance of an object definable in purely physical terms and at the same time embodying a system of invisible and intensive magnitudes. So far as I can see there is no limit in theory to the number of strains which might be superposed in series

upon a single material field. Each of these imposed strains would be the trace of a past event and the promise of a future event. The system would in short consist of a temporal series of past and future events compressed into a series of intensive magnitudes symbolized by the successively higher derivatives of space with regard to time, and actually though invisibly present in their totality at every instant. We may assist our imagination to appreciate the nature of such a system if we think of a rope upon which there has been imposed in succession a long series of twists on twists. As long as such a rope is held tight, it will embody at each single instant the whole series of successive strains to which it has been subjected, in an invisible intensive hierarchy; and if there were a medium suited for the purpose, it might convey to that medium by a kind of induction its own pattern of super-forces. When the rope is released, however, it will unfold or untwist, and yield back in the form of a visible temporal series something like the series imposed upon it, but with the order of terms reversed.

If for the gross and meagre plasticity of the rope we substitute the infinitely varied plasticity of protoplasm, and if for the brief series of crude twists given to the rope and returned by it, we substitute the incredibly extended succession of specific energies which have been received by the cell, and infinitesimal traces of which have been retained, then we shall have something like a mechanistic explanation of the two outstanding mysteries of heredity. These, it will be remembered, were (1) the mystery of how a minute germ can contain and maintain in all integrity the determinants of a million generations of past life; and (2) the mystery of how that same germ with admirable teleology can actualize in unicellular reproduction and multicellular ontogeny the complex of potentialities with which it is invisibly pregnant.

It remains to us now, in the concluding section of our discussion, to meet the last and most formidable of the three challenges of vitalism—the challenge to explain in mechanistic

terms the general characters of conscious thought and activity, and the peculiar characters of the qualitative and durational elements of psychic existence.

III. CONSCIOUSNESS.

The points at issue between mechanistic parallelism and vitalistic interactionism. The general and special characters of conscious life. The mechanistic explanation of the former by the conception of cerebral super-forces or potential energies, and of the latter by the conception of sensations as modes of "anergy."

The general controversy between mechanism and vitalism, when applied to psychology, becomes the more specialized controversy between psycho-physical parallelism and interactionism.

Parallelism, which on all practical issues is indistinguishable from epiphenomenalism, insists (1) that you cannot conceive of a non-spatial state of consciousness in a causal interaction with a physical body; and (2) that even if you could, the law of the conservation of energy would be violated unless every effect in the brain were produced by a physical cause. Consequently, consciousness must be regarded as a non-intervening or "parallel" aspect of brain processes. As against this theory, the interactionists contend (1) that consciousness is of such a character that you cannot conceive of it as a mere concomitant of the blind or mechanical motions in the brain; and (2) that even if you could so conceive it, its existence as an epiphenomenon would be opposed to the biological law that vital functions tend to be developed and preserved on account of the useful effects which they produce. Thus each party to the controversy is supported by the inconceivability of its rival and by the apparent demands of physics on the one hand and of biology on the other.

The psycho-physical dispute between mechanist-parallelism and vitalist-interactionism is not mitigated but only confused

by mixing it with the epistemological dispute between realism and idealism. The problem is just as clear-cut and perplexing when translated into the language of idealism or of phenomenalism as when left in the simpler and more primitive language of realism. To describe the motions in your brain as streams of actual or possible perceptions of an external observer, or as abstractions from an organic whole of experiences, does not make it any easier to conceive them as causally related to the private and personal unity of thoughts and purposes, which constitute your mind.

The characters of mind or consciousness on which the vitalist bases his challenge to the mechanist fall into two groups, which we will call the general and the special. The general characters are those common to all vital systems; the special are those that are or that seem to be peculiar to consciousness, notably the baffling specificity or qualitateness of its elements. Let us consider them in turn.

Under the general characters may be enumerated the following: (1) *Telogenesis*, or the capacity to initiate useful or purposive variations; (2) *Teleology*, or the capacity to reproduce or actualize a form or pattern by transmitting it through a kind of induction from one body to another; (3) *Extension in time*, or the capacity of living matter to sum up at each present moment of its existence a long series of past events in the form of an invisible hierarchy of intensive magnitudes.

