Process Ontology from Whitehead to Quantum Physics

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Summary. Although Alfred North Whitehead probably did not know much of the new quantum theory of Heisenberg, Schrödinger and Dirac, there seem to be deep similarities between his idea of process and the ideas of quantum theory. Both Whitehead's metaphysics and quantum theory are theories of observations: The realities which quantum theory deals with are based on observations by scientists who use the theory. And Whitehead's speculative cosmology is an expansion and generalization of the British empiricists' theory of perception.

Four leading ideas have determined the theoretical sciences in the 19th century: Atomicity, continuity, energy preservation and evolution. According to Whitehead, the challenge to science was not to introduce these concepts but to fuse them together and expand their application. Therefore, the cell theory and Pasteur's work were more revolutionary for him than the achievement of Dalton's nuclear theory, "for they introduced the notion of organism into the world of minute beings. ... The doctrine of evolution has to do with the emergence of novel organisms as the outcome of chance" (Whitehead, 1925, pp. 146–147).

Up until now, neither individual experiences nor the natural sciences gave reason to believe in invariable subjects. On the contrary, the whole being of reality has been in a process of becoming and passing. "On the organic theory, the only endurances are structures of activity, and the structures are evolved" (Whitehead, 1925, p. 158). Whitehead's speculative cosmology is based on the results of the theory of evolution. However, he tries to integrate all experiences of reality. Placing the concept of "actual occasions" in the center of his philosophy of organism, he succeeds in resolving handed-down contrasts within a common framework. The world is made of 'actual occasions', each of which arises from potentialities created by prior actual occasions. Actual occasions are "happenings", each of which comes into being and then perishes, only to be replaced by a successor. These experience-like "happenings" are the basic realities of nature.

Similarly, Heisenberg said that what really happens in a quantum process is the emergence of an "actual" from potentialities created by prior actualities. In the orthodox Copenhagen interpretation of quantum theory, the actual things to which the theory refers are increments in "our knowledge". These increments are experiential events. The particles of classical physics lose their fundamental status: They dissolve into diffuse clouds of possibilities. At each stage of the unfolding of nature,

the complete cloud of possibilities acts like the potentiality for the occurrence of a next increment in knowledge, which can radically change the cloud of possibilities and potentialities for later increments in knowledge.

A philosophy founded on causality and teleology as basic descriptions of reality must dissolve the distinctions between inside and outside, consciousness and matter, object and subject. To achieve this purpose, Whitehead's philosophy of organism offers a starting point. Therefore, I would like to introduce his philosophy and compare its results with interpretations of quantum theory. Here, it will be interesting to take a look at Henry Stapp's theory of consciousness, which is based on quantum theory. He argues that reality is created by consciousness, as consciousness causes the collapse of the wave function that in turn causes reality to "occur". Stapp claims that Whitehead's metaphysics is incompatible with quantum theory by virtue of Bell's theorem and needs to be modified. I disagree with this conclusion because Stapp did not properly take into account Whitehead's theory of prehension.

1 Introduction

There have been countless discussions about the implications of physics, especially quantum physics, for various issues of human understanding. These issues include time, consciousness, and freedom (Griffin, 2005).

- Regarding *time*, it has been argued that modern physics shows time as we experience it – with its distinctions between past, future and present – to be ultimately unreal.
- Regarding *consciousness*, it is thought that any philosophy of mind, to be compatible with modern physics, must regard conscious experience as a by-product of the brain's subatomic particles.
- Regarding *freedom*, it is thought that any understanding of reality based on modern physics must rule out the possibility that our decisions truly involve self-determination.

In light of these supposed implications, it is widely assumed that a worldview that takes physics seriously necessarily contravenes the worldview of ordinary human understanding. In reality, none of these implications must follow from physics *per se*. These are always interpretations from a particular philosophical perspective. Physics as interpreted by Whitehead's philosophy rejects all three implications. They are examples of what he calls "the fallacy of misplaced concreteness", meaning the "error of mistaking the abstract for the concrete" (Whitehead, 1925, pp. 74–75).

By characterizing the basic ideas of sciences and their consequences for philosophy, Whitehead wants to unify different views of nature and to overcome the dualistic tradition of Cartesianism in modernity (Whitehead, 1925). One can summarize his effort against dualisms of three versions (Wiehl, 1998):

Ontological dualism: This denotes the absolute difference between an infinite and a limited substantiality.

Ontic dualism: This denotes the absolute difference between the physical and the spiritual being.

Gnoseological dualism: This denotes the absolute difference between two kinds of knowledge, different in nature, between rational grounds and grounds of experience.

It is interesting that Whitehead's starting point in the analysis of the ideas of the 19th century resembles that of Friedrich Engels. Both selected a nearly identical group of scientific advances which they saw as the deciding factors in the transition from Newtonian to modern science: Atomicity, continuity, energy preservation and evolution. In addition, Whitehead's philosophy of experience resembles dialectical epistemology in stressing the role of negatives (Wiehl, 2000, p. 40). However, instead of representing a dialectical materialism, he arrives at completely different conclusions. He asks himself whether we can "define an organism without recurrence to the concept of matter in simple location" (Whitehead, 1925, p. 149) and radically rejects every type of materialism.

