The Problem of Time in Science and Philosophy

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THE PROBLEM OF TIME IN SCIENCE AND PHILOSOPHY.

I.

ONE generally acceptable conclusion which may be drawn from the discussions of contemporary thinkers is that the question of what kind of a universe we are living in is intimately connected with the problems of time. Whether or not this conclusion is taken as an indication of progress in philosophy depends upon which of two positions it is held to confirm. In the first case a spirit of despondency concerning the value of intellectual analysis may be fostered by the reduction of the problems of speculative thought to some phase of the time problem; for time, it is held by some, appears to be one of those realities which baffle us in direct proportion to the amount of thought we focus upon them.

Not only have such questions as to whether the universe is infinite in duration ('eternal'), or whether it had a beginning in time and may have an end in the remote future (Kant's antinomies), puzzled everyone who has wondered about these matters, but even such persistent and systematic thinkers as scientists and philosophers are still mystified by the riddles of time and change. Indeed, one might argue that Zeno's paradoxes of motion constituted the coming-of-age of philosophy. And this view that time and change are illusory did not pass away with the Eleatics. Among modern thinkers J. E. McTaggart has argued for the unreality of time by trying to show that every event is past, present and future. This view of change also appears in the philosophy of F. H. Bradley, who, like Plato, sees in change a mark of imperfection. The devotees of *Einsteinismus* have also called attention to the fact that motion, and hence change, is relative. And it is but one step from the view that time and change are relative to the view that they are self-contradictory notions. Whether this be true or not, the most cursory analysis will reveal the fact, which Mr. C. D. Broad brings out clearly in his *Scientific*

Thought, that there are a number of distinct meanings of the term 'change.'

The suspicion is growing that even our systems of scientific thought are, at best, only conventionalized patterns of adjustment to the external world, and that this objective order may not for long tolerate these 'laws' which we, with our utilitarian needs, have 'plastered on' to nature. It will be remembered that it was a favorite idea of H. Poincaré's that the axioms of geometry and the principles of mechanics are not 'true,' but only 'convenient.' This position is also taken by Mr. A. S. Eddington, who doubts whether any of our laws of nature (except, perhaps, that of atomicity of action) really inhere in the external world. This pessimism concerning the validity of scientific principles may be used to lend support to the position of those who, like the pragmatists, deny the possibility of a metaphysics of nature. And, in truth, if we can not understand such a universal and common phenomenon as time what hope is there of comprehending that vast evolutionary order of events which, as we say, is 'in' time?

The second, and to me more tough-minded response, is to regard this convergence of the varied problems of philosophy upon the meaning of time as increasing the possibility of understanding nature. This becomes possible through a closer scrutiny of this central and ubiquitous reality, the temporal order. If it be true that many of the problems of science and philosophy center around the question of the relation of time, change and motion to that which is held to be the permanent, immutable and invariant reality (or realities) of nature, it is evident that the prelude to any adequate concept of nature is a clear comprehension of the ramifications of the problems of time. I shall first of all state what these problems are. Then I shall propose an hypothesis to provide possible answers to these problems.

II.

Time and Causation.—Two of the commonest notions in our thinking about the external world are the ideas of *cause* and *effect.* These notions are closely connected with the concept of

time. It is the popular belief that the so-called cause must precede the so-called effect. It is also an accepted dictum of science that there is no more in the effect than there was in the cause. However, in order to reduce to a minimum the qualitative novelties which emerge in the processes of change, the scientist is forced to try to eliminate the temporal interval between cause and effect. He accomplishes this by stating the laws of sequence in differential equations, and causation accordingly becomes functional dependence. Positivists like Karl Pearson, and, more recently Bertrand Russell, tend to adopt this view of causation as dependent variability. To the extent that the time element can be eliminated from the equations of physical science the common-sense notion that the cause precedes the effect is undermined. This is the ideal at which the scientist aims. But he has not as yet realized this ideal, for, as Maximillien Winter [1] has shown, there are still many cases in which 'heredity' (*i.e.*, past history) plays a rôle in mechanics. This same view is expressed by Hermann Weyl [2] when he states that the idea of causation, in contradistinction to functional relationships, is intimately bound up with the unique direction of progress in time, namely Past→Future.