In the first section of this paper, in which *Telogenesis* was the topic considered, we endeavoured to show that between the activity of the germ, giving rise to useful and inheritable variations, and the activity of the brain, giving rise to novel and pertinent ideals, there was not only a vague analogy but a profound identity. By conceiving of germ and brain as systems of forces and super-forces, each element of which could be treated as a vector, we were able to interpret both kinds of telogenesis as a process of vector addition. The germ and the

brain are as closely connected in their teleology as in their telogenesis. The process by which the stress-pattern of hereditary determinants is transmitted in assimilation and reproduction from the original germ-cell to the food particles within it, is identical in principle with the process by which the stress-pattern of a purpose based upon memories stored up in the cerebrum is transmitted to or actualized in a series of moral actions or an artistic creation. For example, a man having as his purposes the artistic telos of painting a beggar and the moral telos of giving alms to the beggar, actualizes those ideals on his canvas and by his conduct. And the capacity to transmit from the brain to the outside world of canvas and conduct these pre-existent patterns is essentially identical with the capacity of the germ-cell to transmit its pattern of chemical forms to the food contained in it and to other cells. To conceive of the pre-existent pattern as part of a system of super-forces and of its transmission as a kind of induction, affords a basis for interpreting both germinal and cerebral teleology in mechanistic terms.

So much for telogenesis and teleology. The third of the general characters in which the conscious action of the brain resembles the ontogenetic activity of the germ is the capacity to extend in time, and embody at each present instant in an invisible system of intensive magnitudes a long series of past events. Here again the arguments for identifying this present past with a hierarchy of super-forces or forms of potential energy superposed one upon another apply equally to the system of acquired memories stored up in the brain and to the system of inherited determinants stored up in the germ. Neither brain nor germ would exhibit to an external observer the essentially private history of the past contained in it. Mere positions and velocities of the atoms, if adequately disclosed by a perfect microscope, could show nothing but what was present. A hierarchy of super-imposed stresses is the only physical analogue of life's power to extend in time.

Despite the resemblances of conscious life to life in general with respect to telogenesis, teleology and temporal extension there are certain differences between the two systems that should be kept in mind. The central nervous system exhibits in a new way the vital capacity for retaining and expressing specific potentialities. Instead of assimilating energy joined with matter in the form of food-particles, the brain takes its energy "neat" and assimilates it as it comes in the form of sensory impulses. And by storing up traces of the specific forms of vibration that proceed from extra-organic objects and traverse the afferent nerves, it builds up a "psychic organism," a life within a life, composed not of differentiated forms of matter, but of differentiated forms of energy. These cerebral energy-forms are the instruments of memory, and they implicate or reveal a world outside themselves both in time and space. It is by virtue of the self-transcending implications of cerebral traces that we are enabled to experience duration and to act teleologically, *i.e.*, to act at each moment with reference to events of the past and future.

There are several other curious analogies which hold between the field of consciousness and a field of super-forces of potential energies. There is, for example, the polarity of subject and object which has its analogue in the universal opposition of forces to one another; every tendency to action engendering an equal and opposite tendency to reaction. There is also the primary unity of a field of force (as distinguished from the essential plurality of a mere aggregate of material particles) and the perfect and instantaneous rapport between its components. These characters correspond respectively to the unity of consciousness and to the organic and reciprocal interaction of its contents.

Aside from these various analogies the hypothesis here defended is greatly strengthened by the fact that sensations seem to arise at the very times when the sensory neural currents are being redirected at the cerebral synapses into

motor currents of discharge. And as no form of motion can be changed in direction without some of its energy passing through a latent or potential phase, it seems highly probable that the not-externally-observable potentialities into which neural energies are transformed are identical with the not-externally-observable psychic states which then and only then come into existence. Moreover, when the neural stress is intense the sensation is also intense; while the smoother and more automatic the neural current, the less vivid is the consciousness that is synchronous with it.

