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BERGSON AND THE UNIFICATION OF THE SCIENCES

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Louis De Broglie[1] and M. Capek[2] have described some interesting similarities between the philosophical ideas of Henri Bergson and the profound conceptual changes introduced into physics by quantum theory and the theory of relativity. These similarities are neither identities nor direct causal links, and hence physicists are likely to regard them as mere curiosities having no import for the development of science. However, another view is possible: if Bergson's thinking presaged, at least in spirit, these two revolutionary advances in physics then his intuitions may accord sufficiently with nature to provide useful guidance in the approach to other deep problems in science. Pursuing this idea I shall indicate here how Bergson's intuitions suggest a possible approach to perhaps the fundamental problem of contemporary science, namely the problem of constructing an overarching theoretical framework for unifying the various branches of science from psychology through biology to physics.

A dominant theme in Bergson's thought is his view that the concept of time used in classical physics does not conform to the nature of real time as defined by the concrete process of becoming. For becoming, as experienced, is based on heterogeneous duration, whereas the time of physical theory is based on a homogeneous collection of instants. In particular, Bergson emphatically rejects, at the level of concrete reality, the Newtonian idea that what exists is never more than a cut of zero

temporal extension separating a past that no longer exists from a future that does not yet exist. This Newtonian idea has now been discredited by the theory of relativity, and this lends support to Bergson's position. However, the connection of Bergson's thought to the theory of relativity has some subtleties that must be discussed more fully.

A common belief is that the theory of relativity entails, as Einstein says, that "becoming in three-dimensional space is somehow converted into being in four-dimensional space."[3] For example, Hermann Weyl says "the world simply exists, it does not develop."[4] Adolf Grunbaum says "coming into being is only coming into awareness."[5] Costa de Beauregard asserts that "For those authors, of whom I am one, who take seriously the requirement of covariance, relativity is a theory in which everything is 'written,' and where change is only relative to the perceptual mode of living beings."[6] He also says "there is no longer any objective separation between 'events which have already occurred' and 'events that have not yet occurred...'"[7]

Einstein's position on this question was, however, ambivalent. His vacillations have been described by Capek, who points out that Einstein warmly praised Emile Meyerson's book, and explicitly agreed with its central thesis which was the rejection of this spatializing interpretation of Minkowski space.[8] Arthur Eddington, Alfred North Whitehead, and Paul

Langevin were others who rejected the spatialization of time. In support of this negative opinion, Capek[9] has explained in detail how the theory of relativity makes the "order of succession" meaningless only for spacelike separated events, while leaving perfectly definite the order of succession of timelike separated events. However, this argument is not decisive, for it pertains only to a mathematical classification scheme whose connection to the concept of "becoming" is not established: it is not evident that the mathematical "order of succession" defined by the formulas of relativity theory is identical to this "order of occurrence" in the sense of coming into existence, or "becoming."

It may seem strange that scientists should still disagree on such a basic point. However, their disagreements point to the fact that the whole issue of becoming lies completely outside physics, as it is now understood, which deals with connections between observations, not with "becoming." In fact, it was precisely by establishing this point of view regarding what physics is about that Einstein was able, in the promulgation of the theory of relativity, to free himself, and physics, from these metaphysical controversies.

The point is simply that the observations that form the data of physics are completely defined by what is observed, including the clock and ruler readings. There is no observable meaning to the concept of "when the event occurred," or "when it came into being," apart from the observed reading on the local

clock. In other words, the order in which events come into being in some overall sense is not part of the data provided by the experiments of physics. Consequently, one is completely free to imagine, for example, that the order of becoming of the events is specified by a succession of dots of a Monet-like painting on a four-dimensional canvas. The demand of relativity theory is merely the demand of covariance, which places rigorous constraints only on the observable features, not on any unobservable overall order in which the observable data may come into existence, or become "fixed and definite." The implementation of this covariance requirements does not depend on determinism: covariance can be applied equally well to the probabilities in a probabilistic theory such as quantum theory, where the individual, observed events are not predetermined.

What is important here in connection with Bergson's ideas is that the theory of relativity logically entails neither three-dimension becoming nor four-dimensional being. Either one of these two alternatives would contradict Bergson's ideas -- three-dimensional becoming because existence would be instantaneous, and four-dimensional being because it contradicts Bergson's ideas about novelty and the process of becoming.

Actually, it is the metaphysical muteness of the theory of relativity that supports Bergson's ideas. For this muteness disconnects the ontological issue of becoming from the spacetime continuum of physical theory. It thereby creates the logical

possibility that this continuum is not the correct foundation for the description of the process of becoming.