We know that in such a view, in which time does not count, the creative aspect of nature, which is identical with the movement wherein the past 'gnaws' into the future, is being ignored. Since the advent of Bergsonism it has become customary to assert that a mechanical universe is one in which time does not count because time, in physical science, plays the rôle of an *independent variable.* A strictly mechanical universe is one in which the processes can be reversed. All that can happen is the redistribution of mass particles in space. In other words, time is spatialized. This follows inevitably, it is generally believed, from the treatment which time receives in the equations of motion of a system.

Now it is true that the spatial coördinates of a system are ordinarily treated as the dependent variables, while time is considered as the independent variable. This is the case, for example, in differential equations where the second derivative is acceleration.

1 "Time and Hereditary Mechanics," *Monist,* Vol. 35, pp. 70–80.

2 *Space-Time-Matter,* Eng. trans., p. 310.

But in general the situation is not quite so simple. Even physical time has no single and unambiguous meaning. For there are also many equations in physics in which time functions as the dependent variable, and yet there is a sense in which time can not be made dependent. We can not control time, but can only make the best use of it. Time has been said to be the direction in which we are all going without effort and without exemption. From this point of view, Dean W. R. Inge has raised the question of whether the time series is reversible. Certainly in the universe in which we live it is not.

In the theory of relativity the ideal simplification of nature is carried to its highest state of perfection. In this physical doctrine space coördinates are tied up with time in one equation. Here any one coördinate could be said to depend on the other three. Analytically, such equations are dealt with in the same way as are those of three dimensions. Under such conditions it is hard to state which is the independent variable and which the dependent. Time seems here to be turned into space merely by giving it a minus sign. This clearly shows that it is not so easy to state just what time really *does* mean in physics, and hence to say that it must necessarily function as an independent variable is inaccurate. Whether, in the last analysis, the Newtonian conception of an absolute and evenly flowing time must be reintroduced into relativity theory, in the form perhaps of the velocity of light, and whether 'simultaneity' can be given an absolute meaning, are matters which the physicists have been unable to decide.

At all events, philosophers who respect the richness of content of the actual universe will not be inclined to accept the mathematical abstractions of the four dimensional space-time manifold as a fair exchange for the creative novelties of the perceptual world. A universe in which time did not count would be a dull universe indeed, for our joy in life depends upon the element of unpredictability in experience. History, and not mathematics, has the last word in the empirical sciences. To regard time (duration) as a fourth dimension (a 'phantom') of space is not in accord with the facts of evolution. Thus far, then, we must agree with Bergson when, in his *Durée et simultanéité,* he insists

that we must distinguish between time as *experienced* and time as *measured.*

III.

The Perception of Time.—Not only is the temporal sequence of nature the most puzzling reality in the external world; it is also the most astounding thing in man himself. Like the problem of space perception, the problem of the perception of time remains one of the old, and ever-new, riddles of psychology. In the days when the reality of sensations was unquestioned it was a simple matter to build up the notion of time by combining the two ideas of the qualities of sensations, in this case that of 'protensity,' 'voluminousness,' or 'duration,' with the belief in the compounding of mental elements ('mental chemistry'). But now that structuralism in psychology, along with sensationalism, is being abandoned, there is a tendency on the part of the adherents of *Gestalt*-psychology to look upon 'temporal patterns' as wholes not analyzable into simpler elements.

While the two principal views of space perception, the 'empiristic' theory and the 'nativistic' doctrine, are also to be found in theories of time perception, it is generally held, as Professor W. B. Pillsbury says, that "much less is known definitely of the perception of time than of the perception of space."[3] This seems all the more mysterious because of the fact that "time is much simpler than space and has fewer components." Perhaps the problem of time perception is more difficult than that of space perception for the reason that there is no known sense organ for the perception of time, whereas space perception can be more definitely localized; *i.e.,* visual space perception might be considered as localized in the thalamus, occipital cortex, etc. (The behaviorists are to be commended for insisting that space perception of *depth* is a conditioned reflex involving a synthesis of visual, motor and tactual space.) The natural assumption would be that if there is any physiological organ for time perception each sense organ ought to be its own time-clock. In addition to this Julius Pikler[4] believes that just as there is a common organ for consci-

[3] *The Essentials of Psychology,* 1922, p. 190.