In terms of experience, language and logic, the teaching of a substance forming the basis of all things seems to be the most natural way to look at last things. In modernity, however, the originally "logical" substance-quality pattern has been raised to the basic structure of reality. The result is that relations between things can no longer be taken into account (Whitehead, 1978, p. 79). Whitehead rejects:

1. a substance as a static substratum (Christian, 1959, p. 108) because
   a) we experience a variable world, and
   b) the natural sciences are becoming smaller and smaller "particle unities" (Whitehead, 1978, pp. 78–79);
2. "the fallacy of simple location" because the objects of the world exist neither in isolation nor independently of one another.

Neither individual experiences nor the natural sciences give reason to believe in invariable subjects; on the contrary, the whole being of reality is in a *process* of becoming and passing. Whitehead suggests seeing reality as analogous to an organism (Whitehead, 1925, p. 159). His speculative cosmology in "Process and Reality" (Whitehead, 1978) is the logical construction of a philosophy of organism based on the results of the theory of evolution. However, he tries to integrate all experiences of reality. For this reason, he criticizes Darwinism, which completely excludes creativity.

2 Bifurcations

The sciences are not concerned with epistemological matters but rather with a coherent explanation of nature. This fact leads to the bifurcation of reality. Whitehead categorically rejects:

- the distinction between events of nature and events as they are formulated in scientific theories, and
- the distinction between events of nature as they exist by themselves and as they appear to us.

The first concept maintains a purely conceptual existence of physical entities such as atoms and electrons. On the one hand, there are phenomena, and on the other hand, logical terms of scientific formulae. For Whitehead, scientific concepts are derived from nature by way of logical abstraction. He argues against the bifurcation of reality into the mathematical world and the apparent world. Concepts, as far as they are true, refer directly to facts of reality.

The second bifurcation is a consequence of the first. It appears between sensory perception and reality itself and results in the banishing of the observer from nature. The observer can have knowledge only of his sensory impressions, not of the objects which produced them. The knowledge of reality now requires a theory since there is a rationally unbridgeable gap between the purely geometrical concepts of motions of particles in space and the psychological realities of conscious sensations, feelings, and ideas. If the material substances are only in space, then a material substance can act only upon material substances – not upon a mental substance. Gottfried Wilhelm Leibniz concluded (Schilpp, 1941, p. 179),

> "either the material substances must be brought within the space in the field of awareness of the mental substance ... or the mental substance must be defined in terms of the material substances."

For Leibniz the latter is impossible because he would then be confronted with Locke's problem.[1] This is why he developed his monads.

3 Perception

To avoid these bifurcations, the origin of every possible knowledge must be considered. Whitehead regards this origin within everyone's daily experiences and addresses directly the British empiricists' starting point:

1. Every experience has its origin in perceptions.
2. The primary ideas of perception join secondary ideas deduced by reflection in order to put the sense data into an order.
3. In addition to these two starting points of the British empiricists, Whitehead integrates psychic impressions such as emotions, beauty, love and satisfaction.

[1] Historically, after separating the realm of apparent nature from that of its physical description, John Locke asked how both realms could be connected. Isaac Newton developed a kinetic theory of atoms, but he did not explain how unperceivable atoms in absolute space and time are connected with our space-time experiences.

If Whitehead would restrict himself to the British empiricists' theory of perception, he would be subjected to the false conclusion that reality is constituted out of static and isolated substances. Because he does not, he can do justice to relations in sensory perception due to the broadening of the theory of perception through the mode of "causal efficacy".

Perceptions are normally described in "presentational immediacy". This mode of perception presents the spatial relationships between the perceiver and sense data, even while temporal aspects are ignored. Perceptions in presentational immediacy are preferred compared to causal efficacy because they are directed by attention. Attention is comprised of a teleological and a temporal aspect. The analysis of past data directs the attention to the emergence of future data. However, the analysis of past data is no longer part of presentational immediacy but rather of causal efficacy. Attention is the cut between presentational immediacy and causal efficacy. All scientific observations are made in the perceptive mode of presentational immediacy (Whitehead, 1978, p. 169). However, physical theories refer exclusively to causal efficacy.

If all knowledge is traced back to perception at one moment, one cannot have empirical knowledge of relations nor of the continuum of reality. Contrary to David Hume and Immanuel Kant, Whitehead finds evidence for causal connections and temporal continuity in sensory perception. He asserts that one can perceive them directly in the mode of causal efficacy, tacitly assuming the experience of temporal and spatial extension.

Temporally adjacent events are perceived directly in a temporal window of perception: the "specious present" (according to William James). It is perceivable that later events confirm earlier ones. We have knowledge of an extensive continuum of reality because of our perception of space-time relations. The specious present contains not only immediately observed events; it also includes the immediate past. The presence of immediately past events shows that present and future events have to confirm earlier events in the same way that immediately past events had to confirm events in the even more distant past. Causality in Whitehead's philosophy means that we never perceive a series of events alone; later events must emerge from earlier events in the specious present. Perceptions in causal efficacy contain the temporal aspects of the process of reality.