But let us turn from these general and structural characters which (with some variation) are shared in common by conscious life and by the life of cells, to those other and more special characters which are peculiar to the contents of consciousness and definable in physical terms. These exclusively psychological characters are (1) the pure qualitateness of sensations; and (2) the duration, or specious presentness, of all former consciousness.

Not even mechanists attempt to reduce these characters to physical terms; they content themselves with the view that mental states, as such, are epiphenomenal concomitants of cerebral motions and thus subject, vicariously as it were, to the mechanistic laws of the motions with which they are concomitant.

I believe that it is possible to interpret in physical terms the very sensations themselves, and furthermore, I believe that this ultra-materialism can be seen to satisfy the legitimate demand of the vitalists, that mind be regarded as a really efficient determiner of bodily motions rather than as the epiphenomenal concomitant of them. But if the hypothesis which I am about to propose is to convey any meaning, it will be necessary to bear with my attempt to express what, so far as I know, is a new category.*

* Some years ago, after I had published a rough preliminary formulation of the conception that I am now about to present, my attention

Our customary modes of thought recognize mere rest as the only alternative to motion; and while there can be many degrees of motion there can only be one degree of rest. I want to suggest that there can be many degrees of rest, or rather that there are modes of existence on the other side of mere rest. Just as zero is the boundary between the decreasing series of positive numbers and an equally rich increasing series of negative numbers, so the resting condition of a body may be the boundary between the decreasing series of its positive velocities and an equally rich increasing series of its negatives of velocity. By these negatives of velocity, I do not, of course, mean what are ordinarily called negative velocities or negative motions, *i.e.*, mere movements in an opposite or negative direction. It is not the direction that is to be negated but the motion itself. Now energy may be roughly defined as the quantity of actual or potential motion, the quantity being measured for certain reasons in a certain way, *viz.*, by the product of a mass-factor and the integral of the velocity, *i.e.*, the square of the velocity divided by two. Energy then is, as it were, the tendency to change spatial position. Now the negative of energy would be a tendency to cling to or endure in one position. It would, perhaps, be related to velocity as inertia is related to acceleration. Let us combine the root of the word energy with alpha privative, and coin the word *anergy* as the name for this new condition. This anergy or duration will increase as the velocity decreases: and if we use the ratio s/t to denote velocity we can use the ratio t/s to denote slowness or duration. As we decrease the fraction s/t denoting

was called to an earlier book, to which I cannot now get access, in which *feeling* was interpreted as a sort of negative correlate to *force*. There was, as I remember it, no attempt to define it in terms of space and time, and no attempt to conceive of the forms or traces which it might leave after the stimulus inducing it had ceased to act. But in its general character it was like what I shall refer to as "*anergy*." The title of the book was something like *Mind and Force*, and the author's name was, as I recall it, Townshend.

the fastness of the change, we shall increase the reciprocal fraction t/s . In other words, the less the speed the more the slowness. Suppose now that the speed becomes zero, then the slowness will become infinite. When slowness becomes infinite it ceases to be a mere negative *adjective* and becomes a true *substantive*, i.e., a thing existing in its own right. As long as a body is actually moving at all, its duration is merely potential. When it stops and its motion becomes potential, its duration becomes actual. That which was a *traversing of space* has become an extension in time, a "chunk" or lump of *durational being*.

When a vibration-wave proceeding over a sensory nerve is gradually brought to a stop by the resistance of the synapse, its energy is transformed from a visible and kinetic form to an invisible and potential form. As its velocity passes through the zero-phase, its slowness passes through an infinity-phase. I ask you to entertain the suggestion that this *infinity-phase of slowness* is the common stuff of all sensations and that the critical points of zero and infinity through which the motion and the slowness respectively pass, afford the basis for that qualitative absoluteness and discontinuity that differentiate sensations from mere rates of change. If we accept this suggestion and admit provisionally that ($t/s = \infty$) is a kind of definition in terms of *quantity* of the general *quality* of mere durational being common to all sensations, we shall find as a reward for our faith, a very striking corroboration of Fechner's interpretation of Weber's Law. For when the wave of neural motion encounters resistance at the synapse, each of its cross-sections in continuous series will be transformed successively into cross-sections of durational being. And the intensive quantity of durational being thus produced will be the result of a continuous summation or integration. Thus, the intensity of the sensation t/s will increase to its maximum through the time that the velocity of the wave decreases to zero; and consequently it can be measured by the product of a mass factor (which is large for sound and small for light and