Bergson's claim that the spacetime continuum is not the correct basis for the description of the real process of becoming can be taken to mean that this continuum cannot provide the foundation for a basic theory of nature that encompass all of science, from psychology to physics. On the psychological end, whence Bergson's intuitions come, it may indeed be necessary to take durations as fundamental, rather than instants. But it would at first seem that there could be little hope of naturally incorporating the vast knowledge contained in contemporary physics and chemistry if the spacetime continuum were abolished. And indeed, if physics were restricted to classical physics then rejection of the spacetime continuum would seem quite unfeasible. On the other hand, quantum effects are important in biology and neurodynamics. Hence quantum theory must be invoked. But quantum theory has a mathematical structure far richer than that of classical physics, and this richness seems to provide for the possibility of unifying the sciences in a way that conforms to Bergson's intuitions.

To show how this can occur certain important features of quantum theory must be made clear. The generally accepted interpretation of quantum theory is the Copenhagen interpretation,[10] which asserts that the theory is to be interpreted merely as a tool for calculating expectations or

probabilities for observations appearing under well-defined conditions expressed in terms of classical concepts. Two monumental philosophical shifts are imbedded in this interpretation. The first is the shift from deterministic to probabilistic theory: physical theory no longer determines what will happen but only the probabilities for various things to happen. The second shift is a change of ontological basis from the external world of geometric forms to the experiential world of observations: the "knowledge of the observer" becomes the reality upon which the physical theory rests. This switch makes explicit in quantum theory the change implicitly adopted earlier by Einstein in connection with the theory of relativity.

Both of these shifts bring physical theory more in line with Bergson's ideas. On the one hand, Bergson continually stressed the importance of real novelty, and hence the failure of geometric determinism. On the other hand, the shift of ontological base from geometric structure to observations provides at least the beginning of a physical theory that includes psychological phenomena, and the associated quality of duration.

Some unorthodox schemes have been proposed, namely the many-worlds[11] and hidden-variable[12] models, that restore to physics both geometric determinism and a Cartesian duality that cleanly separates the geometric and experiential aspects of reality. However, these features are retained only at the price

of interpreting as objectively real some quantities that, by virtue of their mathematical properties, should describe only the probabilities of the alternative possibilities. Thus all possibilities are made objectively real, even those that are contrary to actual experience.

The tidiness of these deterministic, Cartesian models appeals to some physicists. But the clean separation of the two realms of reality, and the consequent absence of any logical necessity for the existence of either in the structure of the other, makes their parallel existence an irresolvable mystery, and the connection between them arbitrary. Thus these schemes appear to provide no basis for a logically coherent theory that encompasses both psychological and physical phenomena.

A possible quantum theoretical framework for psycho-physical phenomena has been proposed earlier.[13] That proposal will not be reviewed here. It will merely be mentioned that in that framework the geometric features of quantum theory were interpreted as pertaining merely to the "tendencies" or "propensities" for the discrete actual events of becoming. This is in line with the probabilistic character of the wave function, and more specifically its "potentia" interpretation discussed by Bohm[14] and endorsed by Heisenberg.[15]

From a strict Bergsonian point of view this acceptance of the spacetime continuum, for the description of tendencies alone, might be objectionable. Even though the actual events of

becoming were taken to lie outside the spacetime continuum, and hence to be describable in terms of duration, still the demands for mathematical cohesion might, in the end, block any logically tight linkage between tendencies and actualities, if the former are based on the continuum and the latter is not. Thus a strictly Bergsonian approach would probably demand rejection of the spacetime continuum even for tendencies. This demand presents an even stronger challenge as regards the retention of the empirical content of contemporary physics.

A hint of how to proceed is given by Bergson's suggestions "... fix your attention on the movements by abstracting from the divisible space that underlies them and considering only their mobility."[16] What can this mean? How can one represent mobility or state of motion without referring to the underlying space, or at least to things in this space?

Quantum theory allows this to be done. For the state of motion of a particle can be represented by the momentum wave function $\Psi(p)$, which can be regarded as logically independent of the spacetime continuum. The variable p represents energy and momentum, the latter being inertia, which is resistance to change. Energy and momemtum are dynamically very fundamental, since they are the quantities appearing in the fundamental dynamical laws of conservation of energy and momentum. And they have psychological corrolates, energy and intertia, that are far

more primitive than the intricate mathematical concept of a continuum.

In classical theory the momentum distribution function is independent of the spatial distribution function. But in quantum theory all the information is contained in either one alone. Thus one can represent the full mathematical content of quantum theory without explicitly referring to the spatial continuum simply by expressing everything in terms of momentum variables, which can be viewed as ontologically basic.

But what about time? Can one represent the full dynamical content of contemporary physical theory without using the temporal continuum. Again the structure of quantum theory allows this to be done. Heisenberg pointed out that the full empirical dynamical content of relatistic quantum theory is contained in a certain function of momentum vectors called the S matrix. This quantity involves neither time nor its dual energy variable. In place of time it has a two-valued process variable that distinguishes "before" from "after."

An important aspect of the S-matrix representation of physics is that the equations that determine the S matrix can be expressed in terms of the S matrix alone, i.e., without reference to the continuous time variable, or its dual energy variable. Thus the S matrix provides a representation of physics that appears to be in principle complete both from the empirical and theoretical points of view.