Sensory perception takes place only in the complex mode of "symbolic reference" connecting the two pure modes. As a result, perception in symbolic reference causes errors and misinterpretations. Symbolic reference is an active synthetic element of the perceiver, producing emotions, convictions and beliefs concerning other elements of reality.

4 Time

Within each period of his philosophical development, Whitehead expresses that space and time do not exist independently. Space-time cannot be consid-

ered a self-subsistent entity. It is an abstraction whose explanation requires reference to that from which it has been abstracted. In Whitehead's natural philosophy, the real world is an extended, continuously flowing process. Later, in his metaphysical period, space and time were seen as abstractions from extended events and are to be experienced empirically.

4.1 Time in Whitehead's Natural Philosophy (1914-1925)

An entity is an abstraction from the totality of the continuously flowing process of reality. Temporally extended events do not exist independently. What scientists accept as elements or parts of the whole are actually abstractions. In reality, the elements only exist and have meaning by virtue of the whole and *vice versa*. Therefore, time does not have any reality in nature but is the property of a perceiver. Reality is characterized by an extensive space-time continuum. Events in nature do not have any reality independent of a consciousness and do not have definite temporal extensions. Time relations are an expression of an ordering relation of a perceiver. Space-time is nothing other than a system for the combining of assemblages into unities. Physical time only deals with certain formal, relational aspects of our changing human experience. Relative to other abstractions, space and time offer a comparatively simple structure, which is suitable as a basis for objective distinctions in reality.

During the specious present one perceives a unit already separated into its parts by the activity of the perceiver. The parts entertain certain characteristics, of which time and space are examples. The common structure of space-time conforms to the uniform experiences of sensory perception. But it is not clear how one can proceed from individual experiences to a uniform space-time structure. Whitehead confesses that what he has termed the "uniformity of the texture of experience" is a mere illusion. This uniformity does not belong to the immediate relations of the crude data of experience but, rather, is the result of substituting more refined logical entities. We are not directly aware of a smoothly running world.

4.2 The Epochal Theory of Time (after 1925)

The transition from momentary events to extended events is not only initiated by the knowledge that perception takes place in the specious present and that causal interactions are directly perceivable. It is also a result of logical difficulties within physical theories and metaphysical outlines. Physical descriptions of dynamic processes like momentum, velocity and tension, and the descriptions of simple physical structures like atoms or biological organisms presuppose the existence of temporal events. In addition, becoming is only possible if reality is constituted out of temporal, atomic events. Becoming and continuity are incompatible (Zenon of Elea). Whitehead shows that momentary events can be deduced out of extended events by means of the

method of extensive abstraction, one of his central ideas. All these points forced him to conclude that reality is not founded on momentary events but rather on spatiotemporally extended events.

Despite the fact that Whitehead probably never became acquainted with the post-1924 development of quantum theory, first results motivated him to transfer the new knowledge of philosophy and psychology to all events of reality. In particular, Bohr's model of the atom (1913) and de Broglie's wave theory (1924) resulted in a critical examination of his natural-philosophical starting point. From that point on, the particles of reality were no longer material, static forms but rather spatiotemporally extended events. The change from materialism to Whitehead's organic realism is characterized by the displacement of the notion of static stuff by the notion of fluid energy. Whitehead got his inspiration from scientific discoveries, without necessarily going into their specific formalism. His doctrine of the epochal character of time depends on the analysis of the intrinsic character of an event, considered to be the most concrete, finite entity, which he calls the "actual occasion".

In the epochal theory of time, Whitehead unifies four different time aspects to be found in the experience of an actual occasion. There are two internal and two external aspects. The internal time aspects are the passage of thought (becoming and perishing, retentions), and the experience of extension (unlimited act, inner time consciousness, retentions and protentions). The external time aspects are the potential physical time (extensive continuum), and the actual physical time (passage of nature, becoming and perishing). The experience of extension corresponds to potential physical time; the passage of mind corresponds to the passage of nature. The physical concept of time unifies the experience of an extensive continuum and the perception of concrete, actual occasions. It unifies the discontinuity and continuity of the external world into one concept.

5 Actual Entities

The assigning of the different time aspects to the final units of reality becomes possible through the transformation of the concept of momentary events into actual occasions.[2] While in Whitehead's natural philosophy events still depend on the activity of a perceiver, actual occasions are in his metaphysics the final units of reality (Whitehead, 1978, p. 75). They are the real things of the world and have their own being. They are not momentary cuts through reality but rather forms which have the properties of spatiotemporal extension and creativity.

The adjective "actual" rejects every attempt to find a reality behind actual entities (Whitehead, 1978, p. 75). An actual entity is limited in terms of space

[2] Whitehead uses the notion of "actual occasions" interchangeably with "actual entities".

and time and, in comparison to other actual entities, owns a defined space-time position (Whitehead, 1978, p. 73). It follows that an actual entity neither moves (Whitehead, 1978, p. 77) nor changes! Entities appear and disappear like the ideas in the stream of ideas in our mind (Whitehead, 1978, p. 141).