which I will not here discuss) and the integral of the reciprocal of the velocity with regard to the velocity, *i.e.*,

$$\int_{v_1}^{v_0} \frac{t}{s} = \log \frac{s}{t} + C.$$

In other words, if the being of a sensation is as I have described it, the intensity of a sensation will tend to increase with the logarithm of the stimulus, rather than with the stimulus directly. This deduction of Fechner's Law, permits us to understand the curious analogy to that law which determines our appreciation of the intervals of pitch. The vibration-numbers which cause sensations of successively higher octaves form a *geometric* series, 1 2 8, 2 5 6, 5 1 2, etc. But our sensations of the successive octaval increments of pitch constitute an *arithmetic* series having equal differences between its terms, and as such proportioned to the logarithms of the series of stimuli. Now if the velocity of each wave when reduced to zero is transformed by integration into a durational quality determined in its nature by the reciprocal of the velocity, and in its degree by the logarithm of the velocity, then the frequency of the waves themselves or the velocity of their succession, will be analogously transformed by integration into a specific quality of being or duration, measured in its degree by the logarithm of the frequency, and modifying, or *inhering in*, the original quality.

There are several other peculiar characters of sensations and sensation-differences which could be interpreted in terms of our hypothesis that they are modes of anergy or durational being which make their appearance whenever energy is transformed from a kinetic to a potential phase. For example, whether a sensory quality will appear as primarily spatial like colour, or as primarily temporal like sound, should be determined not as in the case of intensity by the velocity of the stimulus wave multiplied by a mass factor, but by the length of time which was necessary to absorb the wave. This is very

long in the case of sound and very short in the case of light, hence the former appears as an essentially temporal thing and the latter as essentially spatial or extended.

The modes of anergy which are produced by the modes of energy of the stimuli will have two sets of properties, the one set relative, continuous, and quantitative, the other absolute, discontinuous, and qualitative. The first set will be determined directly by the relations of the stimuli to one another and to the system as a whole, and only indirectly by the character of each stimulus. These will be the so-called "primary" qualities of size, shape and position, and of date and duration. The other set of characters will be determined directly by the intrinsic character of each stimulus, and only indirectly by the relation of the stimuli to one another. These will be the so-called "secondary" qualities, the specific and incommensurable modalities of touch, sight, hearing, taste and smell. Each neural stimulus has what may be called an intrinsic form or pattern constituted by the inter-relations of its velocity, its duration, and its acceleration. Where this complex of measurable properties of an energy or motion is transformed into anergy or duration it ceases to be a quantitative complex and becomes a single unanalysable incommensurable specificity. The primarily extensive quantity of motion has become a primarily intensive quality of being. This change from energy into anergy is a change of the spatio-temporal into the temporo-spatial. If a motion were infinitely fast it would fill many places at a single instant and could be called "matter." If a sensation were infinitely enduring it would fill many moments of time at a single point, and could be called "substance." As it is, motion has only specious extension, and sensations have only specious duration or specious presentness. Thus motion and sensation are partly substantive and partly adjectival. Each can be treated as a self-identical magnitude capable of being conserved and discriminated, but each needs something more substantive than itself in which to

inhere. There could be no motion that was not the motion of an extended object and no sensation that was not the sensation of an enduring subject.