[4] *Sinnesphysiologische Untersuchungen,* Leipzig, 1917, pp. 485–495.

ousness, so there must be one sense organ (*Zeitempfindungsorgan*) for the perception of time.

The sense of time is bound up with the idea of sequence, the irreversible series which enables us to recognize and place events as 'before' and 'after.' This unidirectional character of time is exhibited in our processes of chord resolution in melodic or harmonic progressions. In plain words, playing a phonograph record backwards takes the meaning out of it. This is the main fact of normal temporal perception to be explained. But there are certain abnormal conditions which must also be accounted for. The great accuracy of time perception as shown in post-hypnotic suggestion indicates that the internal time-piece may be as reliable as any clock. What is the origin of this remarkable time sense?

Psychologists are debating this matter. It has been supposed by some that the physiological rhythms, such as heart beat, respiration, or rhythm of nervous discharge, enable one to count time. In the case of post-hypnotic suggestion we are asked by some students to suppose that the subconscious mind has done the counting. The fact that 'filled' time (*i.e.,* time during which we are interested in some series of objective events) should be short in passing but long in memory, whereas 'empty' time is long in passing but short in memory, suggests that time is here discriminated in terms of bodily tensions and relaxations, and that consciousness of muscular sensations (*kinæsthetic* imagery) plays the predominant rôle. But it is not so easy to see how this explanation clarifies certain pathological phenomena. Patients suffering from psychosis may give their age as that at which they entered the asylum. They may lose the sense of time passage. But it is also possible for a person to lose reproductive memory and yet retain the time sense for present events. Again, as James tells us, in hashish-intoxication there is an apparent increase in time-perspective. We utter a sentence and before the end is reached the beginning seems already to date from indefinitely long ago. My own guess would be that in this case there is an alteration of cerebral metabolism, somewhat similar to that in oxygen deprivation. The general explanation which William James [5] offers takes

[5] *The Principles of Psychology,* Vol. I, Ch. XV.

its departure from the fact of the 'specious present' of the organism. As he says, the practically cognized present is no knife edge, but a saddle-back, on which we are perched, and from which we look into the two dimensions of time. The number of units which can be brought under one act of consciousness (span of attention) depends upon the grouping of the units. According to James twelve seconds constitutes the maximum filled duration (*e.g.*, 40 strokes in a rhythmical grouping of sounds composed of 5 sub-groups of 8 units). This grouping is possible because knowledge of the adjacent parts of the 'stream of consciousness,' past or future, near or remote, is always mixed up with a knowledge of the present.

The intuition of duration, which James pictures as fairly constant for each passing instant of consciousness, must be correlated with some fairly constant feature in the brain-processes to which consciousness is tied. This brain process James finds analogous to the phenomenon of 'summation of stimuli' and after-images. In neural terms there is at every moment a cumulation of brain processes overlapping each other, of which the fainter ones are the dying phases of processes which but shortly previous were active to a maximal degree. The amount of overlapping determines the feeling of duration occupied. What events shall appear to occupy the duration depends upon just what the overlapping processes are.

Idealists, however, are not inclined to accept James's version of the unity of the self as the unity of the passing thought. Mental life, they seem to hold, exhibits the sort of thing which Bergson calls 'interpenetration,' which can not be explained by such metaphors as 'overlapping.' But can the idealists really offer a better theory? Kant struggled with this problem of passing from a succession of perceptions to a perception of successions. He solved the problem by creating the transcendental ego; but, after all, was not this only a name for Kant's ignorance? And James admits the deficiencies of his explanation when he confesses: "Why such an intuition should result from such a combination of brain-processes I do not pretend to say."

Moreover, James does not indicate how he would explain the irreversibility of subjective time. We know, however, that

the chemical changes in the various cells of the body are irreversible, in the sense that the original condition can not be restored after a natural process. Is it not a fair inference, then, to suppose that the unidirectional character of experienced time arises from the irreversible series of chemical reactions which is the physiological condition of consciousness? Will this doctrine adequately explain the facts? Idealists would say no. Their dissatisfaction with this explanation would rest upon the conviction that the logical processes by means of which a science of chemistry is created are just as fundamental as the chemical processes which are conceived to be the physiological condition of thought. In other words, the concepts of chemistry are the products of thought, and to say that the thing which makes a science of chemistry possible is itself the product of chemical reactions is assuming a theory which could only be justified by extended argument. This raises the whole thorny question of the problem of knowledge.