The content of physics as represented in the S matrix is devoid of any explicit reference to the spacetime continuum. It is expressed rather in terms of inertial states and a "before and after" variable that accommodates discontinuous jumps between these inertial states. This conceptual framework appears to conform quite well to Bergson's intuitions.

It is of course essential that space and time, though not fundamental, emerge as concepts having sufficient approximate validity. This happens in the following way. The S-matrix is a sum of functions corresponding to the different possible combinations of initial and final stable systems. These are the systems that if left to themselves would endure, unchanging, for all eternity. Each of these functions is a function of the momentum of each of the initial or final stable systems. The space on which each of these functions is defined has certain well-defined surfaces, called Landau singularity surfaces, where the function fails to be infinitely smooth. Each point on any one of these Landau surfaces corresponds to a diagram of well-defined structure imbedded in a four-dimensional continuum. These four-dimensional diagrams can be ascribed an approximate spacetime interpretation: if one introduces, formally, the notion of spacetime by means of a certain mathematical transformation (a Fourier transformation) then the probabilities predicted by quantum theory will become large in circumstances where one can imagine that the process can take place in

spacetime in the way indicated by the diagram. The mathematics of this connection has been worked out in a precise way.[17,18] But the physical connection to spacetime is only approximate. For the importance of the contribution associated with the four-dimensional diagram -- relative to background contributions, which have, in the S-matrix framework, no spacetime interpretation -- depends on the spacetime scale of the process. In particular, the four-dimensional diagram is constructed from a set of line segments in four-dimensional space, each corresponding to one of the eternal inertial states. Each of these segments is joined to certain other ones on at least one of its two end points. But the contribution from the background terms becomes totally negligible only as the scale of the diagram, considered as a spacetime diagram, tends to infinity, i.e., as the line segments that formally correspond to the various eternal inertial states become extended over infinite time. On the other hand, it appears that the connection of the mathematical structure to empirical evidence can be made only to the extent that this approximate spacetime structure just discussed becomes sufficiently dominant to be empirically recognizable. That is, the dominance of certain of these approximate spacetime structures is a precondition to the confrontation of the theory with experiment. That is essentially Heisenberg's original point.

There is a final important point. Our lives and experiences are largely dominated by the electromagnetic interaction, which is responsible for the binding that holds together our bodies, our brains, and the objects we use. It is also responsible for the light by which we see and the sounds by which we hear, etc.

The connection of physics to spacetime discussed above pertained to objects. The other important connection is via the electromagnetic field.

The discussion of S-matrix properties given above was for the idealized case in which the electromagnetic interaction is ignored. When this interaction is included certain infinities occur, and the theory becomes initially ill-defined. This is the famous infra-red catastrophe. It turns out,[19] however, that in order to make the theory well defined, in a satisfactory way, one must introduce an electromagnetic field defined over the spacetime continuum. This field again has only approximate empirical significance, which, however, becomes increasingly precise as the spacetime scale of the process tends to infinity. The situation is analogous to the one discussed earlier except that it appears to give mathematical reasons, starting from an initial presumption of the fundamentalness of the momentum and energy variables, why the world acquires an approximate macroscopic spacetime structure that accords with the concepts and laws of classical physics.

At the microscopic level quantum effects are important. A chief one of these is the coherence effect, which imposes wholistic behavior: a quantum system generally behaves quite differently from the sum of its parts taken separately.

It can probably be taken as a general principle that the quantum acts of reduction occur at the highest level of quantum integration, which would, in general, be at the point of transition to the classical level, where the classically distinguishable parts become effectively independent. Applying this principle to the quantum acts associated with brain processes one is lead to conjecture that there are quantum acts that occur at the highest possible level of integration, and hence involve essentially the brain acting as a whole. They would occur at the point where a separation is being initiated by brain processes between different possible macroscopic courses of action. A quantum act of reduction occurring at this point would be, in the physical world as represented by the state vectors of quantum theory, the act of selecting the particular course of action.

The quantum acts of reduction are identified as the image, in the physicist's representation of the physical world, of the fundamental actual events of becoming. In the experiential realm the choice between the different possible courses of action would be felt as the act of selecting the particular course of action. Thus the acts in the experiential

and physical realms are the same act, namely the act of selecting the particular course of action. This identity removes the arbitrariness in the connection between the worlds of mind and body, as is discussed in detail in Reference 13.

In conclusion, it appears that Bergson's insistence on the nonfundamental character of the spatial and temporal continua is supported by certain recent developments in physics, and that if, as seems likely, the full empirical content of basic physical theory resides in the S-matrix, then the physical and psychological aspects of nature may have a sufficiently common structure in terms of transitions between different inertial states to allow them to be brought together into a single coherent structure that conforms generally to the intuitive ideas of Bergson.

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