Now just as the form of a motion is, as such, independent of the amount of its mass-factor, so the form of a sensation is, as such, independent of its intensity-factor. The kinetic energy of the nerve current that passes into a potential form when a sensation is produced, begins at once to pass back into the kinetic energy of the motor nerve currents of reaction; and as it thus passes out and away, the intensity of the sensation dependent upon it fades towards zero, leaving the anergy-form as a clear sensory trace. The clearness of these sensory traces is independent of the infinitesimal and ever diminishing intensities which they retain as the correlates of the infinitesimal and ever diminishing remnants of the potential energies of the stimuli correlated with them. These anergy-forms are of course our memory images. They sum up at each present instant a succession of past happenings, and constitute an organic system of modifications of whatever it is in the cerebrum that is susceptible of bearing an intensive hierarchy of superposed stresses and strains.

If consciousness is identical with the forms of anergy and their correlated traces of potential energy stored up in the brain, why is it that the brain is not conscious during sleep? And why is it that we are only conscious when kinetic nerve currents are flowing over the sensori-motor arc? It would seem that if consciousness is to be identified with anything in the brain, it should be identified with the active rather than the quiescent cerebral condition. I should attempt to meet this seeming difficulty in the following way.

There may exist many systems of potential energy, or of forces and super-forces, in one material body; and these systems may be relatively insulated from one another. The system of traces of potential energy that controls the action of the body during waking life includes only so many of the

stored-up energy-traces in the brain as happen to be associated with the sensori-motor currents more intimately than with the rest of the brain-traces. Therefore the consciousness of our waking life at any instant includes only those of our memories which are associated more intimately with present sensations than with the rest of our memories. We can think of the totality of the brain's energy-forms as divided into two fields or realms. One set of traces will be tending to discharge towards the sensori-motor arc. The rest will be tending to discharge more towards one another than towards the sensori-motor arc. What I call "my consciousness" at any one moment will be the equivalent of the more intense of these two systems. Now the potential energy produced by the redirection of a present efferent nerve current will usually be stronger than the energies that form the residual potentials of past nerve currents. Hence "my consciousness" or the dominant psychic condition of my brain will usually if not always consist of those ideas which are grouped around a nucleus of present sensation. And set over against it will be the broader and fainter system, the affinity of whose elements for one another is stronger than their affinity for the elements of the first system. This latter system would constitute the sub-conscious. Let me try to make this clearer by a hydraulic analogy. Consider a lake formed by damming a stream. The stream is flowing into the lake, and there is a leak in the middle of the dam almost but not quite large enough to let out as much water as flows in, with the result that the lake grows slowly larger. Now to these natural conditions let us add a circumstance somewhat artificial; let us suppose that there is a certain strong force of attraction between the water of the lake and the containing shores. Then in such a situation we should find the particles of the water tending to divide into two rival systems. The water in the immediate neighbourhood of the stream flowing through the lake would have a bias or tendency to flow with it through the outlet, while the water in

the immediate vicinity of the shores would have by supposition a bias or tendency towards the shores, that was stronger than the suction tendency of the stream. Where the line between the two fields fell would of course depend upon the relative strength of the suction force of the stream, and the counter attraction of the shores. Each field of stress would have a unity of its own. Now for the water of the lake substitute the sensorially accumulated energy in the brain; for the stream flowing through the lake substitute the sensori-motor stream of neural currents that flows through the brain during waking moments; and for the attraction of the shores of the lake substitute the attraction of the anergy-forms for one another (the nature of which is expressed in the psychological laws of association) and we shall have a fair picture of that characteristic of our cerebral apparatus that is responsible for the fact that in waking life the dominant or controlling consciousness will contain in its unified field of attention only a certain small part of the wealth of the psychic reality which the brain contains. In our analogy, sleep would be represented by a partial, and trance or swoon by a total, closure of the gates of ingress and egress of the lake. In that situation the self would cease to be divided into a conscious and a sub-conscious system, and there would ensue a single super-sensory experience over whose mighty array of objects the lines of attention (which have their correlates in the lines of stress) would be uniformly dispersed. But the little rill of sensory waking consciousness which is all of the mind that any of us knows directly would (except perhaps in the case of the mystics) be completely amnæsic with respect to any such subliminal revelation.