IV.

The Relation of Psychical Time to Physical Motion.—The ideas of motion and causality, as we have seen, are closely connected with the notion of irreversibility and the asymmetry of time. Those thinkers who have proposed that subjective time is but an echo of objective time, developed through a process of evolutionary adaptation, as Herbert Spencer supposed, are overlooking the possibility that time is the presupposition of all phenomena and experience. Scientists who turn philosophers are especially liable to disregard the epistemological foundations necessary to a system of scientific thought.

In searching for a set of postulates to form the logical basis of his behavioristic system of psychology Professor A. P. Weiss[6] selects *movement* as the simplest and most universal reality. Movement possesses the added advantage of having the widest range of permutations, such as *rate, direction,* etc. I have no desire to indulge in logical quibbling, but it does seem to me that, in addition to the set of postulates already formulated by Dr. Weiss, another postulate, covering the relation of the logical con-

[6] "Behaviorism and Behavior," *Psychological Review,* 1924, Vol. 31.

cepts and categories of the 'thinking behaviorist' (to use a qualification which Mr. Lovejoy has created) to the underlying realities of his physical monism, is required. The fact that motion, conceptual, if not physical, possesses rate and direction because we endow it with them indicates the extent to which the conceptual element enters into the categories of science.

Now the general procedure of science consists in defining certain *primary magnitudes,* such as length, mass and time, in accordance with the centimeter-gram-second system of units, and then building up the many *derived magnitudes* of the higher sciences out of the primary units. The belief is prevalent that since the phenomena quantitatively expressed in terms of the derived magnitudes (the behavior of protoplasm, for example) can be analyzed into the simpler units of the primary magnitudes, therefore the data of the higher sciences (biology, psychology, etc.) are less real than the realities of physical science. But this is not so. The arbitrary character of the units and dimensions which are used in the quantitative statements of science is brought out by Mr. Norman R. Campbell in his book on *Physics, The Elements* (Part II, Chapters X, XIV, XV). Both derived and fundamental magnitudes contain an arbitrary element connected with the choice of the unit. Mass, length and time, Professor Campbell points out, are not necessarily basic magnitudes, but such special features as they possess are derived partly from the dynamic equations in which they occur, and the high accuracy with which weights and lengths (but not times) may be compared.

In his *The Mathematical Theory of Relativity* Professor Eddington also shows how the consequence of the theory of relativity has been to throw in doubt the postulates implied in the naïve assumption that length, work, potential, etc., are objectively measurable and invariant existents. This is in line with Poincaré's assertion that mass is a constant which it has been found convenient to introduce into equations. Physical quantities are not properties of the external objects alone, but are relations between these objects and the particular frame of motion from which they are measured.

The behaviorists need to be reminded, then, that in spite of its

assumed simplicity, movement is one of the most complicated facts of nature. Mathematically it involves a correlation of a dense series of points in space with an asymmetrical order of instants in time. Psychologically the problem is even more difficult. We know that motion is an amalgamation of the spatial and the temporal orders. Is time a derivative notion, an abstraction arrived at through the perception of motion? Or does the concept of motion depend upon an innate and unique recognition of temporal passage? James holds that we can not intuit an extension in time without sensible content. This seems to eliminate the second alternative. But have we progressed very far beyond the nativist theory when we endow sensations with an irreducible 'voluminousness'? On the other hand, as Professor Bentley[7] tells us, to say that the perception of motion is native to the organism is, in the sight of most psychologists, abandoning the problem as inscrutable. Professor Bentley solves the mystery of the perception of movement by bringing it under his general principle of coalescent integration. Successive trains of stimuli undergo temporal ligation by being incorporated into a 'movement complex.' But this theory of coalescent integration strikingly reminds one of Wundt's theory of space perception as a *creative synthesis*. And as Professor E. B. Titchener[8] has said, this is really leaving us with a miracle on our hands.