Every actual occasion is a spatiotemporal unit possessing an indivisible volume and time quantum, which cannot be disassembled without being destroyed (Whitehead, 1978, p. 219). Actual occasions express the uniform space-time structure of the universe because their external relations fit them into superordinate actual occasions, and their internal relations, the coordinate divisibility, divide them into subordinate actual occasions. The spatiotemporal extensive continuum is the general structure to which all actual occasions must conform. Actual entities, whose unity can be dissolved into subordinated actual entities, are called *Nexus*. The usual things, like trees, houses and cars, are all Nexūs (Whitehead, 1978, p. 56). Nexūs take into account the unity of *contemporary* events which are not causally tied together. If a Nexus owns an ordinal degree, Whitehead calls it "society" (Whitehead, 1978, pp. 89–90). "A society is a sequence, or more generally, a pattern of occasions which ... give rise to the impression of objects existing self-identical in time" (Hättich, 2004, p. 101).

6 Prehension

The content of an actual entity is constituted only by perceptions, like the contents of Locke's "idea". The "perceiving" actual entity is connected with other entities by perceptions. Whitehead's philosophy of organism is a generalization and extension of his theory of perception. However, perception is not limited to sensory perception but refers to every kind of causal influences.

"Prehension" is a short form of "apprehension", which indicates "recognition" and does not mean that the perceived has to be present. However, it presupposes consciousness. Consciousness belongs only to a few highly-developed organisms. Whitehead's concept of perception should describe universals and should also contain "unaware recognition". Therefore, he introduced the concept "prehension". Every entity which is prehended as a unity is an actual entity. "God is an actual entity, and so is the most trivial puff of existence in far-off empty space" (Whitehead, 1978, p. 18). Actual entities are not only microcosmic entities as is often maintained (Sherburne, 1966, p. 205).[3] For Whitehead, the whole universe as well as just a single atom are actual entities.

An actual entity is linked with *every* other actual entity of the universe by means of prehensions (Whitehead, 1978, p. 41). Although all actual entities of the world are prehended, not every actual entity contributes to the new

[3] Abner Shimony's paper on "quantum physics and the philosophy of Whitehead" is based on this misconception (Shimony, 1965).

actual entity. Otherwise, all actual entities would be the same and therefore indistinguishable. The becoming actual entity selects all "positive" prehensions for its construction. They are called "sensations" or feelings. An actual entity "feels" the contributions of other actual entities and integrates them into its construction (Whitehead, 1978, pp. 56–57).

There is a significant difference between perception, which is causally influenced by perceived objects, and prehension, which means a coming together of different parts of reality. The latter could also mean a going together of very distant events. Thus, there is also a strand in Whitehead's metaphysics discussing parapsychological phenomena, especially telepathy (Whitehead, 1978, p. 308; Griffin, 1982). For Whitehead, "physical science maintains its denial of 'action at a distance,' the safer guess is that direct objectification is practically negligible except for contiguous occasions" (Whitehead, 1978, p. 308).

In this respect, I believe that Henry Stapp did not sufficiently take into account Whitehead's discussion of prehensions when he claimed that Whitehead's system of metaphysics is incompatible with quantum theory due to Bell's theorem. In contrast, Bell's theorem could be used to support process philosophy (Klose, 2002, pp. 355–357). Each event does prehend all of creation, not only those events found in its backward light-cone, as Stapp (1977, p. 315) predicated. The unity of the world would be destroyed if each event would prehend only its own actual world (Stapp, 1979, p. 21).

A theory of perception connects causally past events with present ones. But the theory of prehension changes the perspective. It describes the development of reality from present to future. Therefore, a growing actual entity is not the perceiving subject in the process of prehension. The perceiving subject does not exist before the perceived events and is not their contemporary. This would mean a new formulation of a concept of substance, of a basis bearing the phenomena. *Vice versa*, the perceived events are temporal before the objectifying actual entity. Prehensions reach into the future like tentacles. They grow together into a new unity.

However, this process does not take place locally and aimlessly. It is accompanied by an ideal, the subjective aim. Actual entities lead their incremental process. They present themselves as the aim of this process. In this respect, they are both subject and superject in one event, the superject being the decisive element in the process. Whitehead generalizes the structure of perception of a consciousness. He ascribes this structure to nature as a basic structure of reality. Nature does not appear anymore as coexisting, separated particles of matter but rather as a network of organically interconnected entities.

7 Creativity

Every future entity means a coming together of all available elements of reality. The fact that every entity of reality tends to unification and to higher

complexity is an empirical fact (Whitehead, 1929, p. 89). The internal, motivating force of the reality process are creative processes of becoming, which Whitehead calls "concrescence" (Whitehead, 1978, pp. 21–22). The philosophy of organism is based on the generalization of the concept of force (Rapp, 1986, p. 82). One constitutive quality possessed by all entities is creativity. It is the impetus of progress to new units of reality.

The standard (neo-Darwinian) theory of evolution does not explain why evolution as a whole has led towards ever more complicated life forms. At variance with the general laws of physics, which postulate that there will be an equal distribution of energy and decay throughout the universe, we know that processes leading to higher organization forms exist (Whitehead, 1929, p. 24). We know from our observation of human and animal experiences that purposes are immediate components of the constitution of living beings (Whitehead, 1929, p. 13). Physiology and physics, which describe reality only in terms of active causes, ignore these experiences. Therefore, their theories are not adequate descriptions of reality as a whole.