In concluding this last section of our discussion I should like to say just a word as to the bearing of our hypothesis upon the three great questions of traditional philosophy—the Freedom of the Will, the Immortality of the Soul, and the Existence of God. Is a definitely negative answer to each of these questions implied by the ultra-materialistic conception of

consciousness as anergy which we have defended? I believe that this is by no means the case. It seems to me rather that while the theory in question does not in itself commit us either to an affirmative or a negative position with respect to these problems, it does make it possible to formulate them with rather more definiteness than is customary.

Whether the will is free becomes the question as to whether that in the brain which is the bearer of the modes of actual anergy and of potential energy possesses in itself a power of spontaneous and indeterminate activity.

Whether the soul is immortal becomes the question as to whether the system of psychic traces or super-forces can continue to exist, perhaps as a specific deformation or individualized field of strain in the ether, apart from the matrix of material particles which have conditioned its origin and growth.

Whether there exists a God or a cosmic mind becomes the question as to whether the total system of physical energies and forces making up the universe possesses the kind of unity which when found in the human brain expresses an individual consciousness.

While the theory itself in spite of its radical materialism permits, as we have said, either an affirmative or negative answer to all three of these questions, I personally believe, for reasons not stated in this paper, that the affirmative answers are in each case correct. For it seems to me improbable that there could be a continuous and determinate interchange of energies by secondary causality throughout the world unless each real element of the world possessed a spark of primary causality, *i.e.*, of free and spontaneous activity. And it seems equally improbable that the curious intensive hierarchy of super-forces, which embody the present traces of the past, and which constitute vital systems, could be entirely dependent upon the groups of atoms which encase them; and finally, it seems to me improbable, in view of the omnipresence of uniform laws, that the universe as a whole should lack the degree of unity

which we discover in those parts of it that are embodied in protoplasm.

Conclusion.

In the first section of this paper we considered the vitalist challenge to the mechanists to explain in physical terms the origin of those useful variations which arise in the germ-plasm with a greater frequency than could be expected if they were the product of the blind or merely mechanical agencies recognised in physics and chemistry. We attempted to meet the challenge by means of the conception of biological vectors, according to which all of the unpurposed yet purposeful products of telogenesis, not only in the germ-plasm but in the brain when occupied with creative imagination, can be explained as the result of a system of protoplasmic stresses, and, as such, felicitously expressive in their novelty and pertinence of the whole from which they originate.

In the second section of the paper we dealt with the vitalist challenge to the mechanist to explain without the aid of extra-physical categories how the minute germ-cell could be the bearer of a manifold of hereditary determinants involving thousands or millions of ancestral generations in the past, and capable of teleological development into a duplicate of the organism from which it came. We attempted to meet the challenge by conceiving of the germ as a system of superforces or superimposed stresses definable in mechanical terms yet embodying a manifold of invisible intensive determinants equal in richness to the serial events of its ancestral past and capable of unfolding and reproducing its own pattern by a kind of induction through the serial stages of embryonic growth.

Lastly, in the third section of our discussion, we have endeavoured to meet the vitalist challenge to explain mind in physical terms by the suggestion that the structure of conscious life is analogous to the structure of life in general and capable of being explained in the same way, except that

the system of cerebral super-forces in which the past is stored up in the present, is composed of traces of potential energy acquired by the brain through the transformation of the kinetic energies of sensory nerve currents. And as a basis for a physical interpretation of the essentially specific and qualitative nature of mental elements we suggested the new category of "anergy" as a form of durational being inevitably produced whenever the energy of motion was transformed into the invisible phase which we call potential.

Our theory agreed with vitalism and interactionism in recognizing the genuine efficacy in nature of telogenesis, teleology and consciousness; but it agreed also with mechanism and parallelism in refusing to admit the existence of any factor not definable in physical terms. Consciousness is not, as Santayana puts it, "a lyric cry"; nor is it an otiose and epiphenomenal spectator of bodily doings. Our minds are imbedded in the matter of our brains and they play a real part in the economy of nature. It is just because of the physical reality of our minds that we can transcend the mechanical contacts of the *here* and *now*, and, through memory and imagination, adjust our behaviour not only to an environment extending indefinitely in space and time, but also to that Platonic realm of logical and ethical ideals which are independent of the vicissitudes of time and existence.