The present writer sees no difference in principle in assuming a nativist theory of time or a nativist theory of perception of movement. In either case we can only get back from the external world what we have already put into it. In the language of Kant, the idea of time is not of empirical origin, *i.e.*, it does not come through the senses, for it is the necessary *a priori* condition of all phenomena, internal or external. This is only saying that the prime fact of consciousness is the significance of time. What we need, I think, is an evolutionary epistemological monism. But before attempting to reconcile the nativistic and empirical theories of time perception by way of a theory of its genetic origin I wish to turn to certain inter-relations of time and evolutionary products.

[7] *The Field of Psychology*, pp. 137 and 233.
[8] *A Text-book of Psychology*, 1913, p. 338.

V.

Time and the Continuity of Evolution.—The physicist's conception of what the conduct of electrons ought to be has been rudely upset by certain revelations concerning the behavior of electrons inside atomic systems. In dealing with the relations which hold between atomic structure, and the radiant energy which is absorbed and emitted by revolving electrons in their atomic orbits, discontinuity of space and time seem to be implied. This discontinuity is openly embodied in Planck's quantum theory of energy and Bohr's postulate concerning the discrete series of states possible in atomic behavior. Various phenomena of this order suggest that the ordinary laws of classical mechanics are not applicable in the physics which deals with the interior of atoms. This, in itself, is disturbing, for such an absolute breach in nature is not acceptable to the human mind. But additional complications arise when the philosophical implications of this discontinuity are developed.

It is generally accepted that all ordinary processes of nature can be associated with the progress of an irreversible time order, which is related to the thermodynamic probability (*entropy*) of the system. Natural processes are irreversible because of the tendency of energy to become unavailable through heat radiation. Now if nature were entirely consistent at all times there would be no insuperable difficulty in understanding how man, whom most of us regard as a product of evolutionary forces, should have developed an intuitive consciousness of time which is of an irreversible order. But this genetic account of the origin of irreversibility of conscious processes implies, of course, that there must be continuity of evolution in natural processes. Therefore, when we come to the realm of atomic phenomena previously mentioned, where our ordinary notions, implying the continuity of space and time, break down, we discover that we are in the serious predicament of trying to explain facts which are really inexplicable. That is to say, we are confronted with a set of empirical facts which contain what seem to us to be irrational elements, for we find that our customary principles of causal relationship

no longer hold. Hence Professor Wm. S. Franklin's suggestion [9] that we abandon all notions of time when we enter the interior of the atom, *like action at a distance,* upsets our ordinary habits of thinking.

There are facts in astronomy (stellar evolution), physics (radioactive transformations, etc.), and chemistry (periodic table, atomic numbers, and isotopes), which indicate that inorganic evolution is just as real as organic evolution. But if we accept inorganic evolution of the physical elements as on a par with organic evolution we face additional problems, which may be summarized under several heads:

1. If, at bottom, nature is fundamentally irrational (not understandable), in the sense that she jumps from one set of laws to another, (which carries with it a corresponding discontinuity of spatio-temporal and causal relations), and then acts in accordance with new principles of behavior which can not be inferred from previous laws, how are we to explain the possibility of the inductive sciences, the successes of which rest upon the ability to predict what nature will do? And what justification have we for the belief that nature will 'obey' in the future the laws which she now follows?

2. If we give up the notion of causal relations as asymmetrical, and admit that the time order is relative, or can be reversed, are we not sacrificing the possibility of explanation in any ordinary sense of the term?

3. Whenever time does not enter into the behavior of physical elements must we not also surrender the idea of evolution, at least to the extent that atoms, if not molecules, have evolved from previous electron-proton conditions, and admit that the hydrogen and helium atoms and molecules are historically every bit as 'old' as the electrons and protons of which they are constituted?

4. What reply is the physical monist to make to those who, like Professor William McDougall, see in the discontinuities at the bottom of nature an excuse for the introduction of non-physical entities such as mind at the higher levels of nature? The usual objection to the procedure of introducing vitalistic discon-

[9] "The Quantum Puzzle and Time," *Science,* 1924, Vol. 31, pp. 258 ff.

tinuities appeals to the law of parsimony, but if we do not admit discontinuities in the higher sciences must we not also, to be consistent, deny the facts of quantum mechanics? And if we admit atomicity of action (discontinuity of space and time) at the lowest levels, what becomes of the principle of continuity (*natura non facit saltus*) and the law of parsimony in the biological sciences?