An adequate description of the universe has to contain aspects of both efficient and final causation. For this reason, we must not describe nature only in terms that ignore one side of reality. The only kind of entities observable in nature are living organisms, which unify final and efficient causation. It is more reasonable to transfer the concept frame of living organisms to all phenomena of reality than the reverse (Whitehead, 1938, p. 211). Whitehead's philosophy of organism attributes the double character of efficient and final causation to the final things of the universe.

Whitehead identifies the energetic activity of physical entities with the emotional intensity which can be perceived in the life of biological nature (Whitehead, 1938, p. 231). All entities of reality are "living beings". Neither the nature of physical entities nor life can be understood independently of each other. Life implies self-preservation, creative activity, and teleological aim.

The opposites of "efficient causation–final causation", "decay–pursuit of higher complexity" and "body–mind" are unified in the concept of life. All events of reality live if they comprise these tensions. According to neo-Darwinian evolution, primordial physical events enter into mental events and cause them. According to the philosophy of organism, the reverse is basic. It takes back the grounds of mental events by using physical ones. Every event possesses (a) mental and (b) physical experiences (Whitehead, 1926, p. 118):

- Mental experiences are experiences of defined forms (universals, eternal objects), regardless of their concrete determination of being.
- Physical experiences are conservations of facts given to the event by its constitution of being.

An actual occasion is the product of the interplay of the physical with the mental pole. The physical pole is extended over the whole space-time continuum and can be divided. In contrast, the mental pole does not share in

the divisibility of the physical pole. The mental pole has its equivalent in a thought (of mind). It is an act of attention with the duration of the specious present. Passage of mind is confronted with the experience of an unlimited temporal act in the internal time concept.

8 Teleology

Present actual entities do not anticipate their future determination but rather their subjective aim. If an actual entity always and unavoidably reaches its subjective aim, all future events would be determined by present ones and *vice versa*. This is not the case. The subjective aim is a future aim of a present development envisaged by the becoming actual entity. As the entity is an eternal object, it is the vision of a future state, which influences the way it develops into this state. The vision influences the actual entity in its decision but is not the final determination (Whitehead, 1933, p. 249):

> "In the formation of each occasion of actuality the swing over from re-enaction to anticipation is due to the intervening touch of mentality. Whether the ideas thus introduced by the novel conceptual prehensions be old or new, they have this decisive result, that the occasion arises as an effect facing its past and ends as a cause facing its future. In between there lies the teleology of the universe."

The difference between the present state of the development process and the subjective aim is the excitement pushing an actual entity forward to higher states of development. Its "appetite" for completion will have "evaporated" if a state of satisfaction is reached. An actual entity reaches fulfilment if the difference between the subjective aim and the satisfaction has become negligible. The process is finished at a certain state of convergence. One has to understand this approximation process as a process of fulfilling an ideal.

It could be concluded from the pursuit of the subjective aim that there has to be something within which the subjective aim is present. Something exists that moves towards this aim. This thought puts a subject under the reality process envisioning the subjective aim and is the medium of the process of development. This means that there has to be a substrate of changes in reality which contradicts Whitehead's intention. Where does one find the origin of the subjective aim in the concrescence process of an actual entity ?

Whitehead denies the "intentions" of past actual entities. They have passed away and do not possess a transition to future aims. A growing actual entity perceives the subjective aim as a date of the actual world. The subjective aim as a date is contemporaneous with past actual entities; as a purpose, it is neither a cause nor an effect. The "'moving' finis in the final nexus is the interpretation of the purpose as a cause." (Löw, 1980, p. 292) The subjective aim determines which prehension delivers a positive contribution to the growing actual entity. According to Whitehead, the subjective aim is

made available by God. This is a crucial point. From where does mentality get a future picture? Are there experiences or concepts which are not reducible to the observed nature?

One can only distinguish between subjective aim and satisfaction if the process of concrescence is limited in time. Whitehead (1978, p. 19) took for granted that teleology assumes temporal atomicity, and that temporal atomicity is only possible in a state of reality which is teleological. In a cosmology with a continuous concept of time, real becoming is impossible – there are only changes which are transformations from one state into another. However, a physical process, which is teleologically constituted, assumes an aim of development for single entities.

9 Transmission and Concrescence

Process philosophy differs significantly from classical philosophical drafts in its dynamically oriented conceptual design of reality. Dynamic processes can be considered from an internal and from an external perspective (Whitehead, 1978, pp. 51–52). The internal process is the process of concrescence; it makes up the essence of actual entities and is teleologically structured. The external process characterizes the progress from actual entity to actual entity and describes changes within societies of actual entities. It is characterized by causality and conformity (Whitehead, 1978, p. 210).

Reality is the common presentation of two kinds of processes: Concrescence and transmission. The transmission process concerns the steady progress made by atomic unities of reality from the past to the future. This process is described by the theory of evolution. Transmission is a process of concrescence processes, and concrescence is a process of transmission processes. Reality is a process of processes. Every actual process contains a huge number of interlocking actual processes. The whole universe is a single process as well as an infinite complex of processes.

10 Quantum Theory

Whitehead was clearly influenced by the very early development of quantum theory, so one might expect similarities between quantum theory and his process philosophy. In particular, the properties of an actual occasion and a quantum event are quite similar. It appears that the collapse of the quantum state is the atemporal process that corresponds to an actual entity, and the elementary quantum event corresponds to what Whitehead called “the satisfaction of an actual entity” (Malin, 2006).

There is another parallel concerning the conception of a classical trajectory. It is a consequence of Heisenberg’s uncertainty relations that a quantum

particle cannot have a definite position in space and a definite momentum at the same time. Hättich (2004, p. 100) states:

> "Consequently, quantum particles cannot posses continuous trajectories because this would obviously force them to possess a definite position *and* a definite momentum at each time of their existence."

The experimental results one gets from a bubble-chamber experiment look like the spatiotemporally continuous trajectory of a classical particle. Again Hättich (2004, p. 100):

> "But under closer inspection it turns out that this 'continuous' trajectory is merely a succession of discrete, i.e. spatiotemporally non-overlapping, events."

This description of a trajectory is in accordance with Whitehead's concept of a society.

But in how far can Whitehead's metaphysics provide an ontological basis for quantum theory? For Einstein, a theory always represents an extrapolation beyond what we can know (Haag, 2004, p. 54). Although Shimony (1965) concealed the usefulness of Whitehead's metaphysics for an interpreting system of quantum theory, lately some articles and books have been published on this subject (e.g. Burger, 1965; Griffin, 1982; Stapp, 1993; Shimony, 1993a, 1993b; Eastman and Keeton, 2004). There are strong endorsements of process philosophy, and striking parallels to Whitehead's formulations.

The "Copenhagen" quantum theory was formulated as a set of practical rules for making predictions about what human observers would observe under certain well-defined conditions.[4] This pragmatic view "is essentially subjective and epistemological, because the basic reality of the theory is 'our knowledge'" (Stapp, 2001a, p. 2). It contains in itself no definitive criterion of completeness. However, it is guided by two basic principles (Stapp, 1979, p. 9): "The final theory should be comprehensive and unified." In this regard, the Copenhagen formulation includes an awkward feature: Human observers are excluded from the system. The theory is based on a bifurcation of the physical world into observer and observed. This situation is dissatisfying for someone who seeks a rationally and dynamically coherent understanding of what is actually going on. Because measuring devices and human bodies are made up of atoms, one expects that the laws of quantum theory, if universal, ought to work for these physical systems, too.

Two choices enter into the determination of what happens in quantum theory in general and in quantum measurement in particular:

1. the choice of questions which are posed upon nature, and
2. the choices of the answer of nature to the chosen question.

Quantum theory gives statistical predictions for point (2). But the question in (1) is chosen by the experimenter. The exclusion of the experimenter from the

[4] This summary follows Stapp's (2004) ideas.

system being investigated is fixed by the "orthodox" quantum theory devised by von Neumann and Wigner. Von Neumann showed that the observed event in the external world is directly linked to the brain of the observer of that event. The observed system (process 2) is described in terms of quantum mathematics, the observing system (process 1) in terms of human experiences. Due to the fact that it makes no practical difference which of the various placements of the dividing line between the two systems one uses – the placing of the border is a matter of expedience (Haag, 2004, p. 54) – von Neumann put all parts of nature composed of atomic constituents on the side described in terms of the quantum mathematics and only the consciousness of the observer outside of the mathematically described world. In von Neumann's formulation, the whole world is treated as a quantum system.

Because von Neumann's theory is built on the Newtonian concept of an instant of time, it was elevated by Tomonaga and Schwinger to a form compatible with the physical requirements of the theory of relativity. In their relativistic quantum field theory, the Tomonaga-Schwinger surface σ does not differ significantly from the constant-time surfaces of Newtonian physics. Contrary to the theory of relativity, there is a preferred sequence of instantaneous "nows". Direct changes of a part of the surface σ cause *indirect* changes along the rest of the surface due to quantum entanglements. According to Stapp, these indirect changes produce the 'faster-than-light' effects, and elsewhere Stapp (2001b, p. 10) says:

> "Thus quantum theory reverts, at a certain deep ontological level, to the Newtonian idea of instantaneous action at a distance, while maintaining all of the empirical demands of the theory of relativity."

Nonetheless, there must be a dynamic connection between mind and brain: The mind of the observer is obviously connected to what is going on in his brain, and his choice of which question to put to nature influences his brain in ways controlled in principle by quantum laws. Asking a question about something is closely connected to focusing one's attention on it. Due to Stapp, this connection can be found via the quantum Zeno effect, which shows how the choice and timing of questions can influence the course of events in the probed system. Physical principles do not specify which questions are posed to nature. This opens the logical possibility that our conscious thoughts could be entering into the mind-brain dynamics in a way reducible neither to purely mechanical effects governed by the Schrödinger equation of motion nor to the random effects of nature's choices of outcomes.