5. Finally, if the essence of a mechanical theory is that the system in question must be reversible, and if we conclude that brain processes are irreversible, does not this imply that it is impossible for the human intellect to conceive of a mechanical system? This question may revolve upon some ambiguity of the term 'reversible,' but the matter is worth discussing. I am content to point out that there are those (*vide* Eugenio Rignano's *Psychology of Reasoning*) who are prepared to argue that the supposition of the mechanist, that the universe is a meaningless or purposeless system, is really unthinkable.

In the foregoing discussion I have tried to make it clear that the problems of physics can not be solved independently of those of psychology and philosophy. It is equally evident that anyone who propounds a theory of psychic time must come to terms with the time of physical science. The only other recourse would be to throw overboard the doctrine of evolution, and to hold that psychic time is of no kin to the measured time of physics. This doctrine that both orders, the objective and the subjective time orders, are ultimate and irreducible, is presented by Ernst Cassirer.[10] But this is to create a rift between the physical and the psychical, leaving us with a philosophy of nature containing an inexpugnable dualism. In the faith that it is possible to develop a tenable theory of time in physical science, which will also carry us across what some conceive to be the gap separating mechanical behavior from purposive behavior, and which, finally, also provides an explanation of the origin of psychic time, the following suggestions are presented.

[10] *Substance and Function and the Einstein Theory of Relativity*, Eng. trans., p. 454.

VI.

A Theory of Time.—The ultimate reality of nature may be termed Matter-Space-Time. Space and time are abstractions from a fluent universe of changing contours of things. Cosmic space and time are real, but they are real as partial aspects of a changing stuff which gives them empirical content. Pure space and pure time, as such, do not exist. Here we depart from the view which Mr. S. Alexander has proposed in his *Space, Time and Deity;* but in other respects I am following the doctrine of emergent evolution.

There is an absolute order which we may regard, not as in time, but, rather, in which the changing universe perdures. Over and above the local times of existents in the universe there is a temporal order which flows along in an emerging series of events which is the tempo of the creative advance of nature. The time-system of any emergent in nature (what I prefer to call a *continuant,* to use Mr. W. E. Johnson's term) is a partial perspective of the total frame of Matter-Space-Time. Thus relations within this world-fabric are themselves spatio-temporal, though not necessarily material in a purely conceptual scheme. Mental time, therefore, is part of the same cosmic time as is physical time. As Mr. Alexander puts it, mind is a form of time, and not time a form of mind. The reason we can not communicate with the minds of the so-called inorganic elements is that, as Royce indicated, they have different time-spans or rhythms of duration. The human mind is not the cause of purposiveness in human behavior, but, to use Professor Woodbridge's words, it is an instance of teleology. The world is the expression of an eternally creative energy which sustains itself by the self-expressive unfolding of a Cosmic Self along an open time-line. The cosmic tempo, the Soul of the World-Body, is not merely temporal, but it is time-spanning (or trans-temporal, to borrow an expression from Professor Leighton's *Man and the Cosmos*). This seems to me to be only way of reconciling the disjunction between eternalism and the temporalism which constitutes the point of departure of Bergson's creative evolutionism.

Physical Time: I have used the term 'continuant' to designate the unity of any type of object within the Cosmic Matrix. The unity of an object arises from the fact that it remains invariant when viewed from a frame of reference at rest with respect to the time-system of the object observed. Since time in physical science expresses the order of change of material configurations and their interactions, and since matter by its very nature is discrete, physical time may take on the appearance of discontinuity. This carries with it the idea that the probability within any system (*e.g.*, entropy) is not continuous with the probability of another system, if the two systems are distinguished by the qualitative difference which marks the transition states from one type of object to another (*e.g.*, atoms to molecules). Discontinuity in time occurs in its most striking form in physics in the quantum theory of energy. But purpose, I hold, also manifests itself in physical phenomena, and evidence indicating that electrons, in their behavior, manifest 'memory' and can anticipate the future (stressed especially by C. G. Darwin) lends support to this view.