In general, our thoughts issue commands to "attend" to certain questions in the future. These directives supply the missing component of the quantum dynamics: They pose the particular questions that are put to nature. The point is that the occurrence of a conscious thought associated with a quantum system is supposed to cause a reduction of the state of that system to the reduced state. Since the question to be posed is supposed to be an experience, it would appear that it really ought to be part of the mental, rather than

physical, side of the mind-brain dynamics. Quantum theory has a *lacuna* that can very naturally be filled in such a way as to allow our thoughts to exercise real, though not absolute, control over the mechanical aspects of mind-brain dynamics.

11 Process Philosophy and Quantum Ontology

"The natural *ontology* for quantum theory ... has close similarities to key aspects of Whitehead's process *ontology*" (Atmanspacher, 2006, p. 71). Both are theories of perception. Whitehead tells us that it is equally possible to arrive at his organic conception of the world from psychology on the one side and from mathematical physics on the other (McHenry, 2002, p. 168). Otherwise, "quantum theory gives us a mathematical model, not of an independent reality, but of our perception of reality" (Hartshorne, 1977, p. 189). Both are interpreting systems of nature and share the same intention.

On the other side, all Whiteheadian-inspired physicists have in mind a discussion of "a modified philosophy of organism, which would preserve Whitehead's essential ideas while according with the discoveries of modern physics" (Malin, 2002, p. 172). There seem to be great differences deeply rooted in the concept of time. Spatially separated parts of reality must be related in some way that goes beyond the familiar idea that causal connections propagate only into the forward light-cone. Quantum events behave as a unified system: "What *you do to it* in one place can influence how it will react to a *simultaneous* probing far away" (Stapp, 1993, p. 30).

Whitehead has been blamed for having only a causal theory of perception, with which he cannot account for contemporary events (Stapp, 1979, p. 2). Actually, Whitehead introduces three different concepts of contemporaneity: Contemporaneity, simultaneity, and instantaneity. "An instantaneous space is static, being related to the static nature at an instant" (Whitehead, 1920, p. 117). "Actual entities are called 'contemporary' when neither belongs to the 'given' actual world defined by the other" (Whitehead, 1978, p. 66). This concept covers all events in the light cone. But simultaneity includes all contiguous events of prehension. These events need not be causally connected. Two electrons very distant from one another are also contiguous by means of gravity. Prehensions grow together to new actual occasions if they fit to each other, i.e., if they pass in coherence.

Process philosophy can cover the results of Bell and Tomonaga-Schwinger that the available information about a system can be effected by a far-away observation (Stapp, 2001a). For Whitehead, the available information about the (far-away) system which is disturbed by the (nearby) measurement and the nearby system are one actual occasion. There is no need to modify process philosophy at this point. On the contrary, it is actually a release that we have physical as well as philosophical reason to dismiss the idea of mutually independent events (Hartshorne, 1977, p. 185).

Einstein adopted the absence of absolute motion as one of the key postulates of the special theory of relativity. "This resulted in the ontology that the phenomenon of time was essentially an inseparable aspect to space itself; that reality was an unchanging piece of geometry" (Cahill, 2005, pp. 6–7). In this ontology there is no notion of change and becoming nor of the experiential aspects of time. Space itself, in conjunction with the sensitized detector, has some real role in the measurement procedure. Space turns out to be a dynamic system, not some passive piece of geometry.

Parisi and Wu discovered that a formalism of stochastic quantization underlies the functional formalism of Dirac and Feynman (Cahill, 2005, pp. 6–7). Stochastic iterative systems have essentially time-like properties. Why not abandon the static scheme underlying space-time, upon which quantum field theory is constructed, and keep only the stochastic iterative process? Time would no longer be modelled by some fundamentally different system, such as by geometry, but by a time-like process itself. A stochastic iteration model contains no notion of space and matter. It is very similar to stochastic neural networks. If this model of reality proves to be successful, then one could adopt the ontology that reality is *mind-like*, as Leibniz and Whitehead suggested. "Because it involves a modelling of time which matches its experiential properties this radical new modelling of reality is called *process physics*" (Cahill, 2005, p. 11).

Does Whitehead's ontology contain an inconsistency due to the fact that the principle of separateness of all realized regions will generally not be satisfied in his causally local and separable ontology (Hättich, 2004, p. 249)? This would be true if his metaphysics were traced back only to the theory of relativity, if one did not take into account that his ideas originate from a psychophilosophical discussion, that his theory of prehension connects all occasions of the contemporary world, and that the concrescence process selects positive prehensions. If one concluded that, then either the causal independence of simultaneous occasions or the distinctness of their concrescence processes would have to be abandoned in order to secure the separateness of all realized regions, and one would have to answer two questions: What does causality mean? Likewise, what does separateness mean?

In the words of Hartshorne (1977, p. 188):

> "Causality is merely the way in which each instance of freedom takes into account the previous instances, as each of our experience refers back through memory to our own past and through perception to the world's past."