Biological Time: The real time of nature more closely resembles the time of experience than the spatialized time of physical science. Indeed, as Alfred J. Lotka [11] surmises, psychic time can not be deduced from the differential equations of dynamics because these equations of motion are incomplete and do not wholly determine the actual course of physical events. Atoms, if not electrons, have a duration in which they live and move, and this is the time it takes for them to display their properties (presumably one revolution of an electron around a proton in the case of the hydrogen atom). This time-span is enriched and intensified in the higher continuants of nature. Material aggregates are synthesized by the radiant energy of space (*e.g.*, photosynthesis of formaldehyde by chlorophyll), and we therefore remain responsive to frequencies and rhythms, and this provides the basis for the subjective time-sense. Time estimation rests upon a correlation of the subjective span of attention with the rhythms of cosmic stimuli. Abnormalities of time-perception arise from the failure to keep in touch with the socially accepted tempos of objective rhythms.

[11] *Elements of Physical Biology*, p. 37.

Psychological Time: One of the commonest facts of nature is the summarizing of a discrete series of elements into new unitary wholes. Thus what Lloyd Morgan calls the rhythmic whirl of micro-events, which constitute atoms, are again unified into molecules. Similarly, at a higher stratum, the discrete temporal mosaics of sound sequences are unified into new temporal patterns (*pitches*) which, in turn, may enter into higher forms such as musical phrases, themes and movements. Psychic life, therefore, also exhibits levels of synthesis. The base of any series may itself, for its own frame of reference, be a unitary mode of behavior (continuant); but these wholes may be analyzed into the sub-groups of lower continuants. Analytically the unit of the time-sense may be the duration of the sensation (a nerve pulse, neurologically), but a temporal whole is not built up by a compounding of sensations.

Conceptual Time: The body-mind, with its different levels of synthesis, has the power of rising above the objects of lower orders. Thus conceptual schemes, not directly related to cosmical and physical space and time (such as non-Euclidian geometries and reversible time-lines), can be thought out. Following Meinong we may call these schemes the products of objects of higher orders. But conceptual time does not necessarily falsify real time, as Zeno, Bradley, Bergson and James have argued.

To a certain extent, *instants,* possessing no dimensions, are abstractions, and to that extent empirically unreal. Actual time is not composed of an infinite series of infinitesimals of no size. I should prefer to say that an instant is the ideal limit of a temporal series converging towards zero. But even in mathematics an instant is always a unit of a serial order. Any term in an order series implies the other members of the sequence. Motion, therefore, is not inconsistent with time conceived as composed of instants, since each individual of a generating series implies the relation of 'betweenness' holding in the irreversible series of 'before' and 'after.'

Time as we grasp it is largely a product of intellectual analysis, as Professor J. T. Shotwell [12] has shown. Intellectual analysis

[12] "The Discovery of Time," *Journal of Philosophy,* 1915, Vol. 12, pp. 199, 253, 309, ff.

does not 'murder' reality because synthesis is complementary to analysis. Internality and externality are progressively but not necessarily continuously evolving orders of being. The conceptual analysis by means of which we seek to interpret the world is an expression of the same absolute order which makes the external world intelligible to and interpretable by the human intellect. As the present writer has said elsewhere, the organism is not the passively moulded product of the external forces of nature. The organism, and the external world as we know it, have developed together by a give and take, in which conceptual interpretation, supplementing perceptual experience, has partially created the forms of externality; and, in turn, the objective order has forced us to readjust our ideas (cerebral behavior) to its (the environment's) semi-determinate texture. Through the vast span of time in which this process of mutual intercourse and interadaptation of organisms to their environments has progressed, the environment has continued to take on a more articulate character, while the organism has continued to develop an apperceptive synthesis which it is super-imposing upon the external world. Conceptual time results from a process of adaptation of organism to environment, but the 'fitness of the environment' makes possible progressive evolution. To me this implies the truth of Doctor A. N. Whitehead's[13] speculation that the alliance between the passage of nature and the passage of mind, which is given in sense-awareness, arises from their both sharing in some ultimate passage which dominates all being.

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[13] *The Concept of Nature*, p. 69.