According to quantum thinking and process philosophy there is no backward-in-time causation. Rather (Stapp, 1977, p. 321),

> "the basic properties of relativistic quantum theory emerge ... from a logically simple model of reality. In this model there is a fundamental creative process by discrete steps. Each step is a creative act or event. Each event is associated with a definitive spacetime location. The fundamental process is

> not local in character, but it generates local spacetime patterns that have mathematical forms amenable to scientific studies."

And, again, Hartshorne (1977, p. 189):

> "The mutual independence of contemporaries constitutes their freedom. Without this independence, what happens anywhere would immediately condition what happens anywhere else. However, this would be fatal to freedom only if the sole alternative to mutual independence were mutual dependence. And this is not a necessary, it is even a possible, interpretation of Bell's result. What happens here now may condition what happens somewhere else without measurable temporal lapse, although what happens at somewhere else does not condition what happens here, still retains its freedom since ... no set of conditions can be fully determinative of the resulting actuality."

Quantum theory is formulated as an indeterministic theory. Each experimenter can choose freely which experiment he will perform. In addition, the result of the experiment is subject only to statistical requirements (Stapp, 2001b, p. 11):

> "These elements of 'freedom of choice', on the part of both the human participant and nature herself, lead to a picture of reality that gradually unfolds in response to choices that are not necessarily fixed by the prior physical part of reality alone. The central roles ... of these discrete choices ... make quantum theory a theory of discrete events, rather than a theory of the continuous evolution of locally conserved matter/energy."

The internal process of concrescence is not a spatiotemporal process. But the way in which the result of this internal process is "made available" to the external world is an atomic act. "Continuity is rejected as a basic feature of the units of becoming, but in the succession of the units of becoming what becomes is continuity" (McHenry, 2002, p. 168). Additionally, if quantum theory is a theory of observation, what does the term "observer" mean ? Physical instruments of measurement cannot be regarded as observers: They do not generate facts. One would come to a chain of observers. Where does this chain end ? Haag (2004, p. 55) comments:

> "Several eminent scientists (von Neumann, 1932; London and Bauer, 1939; Wigner, 1962) proposed that it terminates when an event becomes consciously perceived. Consciousness is regarded as the ultimate agency."

According to Heisenberg, "each occurring event signalizes a transition of the 'possible' to the 'actual' " (Stapp, 1979, p. 23). A becoming actual occasion receives past actual occasions as potentials for ingression into its own development. The development is one from potentiality to actuality and from actuality to potentiality. The potentials of past actual entities are interwoven into a unit by the activity of the growing actual entity. The newly grown actual entity is a real potential for future concrescence processes.

There are parallels between quantum theory and psychology. Stapp's "quantum theory of consciousness" is based on Heisenberg's interpretation

that reality is a sequence of collapses of wave functions. Stapp observes that this view is similar to William James's view of mental life as "experienced sense objects". According to Stapp, the whole range of science, from atomic physics to mind-brain dynamics, is brought together in a single coherent theory of an evolving cosmos consisting of a physical reality with the closely related, but differently constituted, mental aspects of nature. Stapp holds that (Atmanspacher, 2006, p. 76)

> "Whiteheadian quantum ontology accepts ... the idea that our conscious intentions cause, at least in part, our intentional actions. This can be achieved by regarding the quantum reduction events to be the physical manifestations of the termination of psycho-physical process. ... The physical and psychological aspects of reality are thus tied together in the notion of a quantum event."

Is it now justified to argue that quantum events could be counted as sentient? This assertion would equip elementary quantum events with a degree of creativity. It must first be asked how mentality is to be measured. One observes mentality concerning its effects out of the behavior of the things observed. To argue that each actual occasion possesses a mental pole is a consequence of the transference of human understanding to all events of nature. It conforms to the principle of unity of nature. Finally, quantum theory of consciousness as well as process philosophy delivers a rationally coherent way of understanding our conscious selves within the reality surrounding and sustaining us.

Whiteheadian quantum ontology is essentially an ontologization of the structure of orthodox relativistic quantum field theory, stripped of any anthropocentric formulations. (This means that mentality is no longer reserved for human beings and higher creatures.) But it is to a high degree anthropomorphic because this is the only way we can speak about reality. Thus, Whitehead's philosophy of organism is a logical transfer of the concepts of human experiences onto all entities of reality. In describing the last units of reality, he uses concepts which were derived from living organisms and applies them to the whole of nature.

Why is consciousness needed in the universe at all? Because otherwise there would be no historical development. There were many possible changes from one state to another but no becoming anew. This leads to a "many-minds" picture "Each person's brain evolves quickly into [...] a smeared out continuum, and each stream of consciousness would be part of a continuous blur of classically describable possibilities" (Stapp, 2007, p. 59). The observed particularity would be the particularity of one individually observed branch of the universe. In this view, it is a property of each human consciousness to accommodate only a single one of these branches, even though all the branches exist together (Stapp, 1993, p. 188). The proposal of Heisenberg and Dirac as well as our human understanding assert the opposite: Nature actualizes one observable branch out of the emerging set of possible ones. The conflict

originates from the continuous character of the description of nature provided by the quantum state and the discrete character of human experience. Real becoming necessitates temporal atomicity. But real temporality presupposes teleology, and consequently, mentality.

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